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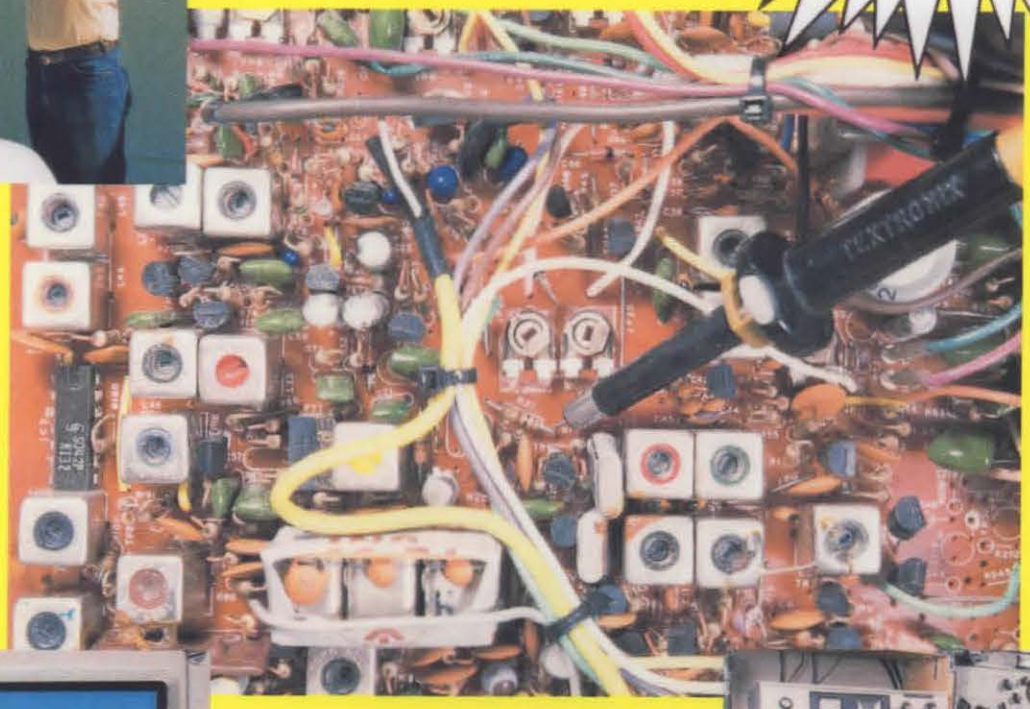

UNDERSTANDING & REPAIRING *CB* RADIOS

For the Professional Technician

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Library of Congress Cataloging in Publication Data

Franklin, Lou
Understanding & repairing CB radios.

Includes index.
1. Citizens band radio. I. Title. II. Title:
Understanding and repairing CB radios.
TK6570.C5F74 1987 621.3845'4'0288 86-73069
ISBN 0-943132-24-X (pbk.)

FIRST EDITION

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Printed in the United States of America

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To the memory of Michael Moyse, who started it all.
And to my wife Sally, who endured it all...

UNDERSTANDING & REPAIRING *CB* RADIOS

For the Professional Technician

Lou Franklin

FOREWORD

This book is the result of many requests over the years from loyal readers of **THE "SCREWDRIVER EXPERT'S" GUIDE TO PEAKING OUT AND REPAIRING CB RADIOS.** At the time I originally wrote that (almost 35 years ago!) I had expected the CB boom to fade away quickly. It's now obvious that CB is here to stay, and the need for technical expertise and information continues to grow. There are several reasons why:

1. More and more people are getting into CB radio as a hobby, and therefore more trained people will be needed to install and service the radio equipment.
2. Since CB is no longer considered a fad on which to turn a quick profit before moving on to the next fad, there are few companies left making the radios, test equipment, or service books. This leaves you the technician to hunt for service information anywhere you can find it. Good luck!
3. In March of 1987, the American FCC finally announced their "Novice Enhancement" rules for Ham operators. Novices could now use the lower section of the 10-Meter band, from 28.100 MHz to 28.500 MHz for CW and SSB. This means a great many CBs will be converted to these frequencies. Since most such conversions involve simple crystal changes and retuning, the need for both radio servicing and the conversions themselves will naturally increase.
4. CB radio is now a worldwide hobby, with many countries having their own 27 MHz Citizens Band Service generally modeled after the American version in terms of frequencies, power output, modes, etc. Most foreigners look to us as their best source of technical information, since even a common schematic is often impossible for them to find locally. After all, we Yanks invented this CB stuff, right?
5. The oldtimers who really understood radio theory are slowly dying out, leaving the hotshot kids to play with computers, cell phones, or I-Pods instead. Not many people left interested in or knowledgeable about RF and radio equipment. But we'll be talking on radios for a very long time yet; somebody must know how to fix them. Might as well be you and me...

CBC INTERNATIONAL is one of the few early entrants to survive this business. I felt the time was right for offering a much more technical reference for CBs, picking up where **THE "SCREWDRIVER EXPERT'S" GUIDE** leaves off, and including both the latest technical changes as well as theory on older models still used by many Americans. This book is the result, and I think those people serious about servicing CB two-way radios will find it very helpful.

This book originally took me about three years to complete, long enough to not only update various changes as they happened, but also to observe trends in the CB industry itself. The CB business is growing again! For example, in the late 1980s the British and Australian CB services finally changed over to the standard FCC/CEPT frequencies, making CB radio a truly universal hobby now with standardized equipment sold everywhere. And the old time manufacturers like Cobra, Uniden, Midland, and Radio Shack are busily updating their CB product lines with new models and new features.

The only catch with all this new equipment is that the current AM-only or FM-only models are basically impossible to modify for non-CB frequencies, or else not worth the cost and trouble to do so. However the American SSB models, while now more difficult, can still be converted. On existing models, there's no expiration date for an FCC Type Acceptance. (The "FCC DATA" number on the radio's ID tag.) As long as the manufacturer doesn't change the circuit electrically, he doesn't have to reapply for a brand new Type Acceptance and the more strict technical rules that go with it.

That explains why most of the best-selling Uniden and RCI 40-channel SSB models like the President/Uniden Grant, Grant XL, Madison, early Cobra 148/2000GTL, or RCI/Galaxy are so popular; they're still easy to modify, and they can keep making them forever. Only the newer models must meet current FCC rules. This suggests increased sales of SSB type models, so prepare for them.

I've drawn upon personal knowledge as well as many other sources for this book. A few are listed in CHAPTER 1 for those wishing to learn more. I strongly suggest you add such books to your personal electronics and CB library.

Unfortunately the few older CB repair books from the major publishers are now long out of print, including the coveted SAMS CB Fotofacts. Since many readers tend to live in rural areas with no easy access to big city bookstores, libraries, or parts houses, I'll explain how you can shop by mail or the Internet for your needs.

My Teaching Philosophy

In my earlier books I purposely did a lot of hand holding, using a "shotgun" approach to CB repairs while skipping most of the technical explanations. Since this book is intended for the serious (or hopeful) electronic technician, don't expect the same sympathy; you should already know basic solid-state electronics. If you don't know the difference between a PNP and an NPN transistor, or how a diode rectifies, you'd better start more gradually with the suggested reading list in CHAPTER 1 first.

There's probably more electronics theory in this book than you'll ever need to know. Anybody can fix CBs using the kind of simple troubleshooting guides usually found in manufacturers' service manuals. But I believe that a true technician understands the how and the why of circuit design. "Why did they put this particular resistor here?" "What happens if that capacitor is removed?" "Why the switch from transformer-coupled audio outputs to direct IC outputs?" I try to answer such questions not only from the purely technical aspect, but also from the manufacturers' marketing perspective. That way you'll understand more clearly why CB circuits evolved as they have.

It's true you don't have to know exactly what's going on inside an IC to decide if it's good or bad, but it sure helps! That's what separates a real technician from all the "shade tree" CB mechanics. I've therefore included a lot of background on CB circuit design theory. There's also a psychological bonus in such knowledge: with so many amateurs working on CBs, if you're better educated your customers will notice, and you'll get more business and more respect.

Unlike many technical writers, I don't use theoretical circuit descriptions except where absolutely necessary. No point in studying a SAMS or factory service manual if the real circuit looks so different from the theoretical one that you can't recognize it. Not my style. I'll emphasize circuits from real radios so you'll recognize them when you see them. These will be the circuits you'll see on a day-to-day repair work basis. Schematics may refer to a specific chassis, but the circuit will usually be so classic and generic that it applies to most other American and foreign models too.

I've often redrawn the manufacturers' original schematics, and sometimes omitted obvious components not essential to the discussion for simplicity. Certain parts have their actual values included when important to the discussion, while others on the same drawing may not. I've chosen as examples the most popular and representative chassis types. The same models are often used repeatedly for convenience, but similar models will use virtually the same circuitry anyway.

A few readers have criticized me for not being more up-to-date, but I stand by my view that CB circuits have changed very little <u>electrically</u> over the years. What appears to be a more modern circuit is usually nothing more than a new manufacturing technique or a newer component to accomplish exactly the same results. If you understand my examples, you'll also understand any of the newer circuits you may see.

To that end, circuits were purposely included from some older 23-channel and tube type radios. They're still quite common in the U.S., especially now that Hams are grabbing them up for 10M use or to sell on Ebay. While this may seem like ancient history to some readers, Americans will find it useful; these rigs will still be around and still need servicing for many more years. I've also included information on many of the so-called "export" radios, since they've widely used here and abroad. The combination of old and new should make this a truly international reference.

This book will be read by many people outside the U.S., but since virtually all CBs work the same way, the principles can be applied equally to foreign models. Yes, British FM-CB isn't that much different! Once you understand these basic principles, you'll be comfortable working on any type of CB transceiver that comes along.

Please don't take my word for everything. Read other books. Read everything on two-way radio repair you can find. If you live in a small town or rural area, take a correspondence course or find the info you seek on the Internet. Try one of the Heath self-study electronics courses, which I think are the best available and reasonably priced. If you live in a bigger city, take an electronics course at the local community college. Get a part-time job at a two-way radio shop, where you can look over the

shoulder of a more experienced tech. I've done all these things myself over the years.

Book Organization

In the following eight chapters I'll try to teach you all about how CB transceivers work, including their circuit design criteria and installation to the outside world via the antenna and power connection. Those who've already read **THE "SCREWDRIVER EXPERT'S" GUIDE** or **THE CB PLL DATA BOOK** may recognize some minor duplication of text or drawings; however subjects are treated in a more technical way here, so don't automatically skip over them.

We'll begin by defining major CB transceiver technical specifications. How would you know a radio's working properly unless you know what "proper" is? Next we'll describe a shopping list of basic tools and equipment that any respectable shop should have, including tips on where to find them. Unlike the boom days, there's no longer any current test gear made specifically for CB servicing. You'll have to use existing test equipment that's still available on the new, used, or surplus markets. I'll tell you where to find it. (See my special note at the top of Page 19.) I'll also throw in some of my famous "cheap and dirty" testing shortcuts using inexpensive circuits you can easily build yourself.

Troubleshooting basics are covered next, with detailed descriptions of receiver and transmitter circuitry in block diagram form for simplicity. The use of logic and other methods to find faults are explained. Following that is a chapter on developing the various required signal frequencies, including synthesizers and mixers. Then come specific circuits for the receiver and transmitter. There's a separate chapter on Single Sideband (SSB) emphasizing its unique circuitry. Power Supplies are covered next. The final chapter discusses antennas and transmission lines. Finally, there's some reference material for solving ignition noise and TVI/RFI problems.

About The Subject Index

The subject index at the end of this book will be very helpful. I spent many days trying to make it as detailed as possible, and it's now hundreds of entries long. Many common CB problems are included there alphabetically, under specific names such as "No Transmit", "Audio Distortion", or "High SWR".

SMD & the Future of CB Radio Servicing

In many ways learning CB repair is a lot easier than most other areas of electronics like computers, medical electronics, avionics, or even automotive repair. These fields require constant re-training as their technologies get more sophisticated. But the basic CB circuitry won't change from its current state-of-the-art unless manufacturers decide there's enough of a market to justify using the newer technologies. For example, they still haven't bothered to make high-power VLSI ICs, where most of a 5-watt transmitter could be put on a single chip.

There is however one major technical change now occurring: the use of tiny Surface Mount Devices (SMD) in manufacturing. These are sometimes called "flatpack" or "chip" components and are often as small as 1/8" long. What is SMD? It's a special miniaturization process where the holes for PCB components are not used. Instead the leads are soldered directly to the top of the SMD-PCB. They can be bent down from the device in a gull-wing shape and soldered to the PC foils, or even folded underneath the device itself before soldering or oven heating.

In mass production, SM parts are first glued to the PC board to temporarily hold them in the right place before the leads are soldered. Needless to say, the component density is incredible. And since there are no lead holes, you can actually put two entirely different circuits on the same PCB, one circuit on each side. Imagine the possibilities!

It's very likely you've already seen some SMD CBs. One of the simplest new CB uses has been the inclusion of a separate VHF weather receiver. For example, some popular Cobra models like the 25LTD and 29LTD became the 25LTD-WX and 29LTD-WX by adding a tiny weather PC board with SMD parts. The PCBs are so small they can bolt the entire WX unit anywhere convenient on the main chassis or the frame, then add a few wires and a switch. Another SMD use is in the PLL synthesizer of more complex multimode rigs like the HR2510 or RCI2950.

When SMD first appeared, there were some people who tried to stop progress by convincing customers to boycott such SMD equipment. They mistakenly thought this would force CB makers to return to using standard leaded components, but the idea failed. Why? Because manufacturing practices in electronics are always dictated by what's already being used in TVs, stereos, DVDs, digital cameras, medical instruments, etc.

Manufacturers are forced to design around whatever the component manufacturers are currently offering. Like the man said, "When you've got 'em by the balls, their hearts and minds will follow."

The biggest drawback to SMD is that servicing and parts replacement is now that much more difficult. New skills and new equipment are needed. It's not impossible, but you will need tweezers, a magnifying glass, and special soldering/desoldering tools. Not to mention patience, good eyesight, and steady hands. The better magazines like POPULAR ELECTRONICS are always running SMD ads and articles, and you should read them regularly.

I suppose you could just refuse to work on SMD models, forcing your customer to go elsewhere. Or convincing him to buy a new radio from you. You might make extra money this way at first, but eventually you'll lose your technical edge along with most of your service income. Meanwhile, the guy down the street who already knows about SMD will get all your old business.

By the early 2000s, standard parts with lead wires on them became harder to find. You won't be able to fix the latest rigs without SMD experience. This factor alone could become the biggest challenge to your future income and enjoyment of hobby radio.

You'll also need a new sales and marketing strategy. Most CBers think "bigger is better" and wouldn't consider a CB radio that's maybe just 5" square as having much inside it worth the price, despite how many bells and whistles they can cram into a small box. It'll be your job to re-educate these guys too.

SMD could become a blessing in disguise. Those do-it-yourself CBers and weekend wizards may finally learn (!!!) to keep their hands out of the radios and leave the work to professionals.

Final Thoughts

Many people have asked where I got my training in CB repair. Mostly I taught myself through many years of Ham radio, broadcast engineering, CB radio, VHF servicing, and a lot of reading. I got many shocks and RF burns along the way. The reading is required. Shocks and burns are optional if you get careless.

I won't make any moral judgments about "legal" or "illegal" CB operation here. Most of you already know the specific operating rules of your respective countries. What you do about them is your business. Don't expect this book to give you step-by-step procedures on how to modify a standard CB; those subjects are covered in other references like our **CB PLL DATA BOOK.** A simple reading between the lines there will answer those questions.

The purpose of this book is to teach you how to properly repair and maintain a CB radio within the manufacturer's specifications. Besides, if you happen to have an FCC General Radiotelephone License, or plan to get one, you're responsible for the proper operation of radios you service. If this is your living, you can't afford to lose your license.

Finally, as I write this latest introduction, the current sunspot cycle (Cycle 24) is in its 11-year high of solar activity. Which means plenty of skip to play with! This can only mean good news for continued CB use. And that translates to more work for the good techs, more CB sales, more conversions to Ham Radio, more DX, and more all around fun.

Over the years, my radio updating information has often come from readers, who send me schematics on new CB models as they appear. I always welcome your comments and sincerely hope this book helps you. Good luck and let's begin!

L.F., Tucson, Arizona

Acknowledgments

Many thanks to all the following companies for permission to reproduce certain materials:

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1 INTRODUCTION TO CB SERVICING

It's been said, "A carpenter is only as good as his tools." Let's rephrase that to say, "A technician is only as good as his test equipment." You'll waste a lot of time without the right tools. That's the difference between making a repair, or embarrassing yourself by admitting to a customer that you can't fix his CB because you just don't have the right tools.

About 75% of all repair problems are easy to diagnose and fix. An experienced tech can probably trace these down with only a VOM, a "buzz-it" generator and a few simple tools. The fact that the majority of repair problems are easy to find was my reason for writing **THE "SCREWDRIVER EXPERT'S" GUIDE** in the first place. It's the other 25% or "tough dogs" that require a lot more time, experience, and money invested in the right test equipment.

If you're serious about CB repairs, don't think you can get away with ignoring that other 25%. New customers come to you expecting an expert, and one with all the right tools. If you disappoint them, the guy down the street will provide what you couldn't, and eventually you won't even get the easy jobs.

In this section I'll discuss the tools and equipment that any respectable CB repair shop needs. Some items you can even build yourself. And if you're a smart shopper, you can find the important stuff on the used or surplus markets. I'll show how you can outfit a complete shop using only your telephone, UPS, or the Internet if you can't get to the sources yourself.

Following are the things I use most, along with appropriate comments. These are in no special order and are by no means complete; they just demonstrate the range of equipment available. Pages 19–25 show some contact info to help you find them. Test set-ups are shown later.

IMPORTANT!
In books like this, I can't possibly guarantee the accuracy of specific listings. Things like Web sites, brand names, addresses, and phone or model numbers change a lot. You need to use the Internet! See the boxed note on Page 19.

TEST EQUIPMENT SUMMARY

SERVICE MANUALS, SCHEMATICS, SAMS FOTOFACTS: Your most important tool! It's incredible how many people try to fix a radio without these. Would you drive in strange country without a roadmap? You need radio roadmaps too, and lots of them. You need one for virtually every chassis type you'll see. Once you're familiar with the radios you'll know which brands and models are the same; this can save you lots of money when buying, for example, SAMS Fotofacts. If ten different radios are exactly the same, why buy ten SAMS Fotofacts, one for each brand name? Besides, most SAMS are now out of print and you'll often be lucky to find even one chassis type that's still in print.

For the major manufacturers still actively marketing CB radios (Cobra, Courier, Uniden, Midland, G.E., K-40, Radio Shack, Regency), you can get service manuals directly from them. Their addresses appear later. For all the other companies now out of business, you'll have to hunt around. Many of those companies used the same chassis types as the current companies; see **THE CB PLL DATA BOOK** or **THE "SCREWDRIVER EXPERT'S" GUIDE** for cross referencing.

POWER SUPPLY: Another essential tool. All mobile transceivers are designed to operate on a DC voltage input of about 13.8 VDC. Since you'll most often be working on the bench, this converts the AC mains to the required low-voltage DC. (We often use the term "12 VDC" instead of 13.8, which is the actual charging voltage on a battery with the engine running. Means the same thing.) This supply should be well regulated. In addition it should have current limiting to protect it from direct shorts, as well as a "crowbar" overvoltage limiter; in the unlikely event the regulator's series-pass transistor shorts collector to emitter, as much as 24-28 VDC could be applied

to the test radio! Current and voltage metering are nice extras, but not essential.

In the early CB days a 2 Amp supply was OK; however with the popularity of SSB and export radios you really need one with 3-3.5 A minimum capability. (The President Jackson for example has a 6 A fuse.) And if you run two radios simultaneously, consider something even bigger. DC supplies of this type can generally be purchased new for under $60 from sources such as Radio Shack, or any test equipment supplier like those listed on Page 23 or the back pages of electronics magazines. MCM Electronics sells some nice Taiwan-made Tenma supplies for only $35 and up. (Address on Page 24.)

At least two DC supplies are actually needed. You never know when you may need to test a base radio's supply, provide an AGC or VCO clamping voltage, have two mobiles on at the same time, etc. I suggest one supply capable of high current output in the 10-20 A range. The high current allows testing of linear amplifiers, several radios at once, etc. It should have at least two voltage output ranges, preferably adjustable, and preferably metered. Again, current and voltage limiting are important.

Current metering can be very useful for checking the current drain of a radio under test. DC power supplies of this type are generally in the $100 and up price range, but are absolutely required for serious radio work. Some typical good examples are made by Sencore, Hickok, and Tenma.

MULTIMETER (VOM): Here I distinguish between analog and digital types. But one of each is recommended. These meters read AC/DC current, AC/DC voltage, and resistance over many ranges. The analog types are most useful when you need to see the meter needle moving, like during alignment procedures, or testing semiconductors with the ohmmeter function. Get one rated at least "20,000 Ohms-Per-Volt"; this provides good sensitivity and a high input impedance to prevent loading down sensitive circuits.

This last requirement is extremely important: when measuring a high-impedance circuit on a low voltage scale the meter impedance can easily be lower than the circuit being tested, which means substantial current will flow into the meter and give false voltage readings. For your analog VOM this can be anything from a simple Radio Shack #22-109 ($25) to the famous (but expensive) Simpson 260, around $220.

For just about everything else, a digital meter (DVM) is preferred. For precise adjustments like a PLL VCO it's absolutely essential, since 0.02 volt change can move the synthesizer over to the next channel! The "3 ½ digit" meter is pretty much standard now. This means it has three digits that read 0-9 and a left-most digit that only displays a "1." Therefore the maximum reading on any range (ignoring the decimal point) is "1999." Digital meters have input impedances on the order of 10M_, which eliminates potential loading or RF effects.

A nice feature of the more expensive types is "autoranging," which means it automatically jumps to the next highest range when the range in use is exceeded. This frees your hands from having to turn the range knob, handy when both hands are already busy. Nice, but not essential on a low budget.

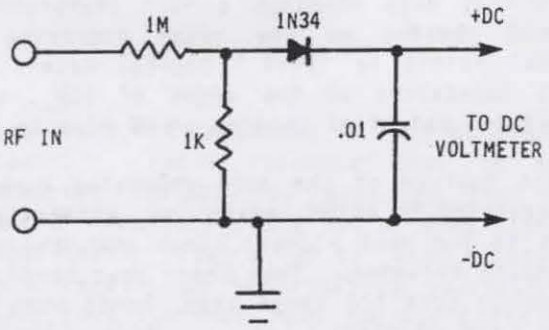
Finally, digital meters have the advantage of being much more immune to strong RF fields which can make most analog meters useless. You can't possibly measure the DC voltages on the transmitter power stages with an analog voltmeter. After 30+ years, I'm still using a Data Precision #935 which was one of the first handhelds on the market. Nowadays everybody makes them including Fluke, Beckman, Hickok, Radio Shack, Dick Smith, and many others. Radio Shack has nice digital autoranging meters like the 22-813 ($40) or the 22-039 ($70). As the price goes up you get the extra features described here, and a lot more ranges too.

VTVM OR FET-VOM: This is an optional item which is handy when you don't want your test probe loading down a sensitive circuit like an oscillator. The Vacuum-Tube-Voltmeter (VTVM) is much less sensitive to RF than solid-state devices. Since both have probe inputs in the megohms, there are virtually no loading effects. The advantage of the FET meter is its portability, but RF sensitivity can sometimes be a problem. I'm really stingy, so I still use my old Heathkit FET-VOM, and an Eico VTVM.

RF PROBE: This is simply a device which when attached to the input of a DC voltmeter can show relative RF measurements. Very handy when peaking RF stages, or for signal tracing transmitter stages without a 'scope. Although there are commercially available probes they're simple to build yourself. See Figure 1-1. Remember though that it shows relative, not absolute, voltage readings. For the truly lazy you can still get these ready-made from Dick Smith Electronics, including the banana clips, but remember you'll be paying a lot more for the Air Mail shipping.

OSCILLOSCOPE: No CB bench would be complete without this extremely useful and versatile

FIGURE 1-1
A SIMPLE RF PROBE



instrument. This is your biggest investment, so consider the choice carefully. An audio type service 'scope just won't do the job; you need one that's capable of viewing the 27 MHz signal directly, and with accurate P-P measurements. In this price range the 'scopes generally come with dual-trace capability, triggered sweep, delayed sweep, and other useful features too.

You can't conveniently adjust AM modulation to the required levels unless you can view the actual waveform. It's possible to connect a simple audio type 'scope to use the trapezoidal measurement method, and we'll demonstrate this later. However you still need a high frequency response for things like transmitter signal tracing. When I was starting out and couldn't afford a 'scope, I did a lot of signal tracing with a VOM and RF probe. This method works, but without a 'scope you can't analyze the more subtle problems like noise and distortion. A good 'scope is actually cheaper today than when I was starting, due to Far East competition and improved production methods. You don't need a Tektronix, even though everybody wants one; excellent instruments are now made by B&K, Hitachi, Kikusui, Hickok, Leader, and others.

A simple 'scope extender may help for small budgets. This is basically a mixer circuit and local oscillator, designed to down-convert signals up to say, 50 MHz, so they're visible on a simple 5 MHz type 'scope. Search for something in the ARRL HANDBOOK or the Internet.

FREQUENCY COUNTER: Another essential tool, but a lot more affordable. You can't possibly measure channel frequencies for correct tolerances or analyze other signals in a CB transceiver without one. The important factors to consider are upper frequency limit, accuracy, and sensitivity. The 30 MHz counters are the low end pricewise and are quite passable if good on the other two qualities. For accuracy you need at least one order of magnitude more than the measurements you'll be making, which means at least seven digits total. For sensitivity, 25 mV will catch even low-level oscillators and mixers. Also desirable is a high-impedance input to prevent loading the measured circuit. Some counters have switchable or separate HIGH-LOW impedance inputs. Thanks to improved production methods there are many good brands of AC-powered or portable counters for under $100.

A neat little add-on gadget for both your 'scope and frequency counter is an "RF Sniffer" preamp. This is a battery powered broadband amp in a small aluminum box with BNC jacks. When connected to a 'scope or counter, it can really boost low-level signals without loading down the test circuit, since there's no physical connection. You just put its probe near the stage to be measured and it "sniffs" the RF signal. Keying a 4-watt CB into a dummy load will make your counter read out in the next room! You won't be able to read oscillator signals except on Receive though; the transmitted 27 MHz signal will overpower all other signals. My unit was made by a company that's now out of business, but I've seen them, advertised by companies like Ramsey Electronics (Page 24) for around $40.

RF SIGNAL GENERATOR: This will be your most important instrument for testing receivers. It must produce a 27 MHz carrier signal with high stability and calibrated output levels down to the 0.1 µV level. It must also provide for modulating the carrier up to 50%, preferably using standard 400 Hz and 1 KHz tones. Most generators have AM modulators; only the most expensive have FM ability with fully adjustable deviation levels. A nice extra feature would be separate outputs for standard 455 KHz and 10.695 MHz IF signals, although if it's tunable through these ranges that's OK too. Another nice feature is multiple BNC output jacks so you can couple one of them directly to your frequency counter; since channelized CB signal generators are no longer made and the dial calibration of most other generators is notoriously inaccurate, you'll need the extra jack to monitor the exact output frequency.

Unfortunately generators with these features aren't cheap! But I have a suggestion worth

investigating: my generator is an old surplus URM25/F, made for the Navy by Uncle Sam in the 1950s. (You can see this just in front of my head in the photo on the front cover.) It probably cost American taxpayers $10,000 then. Mine cost $150 in working condition. My friend Norman used to bid on government surplus and he picked up a bunch of these boat anchors for a few bucks, and sold one to me. They have all the above features, plus an incredible range of 10 KHz to 50 MHz. It's built like a tank and uses common tubes which are still readily available. The only modification I'd suggest is a vernier reduction drive on the tuning shaft, or it'll whiz right past the CB band. This instrument is still available on the surplus market from places like Fair Radio Sales.

There were some special CB-only signal generators made during the boom days like the B&K 2040, Sencore CB42, and Hickok 266. You might still find one from ads in Ham type swap sheets or other electronics magazines. All are excellent and probably sell used for $200-$400.

A simple RF generator I often use is the "buzz-it" type, which is a battery-powered oscillator that generates lots of RF hash and harmonics well into the VHF region. It's about the size of a pocket penlight. When you stick the probe into the coax socket or a working receiver stage, the speaker hiss noise increases, so it's good for simple in/out signal tracing. You can find these at many electronics stores for under $20. (Eg., Dick Smith #Q-1270.)

AUDIO SIGNAL GENERATOR: This is often useful for tracing signals through the transceiver's audio stages. Many RF type generators have a separate output jack from their internal modulation which can also be used. However for servicing SSB transceivers a two-tone audio signal is absolutely necessary. Besides if you want to perform overall frequency response tests, you must be able to sweep the entire voice audio range, typically 300-2500 Hz. The unit should have an output calibrated in millivolts (mV) so you can properly adjust the AMC or ALC of a transmitter. Audio generators are fairly inexpensive, typically $50 on up. You can build a Heathkit or find any number of commercial models. You can also build a simple fixed output two-tone generator from an IC or transistors for even less money.

SIGNAL TRACER: This is extremely handy in troubleshooting IF and audio receiver stages, the transmitter mike amps, add-ons like Speech Processors, etc. Basically it's an audio amplifier with a built-in speaker and a diode RF detector. By using its probe and injecting a signal, you can determine exactly which stage is not passing the signal and isolate it more specifically. It's fairly cheap; Heathkit makes one, the IT-5283, for $60. Mine's an old tube-type Heathkit IT-12, which could probably be found on the used market.

There's also a much cheaper and simpler tracing method: Radio Shack makes a little 200 mW audio amp with built-in speaker, Catalog #277-1008 ($11.95), which is perfect for this use. It runs on a 9-volt battery and has an input jack and an output jack for an external speaker. With a simple diode detector for a probe, you can use it at RF/IF frequencies too. (Heathkit makes a switchable AF/RF detector probe, #337-C kit, $12.95.) NOTE: If you get the R/S unit, be sure to modify the input by adding a coupling capacitor of about .01 µF in series with the center conductor of the input jack. Otherwise you may load down the test circuit since the input goes directly to its VOLUME control wiper, which is a low-impedance ground path.

RF WATTMETER & SWR METER: Two more necessary instruments that determine correct transmitter and antenna operation. The directional thru-line types such as the Bird 43 are the most popular. You just rotate the plug-in element to get the actual forward and reflected readings directly in watts. Thus it's also an accurate SWR Meter, but you need a special nomograph to compute the SWR value. The Bird is probably the industry standard because it's extremely rugged, accurate, and offers a wide choice of plug-in elements for many power levels and frequency ranges. A variation of this popular meter is the Bird 4314; it adds a peak-reading (PEP) function for SSB work. Price around $200.

There are many other SWR and RF power meters. I suggest a quality instrument for each function, since most of the cheap combination types are notoriously inaccurate. You get what you pay for. The power metering in the combo units is generally useless when connected to a reactive antenna rather than a pure 50Ω dummy load. With reactance, the sampled RF voltage driving the meter is phase-sensitive, and can make it read power that's too high or too low. You do need an SWR indicator of some sort to know you even have a reactive load, but don't settle for less than precision instruments here.

If you have the slightest doubt about wattmeter accuracy, use the basic electronic formula,

$$P = \frac{E^2}{R}$$

where P = power in watts,
E = measured RMS RF voltage
R = resistance in ohms.

Since "R" will always be 50 when using a standard dummy load, connect an RF probe from an FET-VOM or a VTVM to the center coax pin, either from inside the chassis or with a coax "T" connector. For example, if the measured RMS RF voltage is 15 V, the power will be

$$\frac{15 \times 15}{50} = \frac{225}{50} = 4.5 \text{ watts}$$

If you use a 'scope for RF measurements, remember they read peak-to-peak (P-P) voltage, not RMS like voltmeters. This means you must first convert the P-P 'scope voltage to RMS. The conversion formula is

$$V\ (RMS) = \frac{V\ (P\text{-}P)}{2.828}$$

For example, with an unmodulated AM carrier into a 50Ω dummy load reading 40 V P-P on the 'scope, the RMS voltage would be

$$\frac{40}{2.828} = 14.14427\ V_{RMS}$$

Now use the standard formula:

$$\frac{14.14427 \times 14.14427}{50} = \frac{200}{50} = 4.0 \text{ watts}$$

Some of the newest state-of-the-art 'scopes (Tektronix 2246, etc.) now offer pushbutton choices of P-P or Average displays; no more calculations, if you can afford these!

RF AMMETER: You can sometimes save money with a thermocouple RF Ammeter instead of the more expensive RF Wattmeters. (See photo later in this chapter.) Buy a surplus RF Ammeter of a suitable current range for CB use and mount it in an aluminum meter box with standard SO-239 coax sockets on each side. Wire the meter terminals in series with the center pins of the coax sockets. Then make up a little conversion chart which you can attach to the back of the meter box. The chart converts the RF amp reading directly into watts. Use the formula,

$$P = I^2R,$$

where P = power in watts,
I = RF current in amps,
R = resistance in ohms.

Use your pocket calculator and compute about 20 different current values from zero to the full-scale meter reading. "R" will always be 50 ohms, because you terminated one coax socket in a non-inductive 50Ω dummy load.

For example, I bought two RF Ammeters at a surplus place, one with a scale of 0-1.5 RF Amps, and one with a scale of 0-0.5 RF Amps. Using the formula, the 0-0.5 RF Amp meter gives a full-scale watt reading of 12.5 watts, and the 0-1.5 RF Amp meter a full-scale reading of 112.5 watts. Thus I have one meter suitable for AM/SSB CB rigs, and one for testing many medium power Ham transmitters, linear amps, commercial VHF rigs, etc.

The RF Ammeter makes an excellent wattmeter for SSB power testing, because the reading is proportional to the actual power consumed by the load. PEP measurements with two-tone tests are therefore quite accurate. Also the needle moves more slowly and with less bounce than a DC current meter. That's because the meter works on the principle of heat, not magnetism. The sensing element is actually a strip of thermostat type metal attached to the needle, and it heats up as RF flows through it. (If you've ever received an RF burn, or cooked with a microwave oven, you know that RF does burn!) The heating of the dissimilar metals generates a small DC voltage which is applied to a DC milliammeter calibrated in AC units instead.

You'll find these meters at surplus stores or major electronic parts suppliers for about $30-$50, which is a lot cheaper than the $200-$300 you'd pay for a Bird or similar instrument.

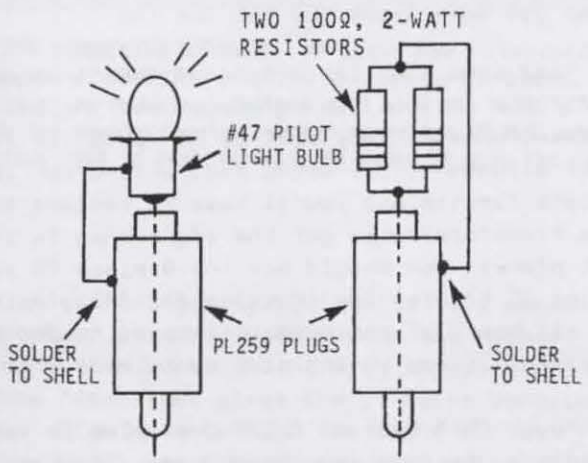
NOTE: RF Ammeters are compressed at the low end of the scale, making reading there difficult. Get one having a range where the expected deflection will be near the mid-scale for more linear reading.

DUMMY LOAD: (See photos in CHAPTER 8.) You'll need something to dissipate the power of a transmitter under test without actually getting on the air and causing interference. A dummy

load serves this purpose. It's a special resistor which appears to be a pure 50Ω antenna to the transmitter output stage. However it's very important that the load be non-inductive and purely resistive; any reactance will cause inaccurate wattmeter readings.

There are all sorts of commercial loads available and the only real difference is the maximum power rating. For CB work you can get a simple 5-watt "sponge" type load from companies like Gold Line (#1072) for about $4. This has a small resistor soldered directly to a PL-259 coax plug. Another popular load is the Heathkit "Cantenna" or Gold Line "KW Kan," which are big resistors inside a one-gallon paint can of transformer or mineral oil. These will handle 1000 watts when transformer oil is used. For intermediate power, try Dick Smith Electronics (15 W-#D7025, 100 W-#D7010, 300 W-#D7030), or Gold Line (100 W-#1054B) models.

FIGURE 1-2
SIMPLE 50Ω 4-WATT DUMMY LOADS



For you builders, a low-power load can be made from a few carbon composition (not wirewound!) resistors, or a #47 flashlight bulb (Radio Shack 272-1110) soldered across a PL-259 coax plug. Even though a light bulb is actually a wirewound resistor, for some reason the #47 makes an almost perfect 50Ω non-reactive load. These "modulation bulbs" are still sold by Dick Smith (#D7024) and Gold Line (#1057) for about $4. I like them because you can whistle up a modulation test on a CB when its own S/RF meter may not work properly. Figure 1-2 shows how to make your own simple dummy loads.

When testing antennas you'll occasionally need a special dummy load which you must make yourself. For example, I have several 5 W loads made from various junked antenna fittings. One fits the standard 5/8" threaded trunk lid mount, one fits the oversize A/S "Big Momma" type coil mount, one fits the K-40, one fits the Hustler base-load type, etc. When you can't match a loaded mobile antenna with a decent low SWR, these homebrew loads allow you to quickly determine if the problem is in the coax or the antenna itself. Get a junked loading coil of every major type, break it open and remove the coil, saving only the threaded metal base which is usually brass. Parallel two 100Ω, 2 W carbon resistors and solder them across the center and outer parts of the coil base. You now have an extremely useful dummy load which may save you countless headaches when troubleshooting SWR-related problems. More on this in CHAPTER 8.

The following miscellaneous items are also quite helpful at times.

FM DEVIATION METER: There's been a flood of CB radios with FM capabilities into the U.S., as well as converters for existing radios. Some foreign countries allow the legal use of FM CB. And Ham operators convert CBs to the 10-Meter Amateur Band. For these reasons, expect to work on FM CB radios. It's very difficult to set the proper modulation level on an FM transmitter without a Deviation Meter. If the radio has excessive deviation, it won't even be detected in other FM receivers.

These instruments are usually very expensive and are normally part of a multi-function tester for commercial VHF/UHF radio servicing. The best-known names are Cushman, Gertsch, and Lampkin, and the prices of $2,000-$10,000 could never be justified in a shop doing only CB servicing. However there are a few more reasonable ways to make this measurement:

1. Build your own. Check the chapter on "Tests & Measurements" in any edition of THE RADIO AMATEUR'S HANDBOOK.
2. An English company called CIRKIT makes a complete kit for about U.S.$20 with shipping. Stock #46-010040. All you add is an aluminum mounting box. Address is Park

Lane, Broxbourne, Herts. EN10 7NQ, ENGLAND. Telephone (0992) 444111. (American readers can write for the price in Pounds Sterling and then buy an International Money Order in British currency from your local bank.)

3. Use a second FM CB like one of the export models to check both the received and transmitted FM signal of the test radio.

TRANSISTOR CHECKER: Personally I rarely use one, instead choosing an ohmmeter for quick go/no-go tests. With a tester you can measure gain and leakage more accurately, and also identify leads of PNP or NPN types. This can be useful if you're unsure of the lead basing and have no device information. However as we'll show later, an ohmmeter can easily be used to determine bipolar transistor basing. Transistor Checkers come in all price ranges, from the Radio Shack and Heathkit models on up to the more sophisticated types.

A SECOND CB TRANSCEIVER: This is probably the easiest and cheapest way around the problem of expensive test equipment, although purists will disagree since exact measurements can't be made. I've done it this way for years except in cases requiring the standard bench equipment. With another radio permanently on your bench, you have a very handy modulated RF signal source for testing a receiver, and a sensitive receiver for testing a transmitter.

I suggest one of the multimode export type radios having AM/FM/SSB capabilities and the additional "expanded" frequencies. Almost every CB you see will already have been modified for extra channels anyway. And there are so many export radios out there with FM in them that you need a good FM Receive/Transmit source. The other use for a second bench CB is for precise SSB offset adjustments. If your bench rig is known to be accurately on frequency when the Clarifier's centered, you can tune the LSB and USB offsets for the most natural voice quality rather than the frequency specified in the service manual. More on this in CHAPTER 6.

CAPACITANCE METER: These are nice to have and nowadays the price is very reasonable. In critical circuits like oscillators you sometimes need to know more than just whether a capacitor is shorted or open. A few picofarads can change everything. I got this neat little digital meter called a Krista for about $50 from one of the mailorder houses that advertise in RADIO-ELECTRONICS magazine. I've seen what appears to be the same meter under various brand names and since all the prices are comparable, the guts are probably made by a single manufacturer with everybody putting their own names on the case.

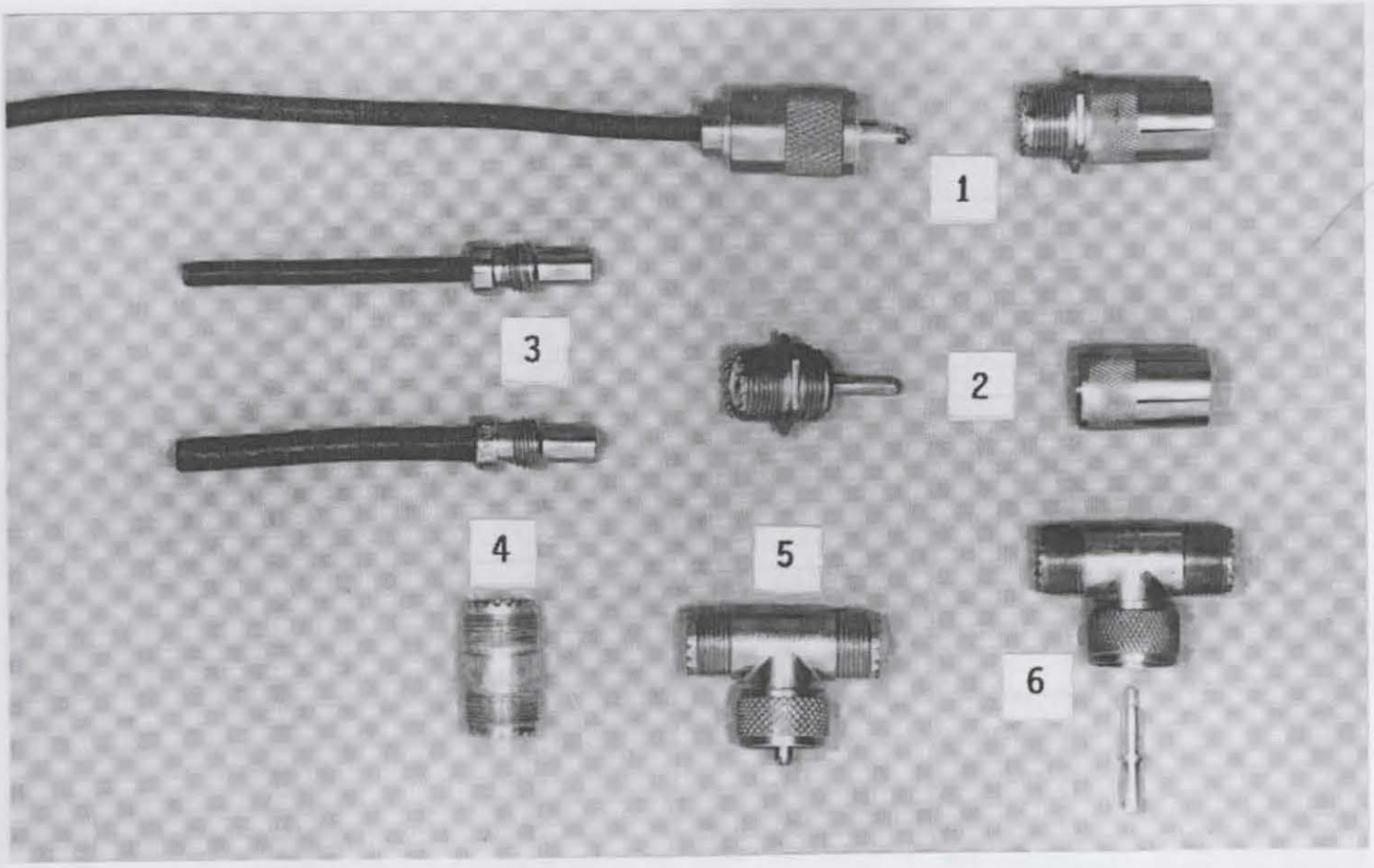
Here are a few more goodies which are strictly optional in most cases: A Tube Tester (yes, many CBs still use them!), Grip Dip Oscillator (handy for finding the resonant frequency of unknown coils, for antenna tuning, as a broadband portable RF source), a Walkie/Talkie for quick mobile troubleshooting, and a Spectrum Analyzer. (Handy for just about everything dealing with radio but priced beyond the reach of most of us!)

ODDS & ENDS:

Clip leads are a must. Get more than one size. (Radio Shack 278-1156, 278-1157, etc.) Besides the standard alligator clips, you need some insulated spring-hook types. They're similar to 'scope probe hooks but smaller. These can be attached to transistor leads and other very tight spaces without causing shorts. The biggest source for these is Pomona Electronics, although Radio Shack does sell just the hooks. Better get some leads for SMD use too.

You need some plastic CB-type alignment tools to fit the various tuning slugs used in coils and transformers. They must be non-metallic for proper alignment. The wrong tool will crack the delicate ferrite and you'll have to replace the whole transformer, so get the right ones in the first place! You should buy the 8-piece CB set made by GC Electronics (Catalog #18-530), which has all the slot and hexagonal types needed to fit virtually any tuning slug or trimpot.

The "push-fit" type of PL259 coax plug is very convenient for everyday bench use. It has a springy outer shell instead of the standard threaded shell, so you can quickly push the plug on and off the radio's coax socket as needed. The Gold Line #96 is an adapter that simply screws on to a standard PL259, and the Amphenol #83-5SP is designed for direct soldering to RG58 coax. I have two RG58 cables using these: one with a BNC on the far end to my signal generator for receiver tests, and one with a standard PL259 on the far end to connect a splitter that drives my various transmitter monitoring equipment. ('Scope, dummy load, frequency counter, wattmeter, etc.)



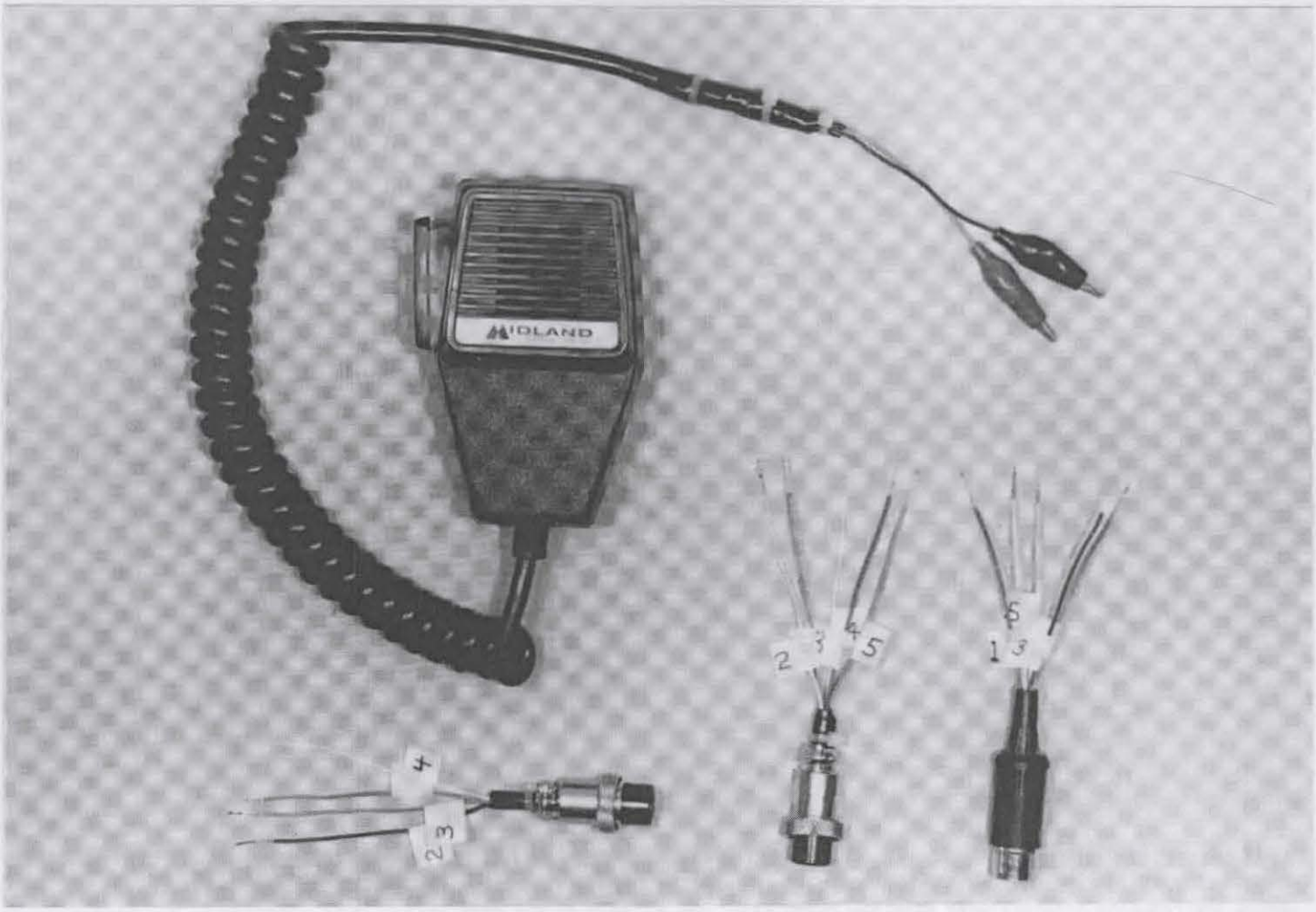
COAX CONNECTOR HARDWARE: #1 shows how a standard PL259 plug can be adapted to a push-fit plug (Gold Line #GL259-PF, Amphenol 83-5SP) for quick hookups on the bench. #2 shows the two threaded pieces that make up this special plug. #3 shows the reducing adapters used with the PL259 plug; the UG175/U is for RG58 coax, and the UG176/U is for RG59 coax. #4 is the double-female "barrel" connector (PL258) used to splice cables with PL259 plugs. #5 is the "T" connector (M358) often used in test set-ups; #6 shows it with the center pin removed to make the RF sampler described in CHAPTER 5.

A flexible magnifying lamp is very useful for finding cracks in PC boards and other close inspection work. Along with this, a penlight type flashlight gives the pinpoint backlighting you often need to find the right PC foil trace. They use those pre-focused #222 bulbs which you can put right up against the PC board for maximum pinpoint intensity.

An external speaker is very useful to quickly indicate if the radio's own speaker is open, damaged, or missing continuity from the PC board. Many radios don't have lugs on the speaker wires and are soldered directly; this is a real pain when constantly turning a radio over and over. If the work's going to be involved, I unsolder the radio speaker after unscrewing the cabinet, and connect my bench speaker to the "EXT SP" jack until I'm done.

A test mike with clip leads is very handy. Take a good dynamic mike from a junked radio and remove the plug. Jumper the audio line across the PTT switch so it's always hot. Cut off the T/R switching wires since you won't need them. Install a clip lead on the shield and audio wires. Now you can conveniently isolate mike audio vs. radio audio problems by direct substitution.

Along with the test mike, I suggest some mike test plugs with colored wires about 6"-12" on the pins. Make one for each major type, like the 4-pin, 5-pin, or 6-pin female with threaded coupling nut, 5-pin DIN, 6-pin DIN, etc. Use a different color for each pin on the plug. Label each wire with its pin number. Now you have a handy way to determine the audio, ground, and T/R lines in an unknown radio. You'll get lots



MIKE TESTERS: A standard dynamic CB mike is often convenient for tracing mike-related problems. Jumper the PTT switch so the audio is always hot, and remove the T/R wires. Also shown are three common mike plugs which can be used to figure out mike socket functions without a schematic. Connect colored wires to each pin, and number each pin as shown. (See text for details.)

of radios with no mike, no schematic, customer wants a power mike installed, etc. It's also useful for testing a suspicious mike with internal wire breaks or a faulty PTT switch. If the radio works when shorting the correct test plug wires you've isolated the problem.

For professional PC board cleanup, use a solder flux solvent. The old type Freon has now been banned in place of something less polluting. The new one seems to work well but can still remove paint from parts markings. And like all solvents it will dissolve plastic, which means sloppy spraying will ruin the plastic trim or S-Meter face. Especially if it's a brand new radio! The stuff I use comes in a regular aerosol spray can with an optional special hose and brush attachment that snaps on to replace the tip. You can then clean up PC soldering with the trigger on the brush attachment; the solvent flows right out of the bristles. The proper stuff is available from:

Miller-Stephenson Chemical Co.
Danbury CT 06810
(203) 743-4447, (800) 992-2424
www.miller-stephenson.com/contact_us.aspx

Ask for their solvent which replaces the old Freon they sold as "MS-190HD." It's expensive but the price drops way down if you buy the 24-can case, Assuming you plan to do a lot of radio work. The hose/brush used to be about $15. Contact M-S for your nearest rep. (There is also the GC Electronics #10-620.) It's a lot easier to spot bad solder joints or broken

traces when there's no solder flux to hide them! And customers will be impressed by the neatness of your work; they probably won't even be able to find the area you worked on.

On the subject of chemicals, no bench should be without a good cleaning spray for noisy pots or dirty switch contacts. I use Chemtronics' Tun-O-Wash. Many cleaners also have lubricants in them, but I prefer a separate lubricant after cleaning. A good one is Tech Spray's Blue Stuff. These are sold at all major electronics parts stores, especially those catering to TV repairmen. Similar chemicals are available from Radio Shack and GC Electronics.

Don't forget the thermal heat-sink compound. If you replace power ICs or transistors, you must include this or the new part may overheat and fail too. This is a silicone-based white grease that you apply to the mica insulator and/or metal heatsink before bolting in the new part. Good examples are Dow-Corning #340, Radio Shack #276-1372, and GC Electronics #10-8108.

How about a crystal checker? Could save you lots of head scratching, and crystals often go bad. All you need is an oscillator circuit and your 'scope, frequency counter, or voltmeter/RF probe. Figure 1-3 shows the simple Colpitts oscillator of the type used in virtually every CB crystal oscillator. (See following photo.) With the capacitance values shown you can check fundamental crystals from about 7-20 MHz and third-overtone types too. (These are generally in the 36 MHz range.) Connect your monitoring instrument to the loose end of the output coupling capacitor; a good crystal would typically generate a level of 1.5-2.5 V P-P RF output in this circuit.

Alignment of Noise Blanker circuits requires a source of broadband noise. You can build a

FIGURE 1-4
20dB ATTENUATOR PAD FOR SIGNAL GENERATOR

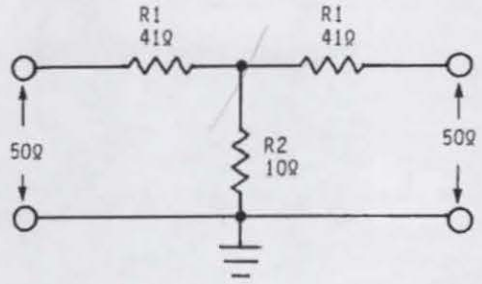
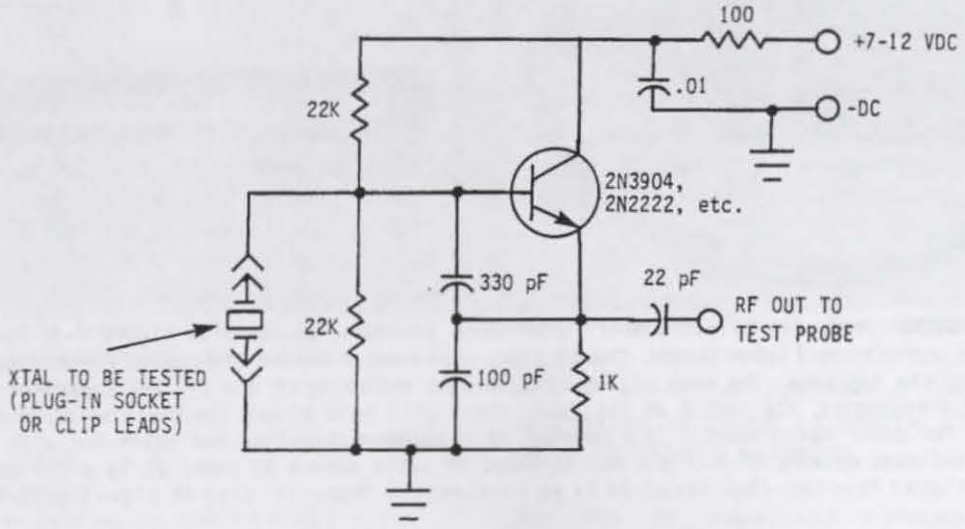
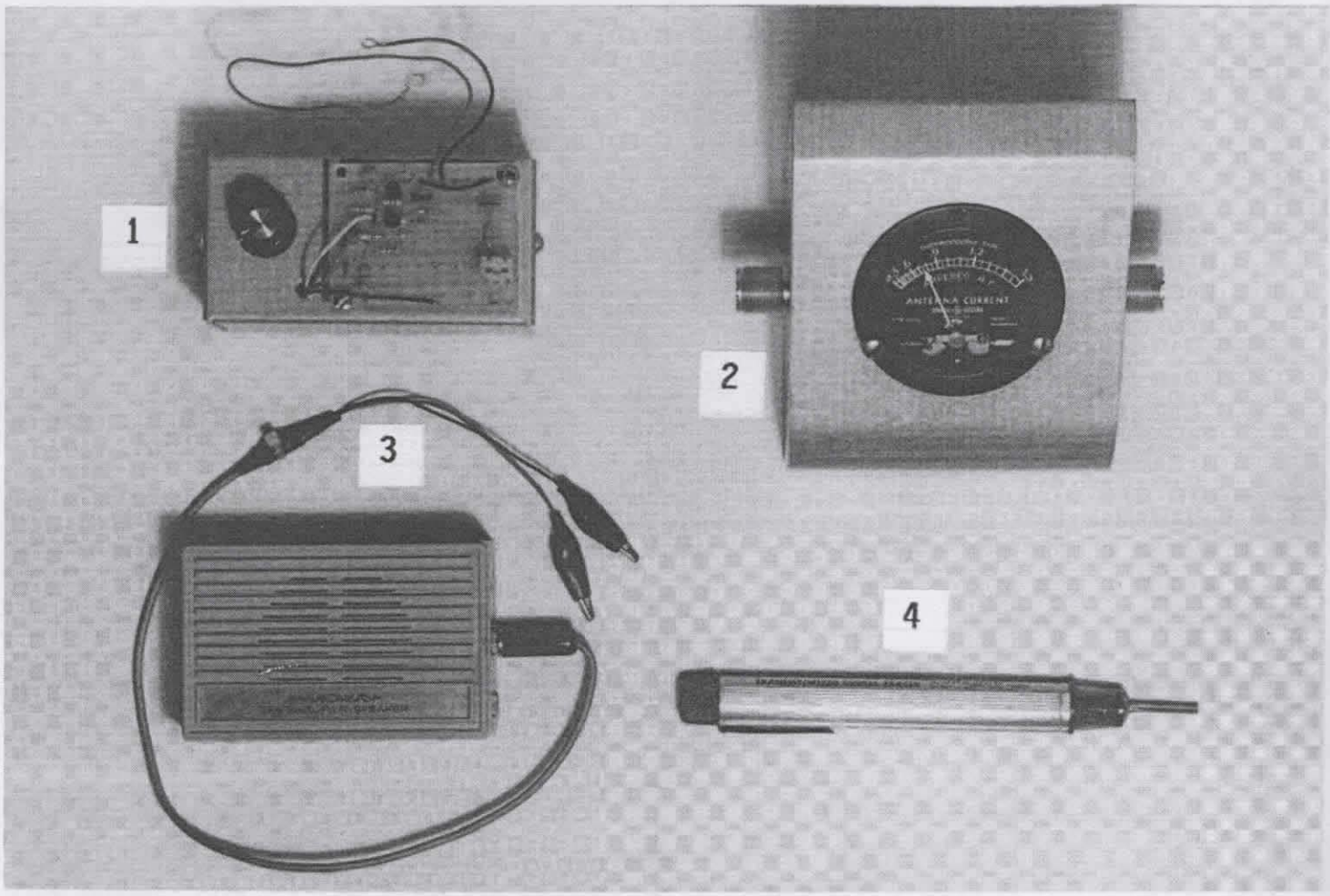


FIGURE 1-3
CRYSTAL CHECKER



simple diode noise generator for this purpose; the RADIO AMATEUR'S HANDBOOK shows examples. You could even use a hair drier or electric drill as noise sources but these are less reliable. Better to inject the noise directly into the coax socket.

Most RF signal generators have calibrated output steps down to about 0.3 µV. Modern SSB transceivers have extremely good sensitivities, often as low as 0.15 µV. Obviously you can't measure this accurately without some help, like a resistive attenuator pad in series with the generator and test receiver. A 20 dB pad is shown in Figure 1-4. The most convenient way to get ultra-low signals is to insert this pad in series while setting your generator for a higher output range. The value of 20 dB is purposely chosen for simplicity in converting the readings, since 20 dB equals a voltage ratio of 10:1. The pad therefore cuts the output from the generator to 1/10 what it says it is. For example, if you needed a 0.1 µV signal, a 20 dB pad in series with 1.0 µV from the generator gives the required 0.1 µV.



MISCELLANEOUS TESTERS: #1 is the Colpitts oscillator whose schematic appeared in Figure 1-3. This was made from one of our EXPANDER 160 crystal oscillator boards. The DC power wires and a hooked test point for a 'scope or frequency counter are located along the top edge. The knob allows simultaneous switching of the divider capacitor values to test a wide range of crystal frequencies. The socket at its lower right will hold either the HC/18 or HC/25 crystal types. #2 is an RF Ammeter used for power measurements. It's mounted in a standard aluminum Bud meter box with SO-239 coax sockets on each side. The indicated reading of 0.75 RFA equals about 28 watts across 50 ohms. #3 is a 200 mW Radio Shack audio amp used for audio signal tracing. (See text.) #4 is an inexpensive "buzz-it" type RF signal generator.

The T-pad shown doesn't really require these precise resistance values; a standard 39Ω resistor could be used for R1. This pad is designed for a 50Ω impedance and it's very important to keep the leads short to minimize stray reactances that would spoil the impedance matching. Mount the circuit in a small aluminum box with BNC jacks at both ends and you're all set. You can also find ready-made pads at the same surplus places that sell the URM25/F signal generators.

CB TECHNICAL SPECIFICATIONS DEFINED

Now that you have an idea of the type of test equipment you'll need, I'll explain more exactly what they tell you about a radio's performance. All the major measurement areas are discussed in the following paragraphs.

THE DECIBEL

Perhaps the most common power measurement unit in electronics is the "decibel" or "dB." The strength of a signal may be defined in terms of its relative loudness to the human ear, which responds to an increase or decrease in loudness by the ratio of the power levels without regard to their absolute values. If a listener estimates that a signal sounds "twice as loud" when going from say, 5 W to 10 W, he'd also estimate that a change from 1 KW to 2 KW sounds twice as loud. In other words, the ear responds to logarithmic changes.

Such changes are the basis for the decibel, which is a unit of relative power. The definition of "1 dB" is that amount of loudness change (up or down) which is just detectable to a listener under ideal conditions. The exact mathematical relationship is one of the most basic of electronic formulas:

$$dB = 10 \log P_2 \div P_1$$

Common logarithms (Base 10) are used, and the larger value is always P_2 so the ratios will be greater than 1. Logarithms can be found using a scientific pocket calculator, or looked up in a table in electronics or math books. For example, what would be the dB power gain of an RF amplifier which produces 4 watts output from a 0.4 watt (400 mW) input signal? Ignore any circuit losses for the moment. Using the above formula, determine the P_2/P_1 ratio first and the rest is a snap:

$$\frac{4 \text{ watts}}{0.4 \text{ watts}} = 10;$$

the log of 10 (from tables or calculator) = 1.

Therefore the dB power gain is 10 x 1 = 10 dB. Simple eh? (By the way, the figure of 10 dB power gain is typical of the Driver and Final RF stages in most solid-state CB transmitters.)

Since decibels are based on logarithms, they can be added or subtracted algebraically. For example, what's the net gain (or loss) of an antenna system with 6 dB antenna gain and 1 dB loss in the coax feedline? The answer is

$$(+6 \text{ dB}) + (-1 \text{ dB}) = +5 \text{ dB system gain.}$$

Note the dB is based upon power ratios. However many times you're not dealing with power but with voltage or current instead. So it's convenient to use the decibel for these units, if the measurements are made across the same value of impedance. When the input and output impedances are equal, the formulas are:

$$dB = 20 \log V_2 \div V_1 \text{ (for voltage ratios)}$$
$$dB = 20 \log I_2 \div I_1 \text{ (for current ratios)}$$

Recalling the 20 dB pad used with the signal generator, you'll see that 20 dB of voltage change is equal to a ratio of 10.

The dBm Reference

A related measurement unit is the "dBm," which means "dB referenced to 1 milliwatt." It's often handy to have some zero reference point from which to make a measurement, and the dBm fits this purpose since dB units may be added to or subtracted from the zero reference level. The dBm value is found by the formula

$$dBm = 10 \log [20(V_{RMS})^2],$$

where dBm is the power referenced to one milliwatt and V is the RMS voltage across the output source's impedance. The values can be calculated or found in charts like those in THE RADIO AMATEUR'S HANDBOOK.

The dBm is important because an alignment procedure sometimes specifies signals in dBm rather than microvolts, which may confuse you

if you don't know what it means. For example, an RF signal of 1.0 µV equals -107 dBm. So if the alignment procedure said to "inject a signal of -107 dBm" you'd know what that means, especially if the signal generator is calibrated in microvolts. Or suppose an RF amplifier stage had a 20 dB gain. Injecting a signal of -107 dBm at its input would result in an output signal of -107 dBm + 20 dB = -87 dBm.

A SAMPLE TRANSCEIVER

Figure 1-5 is typical of the specifications found in CB radio service manuals. These particular specs come from the popular Cobra 148GTL-DX/Superstar 360FM Uniden chassis. I've purposely chosen this model because it has FM as well as AM/SSB modes and there are some unique properties of FM worth pointing out. First we'll list all the specs, then we'll talk about what the most important ones mean. We'll skip the obvious specs like size, weight, number of channels, etc.

Definitions (From Chart Page 15)

FREQUENCY TOLERANCE: This spec refers to the guaranteed carrier frequency accuracy. It's usually expressed as a percentage, like ".005%" in this example. Sometimes the actual tolerance in Hz is given; the Cobra 2000GTL specifies ±130 Hz. To figure the tolerances, multiply the carrier frequency by the tolerance percentage. Assuming a frequency of 27.185 MHz (Ch.19) and a tolerance of .005%, the actual value is

$$27{,}185{,}000 \times .00005 = \pm 1359 \text{ Hz}$$

Note the tolerance will change slightly from Ch.1 (1348 Hz) to Ch.40 (1370 Hz), since you're multiplying by different channel frequencies. (That's why the SAMS Fotofacts from Volume #194 on show the actual frequency limits, where earlier volumes only listed the center carrier frequency itself.

By the way, the value of .005% is the FCC maximum, and practically all PLL CBs exceed this. As shown above, the Cobra 2000GTL with its ±130 Hz tolerance is ten times better than the specs allow! The older crystal type radios needed that extra tolerance for drift caused by temperature and voltage fluctuations.

FREQUENCY STABILITY: This figure, expressed as a percentage of the center carrier frequency, indicates how much the frequency will drift after the unit warms up for 30 minutes. This is a measure of the transceiver's voltage regulation, operating temperature range, quality of crystals used, and general overall design. Again with PLL control, frequency stability is excellent.

MICROPHONE: Nowadays these are always dynamic types with an impedance of 300-1KΩ. They may plug in or wire directly into the chassis as in some older 23-channel types. The dynamic element is the most desirable since it's very rugged, immune to temperature and humidity changes, and being low-impedance is compatible with solid-state audio amps without needing transformers or other impedance matching circuits. Oldtimers may remember the Johnson CB line with its high-impedance ceramic mikes; being less common, they were harder to repair.

While we're at it, let's clear up all the confusion about "low-impedance" and "high-impedance" mikes. The only mikes that are truly high-Z are the crystal or ceramic types; the impedance is generally about 50K-100KΩ or more. Being high-Z the output levels are somewhat higher than dynamic types, but modern high-gain mike amp circuits are cheap and easy to design so the output level is no longer important. All other mike types are low-Z, <u>including</u> power mikes. The output of a power mike amp is generally 1K-5KΩ which can be considered low-Z. Even if the mike element itself is high-Z (like the ceramic element of the popular D-104) its amplifier has already converted the high-Z input to a low-Z output at the mike cable, which is all the radio input sees anyway.

INPUT VOLTAGE: This describes the permissible range of DC input voltages for proper operation. The nominal value of 13.8 VDC is generally the charging voltage across the battery terminals of a running auto engine, so this figure has become standardized for solid-state mobile equipment. Since the modern CB has been designed for proper biasing from a main input source of 13.8 VDC, even the base versions set their AC-to-DC converter at this level. Walkie-Talkies are the only real exceptions and actually do run on 12 VDC from internal batteries.

It's extremely important to maintain the proper

FIGURE 1-5
CB TECHNICAL SPECIFICATIONS

GENERAL

Frequency Tolerance:	.005%
Frequency Stability:	.001%
Microphone:	Dynamic, 600 ohms
Input Voltage:	13.8 VDC nominal, 15.9 VDC max., 11.7 VDC min., pos/neg ground
Current Drain:	TX: AM full mod., 2.2 A. SSB 12 W PEP, 2.0 A. RX: Squelched, 0.3 A. Maximum audio, 0.7 A.

TRANSMITTER

Power Output:	AM/FM/CW, 5 watts. SSB, 12 watts PEP.
Modulation:	High and low-level Class B, AM. Variable capacitance, FM.
FM Deviation:	±1.5 KHz @ 20 mV 1 KHz audio.
SSB Carrier Suppression:	-55 dB.
Unwanted Sideband Suppression:	-50 dB.
SSB Intermodulation Distortion:	3rd order, more than -25 dB. 5th order, more than -35 dB.
Spurious Harmonic Radiation:	-65 dB.
Output Impedance:	50Ω unbalanced.

RECEIVER

Sensitivity:	SSB/CW: 0.25 µV for 10 dB (S+N)/N at more than 1/2 watt audio output. AM: 0.5 µV for 10 dB (S+N)/N at more than 1/2 watt audio output. FM: 1.0 µV for 20 dB (S+N)/N at more than 1/2 watt audio output.
Selectivity:	AM/FM: -6 dB @ 3 KHz, -50 dB @ 9 KHz. SSB/CW: -6 dB @ 2.1 KHz, -60 dB @ 3.3 KHz.
Cross Modulation:	-60 dB
Adjacent-Channel Rejection:	AM/FM: -60 dB; SSB/CW: -70 dB.
Image Rejection:	More than -65 dB.
IF Frequency:	AM/FM: 10.695 MHz 1st IF; 455 KHz 2nd IF. SSB/CW: 10.695 MHz.
Automatic Gain Control (AGC):	Less than 10 dB change in audio output for inputs from 10 µV to 100,000 µV.
Squelch Range:	Adjustable, 0.5 µV to 1,000 µV.
Audio Frequency Response:	450-2500 Hz TX, 300-2500 Hz RX.
Maximum Audio Power Output:	4 watts into 8 ohms.
Audio Power Output @ 10% THD:	3 watts.

input voltage. Low voltage won't damage anything but will degrade receiver sensitivity and greatly reduce transmitter output power. But excess input voltage can quickly burn out the transmitter RF amplifier stages, as well as ICs and other voltage-sensitive components. Always verify correct input voltage on radios you're servicing!

All modern transceivers operate with positive or negative ground electrical systems, which means the main PC board isn't making a direct electrical connection to the radio frame but is "floating" instead. This allows the radio to be bolted directly to the body of a positive-ground vehicle without causing a short circuit, and is a convenience feature since some large trucks and foreign autos do use positive ground electrical systems. The PC board is grounded to the radio frame for RF via several disc decoupling capacitors, and that's why you'll see two different ground symbols on the schematic. One symbol actually means "vehicle body" ground and one means "chassis common tie point." Mixing the two different grounds can cause ground loops and other problems which may drive you crazy trying to solve!

CURRENT DRAIN: The CB transceiver will draw different amounts of power depending upon operating mode. This spec can help determine if an internal problem is causing excessive current draw, and also suggests an adequate power supply size for the type of radio being serviced. Typical values are:

Transmit AM/FM/SSB @ full modulation = 2.2 A*
Receive squelched = 300 ma to 650 ma
Receive @ full rated audio = 700 ma to 1.2 A

*Higher power radios like the President Jackson may draw over 3.0 A on transmit; use a heavier power supply.

TRANSMITTER POWER OUTPUT: This is the RF power output measured at the antenna jack when terminated in a non-inductive 50Ω load. The power output depends upon the mode, and is the unmodulated value for AM (and FM) and the peak-envelope-power (PEP) for SSB. For American CBs this is always 4 watts for AM and 12 watts PEP for SSB. Since these levels are the legal limits, the manufacturer is never going to say his equipment puts out less power! For export models the RF power may be higher, and in some (President Jackson, Franklin, Grant, Ranger AR3300, Super Galaxy and Galaxy II, etc.) is actually double the normal power.

MODULATION: This is almost always high- and low-level Class B for AM, and variable capacitance for FM. Exceptions include the Uniden Jackson and all the CPI radios, which use low-level AM. We'll discuss classes of operation and FM generation in CHAPTER 5. This is really more of a circuit description than a specification, since it can't be changed.

FM DEVIATION: This refers to the amount of frequency shift above and below the unmodulated carrier frequency. Since the total deviation depends upon both the modulating frequency in Hz and the input amplitude in millivolts, these figures must always be included for the spec to be meaningful.

SSB CARRIER SUPRESSION: The whole idea of SSB is that supression of the unwanted carrier allows more useful power to apply to the sidebands. This spec indicates how well that's being done. If the carrier is not fully supressed the listener will hear an annoying heterodyne along with the voice. The higher the dB suppression figure, the better. Modern CBs generally specify at least -45 to -55 dB, which is good to excellent. Carrier supression is affected by both the balanced modulator circuit used, and the crystal filter which eliminates the unwanted sideband.

UNWANTED SIDEBAND SUPPRESSION: This measures the ability of the SSB transmitter to eliminate the unused sideband. Like carrier suppression more is better, with -40 dB the FCC minimum but -55 dB being more typical of modern equipment. The spec is most affected by the quality of the crystal filter removing the unwanted sideband. This filter may also be used for SSB reception and therefore affects receiver IF selectivity. You'll find that the radios with the poorest adjacent-channel rejection also have the worst spec in this category.

INTERMODULATION DISTORTION (IMD): This measures signal purity in the mixer stages. If excessively strong RF signals are fed to the mixer, its output no longer changes linearly with the input. When not purely linear, distortion products form which can cause interference to nearby frequencies on Transmit or desensitization on Receive. The IMD products are similar to harmonics and are assigned numbers indicating their strengths relative to the carrier. The most important products are

the 3rd, 5th, 7th, and 9th "order", which is why they're often specified individually. Once again, the more IMD suppression the better.

CROSS MODULATION: This is a form of receiver distortion closely related to IMD and most noticeable on AM. It's possible for a signal on a nearby frequency to modulate the signal on a desired frequency, even though the unwanted carrier is well outside the receiver's IF passband. A good spec for this is -60 dB, and is typical of better radios. It's basically a reflection of careful receiver design.

FREQUENCY RESPONSE: This indicates the range of audio frequencies transmitted and received. Since voice communications require a much narrower range than say, a hi-fi FM stereo, only a narrow band is allowed to pass through the audio circuits. There's little reason to even specify this, since virtually all two-way radio equipment operates in the audio range of about 300-2500 Hz anyway.

OUTPUT IMPEDANCE: Why this is even listed I'll never understand, since it's always 50 ohms by design. This is standard for virtually all two-way radio equipment. "Unbalanced" means there's a single hot conductor, with the radio's frame providing the ground return. This allows the use of coaxial cable to connect the equipment to the antenna.

SPURIOUS RADIATION: When CB really got popular in the mid 1970s, TV viewers screamed bloody murder from all the interference they received. During the 23-to-40 channel conversion period the FCC tightened certain technical specs, including this one. This is a measure of all the unwanted junk (like harmonics) radiating from the radio cabinet. The FCC spec is -60 dB. All American CB manufacturers must comply anyway, so any 40-channel FCC-approved model is going to specify this figure. (Unless of course the radio is even better.) This spec is determined by the amount of metal shielding and filtering used in the transmitter circuits. You oldtimers from the 23-channel era have probably noticed all the extra metal shielding in the 40-channel transceivers. Spurious radiation is measured with a Spectrum Analyzer, a very expensive instrument usually reserved for the R&D lab and not the average CB shop.

RECEIVER SENSITIVITY: This is one of the best indicators of quality and careful design, and measures the ability to detect very weak signals against the normal background noise. The zero reference level is the noise itself, and a standard figure of 10 dB compares the signal to the noise. Hence the term, "Signal + Noise to Noise Ratio," or "(S+N)/N." The signal strength in microvolts when it's 10 dB louder than the noise is the rated sensitivity. For this measurement less is better; the lower the µV reading the better the sensitivity. Anything under 1.0 µV is good, with many transceivers having even hotter specs. An audio output level like "1/2 watt" is often included to give the spec a meaningful reference.

Note different specs were quoted for the AM, FM, and SSB/CW modes. Note also that SSB sensitivity is better than AM, and FM is specified differently than AM. The reason SSB is better is because the signal is being passed through a narrower IF filter which occupies only half the bandwidth of a comparable AM or FM signal. Since the receiver bandwidth is narrower, less noise gets through, thus improving the S+N/N ratio.

FM is unique. When the received signal is strong enough to start limiting action the set begins to "quiet," meaning the background noise disappears. FM sensitivity is rated in terms of the amount of input signal required to produce a given amount of quieting, usually 20 dB. In other words, the amount of signal required to reduce the background noise by 20 dB is the rated sensitivity. With modern IC FM Detectors, sensitivities of less than 1.0 µV are easily attainable. Because of the inherent noise reduction of FM it can function with much higher background noise levels. This partly explains why the background hiss noise is so much louder than AM in a multimode radio. Note the µV rating is for 20 dB quieting, compared to the 10 dB S+N/N for comparable AM.

SELECTIVITY/ADJACENT-CHANNEL REJECTION: These are the other major indicators of quality receiver design. Some manufacturers give both specs and some use only the Selectivity spec, but both mean almost the same thing. The listener shouldn't be bothered by "bleedover" interference from an adjacent channel during normal reception. Basically this says a signal of a given strength will be so many dB weaker one channel (10 KHz) higher or lower than in the center of the desired channel. For the Adjacent-Channel spec, more is better; -30 dB is the absolute minimum and the better radios may specify up to -70 dB. The spec will be

better for SSB (or CW), since a narrower IF filter is used. (See CHAPTER 6.)

Selectivity is defined in a slightly different way. It states the attenuation as a function of how far removed the signal is from the center frequency: at so many KHz from center, the signal will be reduced so many dB. Two points are chosen and a graph of attenuation vs. center frequency has the shape of a skirt; i.e., flat across the top and dropping off sharply on both sides. Hence the term "skirt selectivity." The IF bandwidth at the -6 dB and -60 dB points is most often used, although CB manufacturers vary widely in their choice of measuring points. In our example, the AM/FM spec states that "at $\pm$3 KHz from center, the signal will be reduced by 6 dB, and at $\pm$9 KHz, by 50 dB." Notice again the SSB/CW spec is better due to its narrower IF filter.

Receiver selectivity depends upon factors like the number of tuned circuits, single- vs. double-conversion, etc. More in CHAPTER 4.

IMAGE REJECTION: Images appear whenever two signals mix together to form an Intermediate Frequency, or IF. If not attenuated they can be annoying and show up as "birdies" at many places around the band. This spec indicates how well they're reduced. More is better. Some of the cheaper CBs have only about -40 dB image rejection even with dual-conversion, while the good ones measure more than -60 dB.

IF FREQUENCY: This isn't really a spec but a circuit definition. The industry standards are 455 KHz and 10.695 MHz, and these are used in most modern CBs. Some radios use 7.8 MHz, 11.275 MHz, 9.785 MHz, 4.3 MHz, and other odd frequencies for the high IF. All this really tells you is whether the radio has a single- or dual-conversion receiver. Dual-conversion is better. Radios having FM will always be dual-conversion because narrow-band FM of the CB type is easy to detect at 455 KHz but not at the higher IFs of single-conversion receivers, which have much narrower IF bandwidths.

AUTOMATIC GAIN CONTROL (AGC): This is a circuit that keeps the receiver volume level constant with widely fluctuating input levels. It's especially important for SSB, since with no carrier the signal strength changes only with speech. Without AGC you'd be blasted out of your chair whenever a stronger signal came on the channel, and that signal would probably be very distorted too.

This spec measures how wide a range of signal inputs can be handled by the receiver, called its "dynamic range." The EIA (Electronic Industries Association) specifies that audio output should be maintained within 30 dB for input levels from 1-50,000 µV for AM receivers, and within 16 dB for SSB receivers. Most CBs (including our example) specify an audio change of no more than 10 dB, which obviously exceeds the EIA specs. The better the AGC circuit, the wider the dynamic range it can handle. AGC may be specified in terms of signal strength limits, or by a straight dB figure for dynamic range. The example quotes 10-100,000 µV for the signal range. We could easily convert this to dynamic range using the previous formula,

$$dB = 20 \log E_2 \div E_1$$

Remember we're dealing with (micro)volts so we use that formula. Dividing 100,000 by 10 equals 10,000. The log of 10,000 is 4. Multiplying 20 x 4, we get the answer of 80 dB. This is a very good AGC dynamic range figure and is typical of the better CBs; 100 dB would be outstanding.

SQUELCH RANGE or SQUELCH SENSITIVITY: Usually one or the other is specified. The sensitivity figure, which is the most common, indicates the weakest signal that will break squelch. This is usually close to the main sensitivity spec; i.e., about 0.5 µV. When stated as a range this tells you the weakest and strongest input signals that can be squelched. A good squelch circuit can handle from 300-1,000 µV, right on down to the rated receiver sensitivity.

AUDIO OUTPUT POWER: This is specified at some percentage of total harmonic distortion (THD), usually 10%, and across some load impedance like 8Ω, but occasionally 4Ω or 16Ω. There's nothing you can do to increase the audio power output so if a customer needs the radio's PA function, suggest one having a 4-watt output rating which is about the maximum available. Many older models only had about 2 watts output, barely adequate for a PA or inside the cab of an 18-wheeler. All the better radios have 3-4 watts of output power.

AUDIO FREQUENCY RESPONSE: This range is about 300-2500 Hz for communications purposes and you'll never see anything much different. RC filtering in the receiver and transmitter audio circuits keeps the response within this range.

This sums up all the most common transceiver specs you're likely to see. I've left out the obvious ones like Clarifier Range, RF Gain control range, metering, dimensions, number of semiconductors, etc. In later chapters we'll learn how many of these specifications can be measured or affected by alignment.

WHERE TO FIND JUST ABOUT EVERYTHING

Following is a partial shopping section. U.S. readers can probably find most things for a complete CB shop here, or on the Internet. Foreign readers should try to use local sources or the Internet. Many of these sources offer free catalogs if you ask for them.

IMPORTANT NOTE!
In a book like this which may only get reprinted every few years, it's almost impossible to keep this section updated. People and companies move, go out of business, change their phone numbers, merge with other companies, etc. If a particular company shown here winds up a dead end, I strongly suggest searching the Internet; specifically, see Amazon, Google, our Web site, or other places for newer contact details. We do try to keep an updated, categorized list at:
www.cbcintl.com/suppliers.htm

Please tell us if you come up empty. Meanwhile, many good sources for parts, books, and test equipment are in any of the Ham Radio magazines like **CQ** and **QST**. (QST is the ARRL's Ham magazine; see column at right.) Most of the other general electronics mags have either changed to computers or fallen victim to the Internet. Among the best Ham magazines are:

CQ AMATEUR RADIO MAGAZINE
25 Newbridge Rd., Hicksville NY 11801
(800) 853-9797 • www.cq-amateur-radio.com

A sneaky way to get a free sample is to ask them about advertising by using your printed letterhead, and they'll usually do it. A very good idea in case you live in the boonies or can't find it locally. All the good books and magazines can be found in the pages of CQ or any of the other sources shown on our Web page.

A very handy source for all kinds of electronic parts and manufacturers (by category) is the annual ELECTRONIC INDUSTRY TELEPHONE DIRECTORY. It's expensive ($60+), but you can often find a used EITD on Amazon. There's probably an online version by now too. Try their publisher:

HARRIS PUBLISHING CO.
2057 E. Aurora Rd., Twinsburg OH 44087
(330) 425-9000

REFERENCE READING LIST

Some of the following are classics and are now out of print. Check with the publisher or your local book store, library, or online for availability, or if there's a newer edition.

THE CB PLL DATA BOOK, by Lou Franklin ($25).
Published by CBC INTERNATIONAL
P.O. Box 30655, Tucson AZ 85751
FAX: (520) 298-7980. Internet: www.cbcintl.com

How PLLs work and how to modify them for more channels or 10-Meter Ham use. This is my complete reference with simplified circuit theory, complete pin-out specs for every known chip, PLL block diagrams of most common types, all cross-referenced by make and model, etc.

THE ARRL RADIO AMATEUR'S HANDBOOK
American Radio Relay League Inc.
225 Main St., Newington CT 06111
www.arrl.org • QST Magazine
Main: (860) 594-0200, Orders: (800) 243-7767

This is the classic "bible" of radio communications and no bookshelf is complete without a copy. Originally intended for Hams, many people (including me) consider it the single most important reference for any serious electronics student. Detailed background theory, building ideas, and reference tables. The editions from 1986 on are huge, and now include PC artwork for many test equipment construction projects. Starting with the 1996 edition, they've combined this with their equally great **ARRL ANTENNA HANDBOOK**. That one has the most detailed antenna theory you'll find short of an engineering library. Learn the dope on SWR once and for all. Includes many practical antenna projects for mobile and base HF and VHF/UHF antennas. One huge new electronics reference work in a beautiful hardbound cover. You need this one! The ARRL also has a big bookstore, sunspot info, etc.

The European equivalent is the **RSGB RADIO COMMUNICATION HANDBOOK**. Available from the Radio Society of Great Britain, Alma House, Cranborne Road, Potters Bar, Herts. EN6 3JW, England. Also stocked by Ham Radio Outlet in the U.S.; see Page 21.

The following titles are a few of the many books available. Although some are old, they're just as relevant to CB technology today. I've got them all in my personal library, and in fact have used them all in researching this book. Nothing's more important than reading everything you can find and learning from it. You're not a true technician unless you also understand the theory and can design simple circuits yourself, or at least being able to modify them or draw them schematically. That makes you better than the next guy and gets you the extra business!

Many of these books are available in the better Ham Radio stores such as those listed here. As of early 2013 I searched for all of them online and found they're still available, new or used, at Amazon, Google Books, Barnes & Noble, etc. If you search these sites you'll find them and a lot more electronics books.

LANDMOBILE AND MARINE RADIO TECHNICAL HANDBOOK
by Edward M. Noll
SAMS Technical Publishing
9850 E. 30th St., Indianapolis IN 46229
Orders: (800) 428-7267 • **www.samswebsite.com**
An excellent 576-page SAMS book covering all aspects of two-way radio operation and repair, including solid-state radio fundamentals, CB, marine, VHF/UHF, testing procedures.

MOBILE RADIO SERVICING HANDBOOK
by Belcher, Ogley, & Fitch.
Heinemann-Newnes Books, London, England
Like the SAMS "Landmobile" handbook above. Emphasis is on evolution of radios to the current state-of-the-art, diagnostic and component replacement procedures, what to do in the absence of proper circuit data.

RADIO HANDBOOK, by William I. Orr
Sams Technical Publishing. (See above.)
One of the world's most famous Hams, Bill Orr (W6SAI) wrote countless books and articles on all areas of electronics. The "W6SAI HANDBOOK" is yet another author's way of teaching, and some areas are more or less detailed than the comparable subject in the **ARRL HANDBOOK.** Loaded with theory and many electronic construction projects. This book is also a free download!

ELECTRONIC COMMUNICATION, by Robert L. Shrader
McGraw-Hill Publishing Co.
Orders: (800) 262-4729
www.mhprofessional.com
Another classic textbook. The fact that it's still around after all these years attests to its quality. Covers all areas of two-way radio and broadcasting. I used it to study for and pass the FCC 1st Class Commercial license exam.

PRACTICAL RF COMMUNICATIONS DATA by Doug DeMaw.
Available online, at the **ARRL** & **SAMS**
SAMS: (800) 428-7267 • ARRL: (800) 243-7767
www.samswebsite.com
DeMaw is an engineer and former president of the ARRL who really knows his stuff. This is a great little book on designing all kinds of RF circuits like crystal oscillators and VFOs, mixers, filters, linear amplifiers, etc.

MODERN ELECTRONIC COMMUNICATION
by Gary M. Miller
Prentice-Hall Inc.
(800) 383-2419, (201) 592-2000
An excellent start-of-the-art reference that details radio, TV, microwave, and digital communications theory. Heavily technical and mathematical though, for those of you who really like to dig into the subject.

BASIC DIGITAL ELECTRONICS WITH MSI APPLICATIONS
by John A. Dempsey
Addison-Wesley Pearson Co. (800) 447-2226
This 1977 book is still worth a trip to the library, or get a used one online. All you ever wanted to know about digital stuff. Modern CBs use ICs and even microprocessors. But the only real difference is that those earlier ICs had separate functions which today are found in just one or more really large chips. An example was the SBE Formula D, one of the very first digital CBs whose PLL used 9 individual chips (several with multiple circuits); today all those PLL circuits can be found inside one very large IC.

GENERAL RADIOTELEPHONE LICENSE HANDBOOK
by Edward M. Noll
This and many others with similar titles can be found by searching Barnes-Noble, Google, or Amazon. Excellent Q&A/Theory books to help you prepare for the commercial FCC exams.

NOTE: An FCC license is no longer required to legally repair CBs. A license is still needed for certain other radio services. To learn about the new requirements, write to the FCC, Field Operations Bureau, Washington, DC 20554.

THE TRUTH ABOUT CB ANTENNAS
ALL ABOUT CUBICAL QUAD ANTENNAS
THE BEAM ANTENNA HANDBOOK
all by William Orr
Everything you need to understand CB antennas in general, and high-gain base beams in particular. These guides and lots of other good books are available from the sources mentioned here.

Other Web sites with good book sources include: **eham.net, qrz.com, radio-ware.com,** etc. The Web is the obvious place to start looking.

AMATEUR RADIO EQUIPMENT & DEALERS

HAM RADIO OUTLET (HRO)
933 N. Euclid St., Anaheim CA 92801
(800) 854-6046, (714) 533-7273
hamradio.com/contact.cfm
Probably the biggest, now 12 stores nationwide. The main store is shown here. Or you can use the link above to find your closest store.

HENRY RADIO
2050 S. Bundy Dr., Los Angeles CA 90025
(800) 877-7979, (310) 820-1234
Another great Ham store that refuses to die!

MFJ ENTERPRISES
See listing details under TEST EQUIPMENT – NEW

SPECIALIZED SERVICE INFORMATION

SAMS "FOTOFACTS" CB Radio Series
See address on Page 1. Orders: (800) 428-7267
They finally stopped publishing the CB series of Fotofacts in 1981, after 293 volumes. Each volume covered 3 or 4 models. You will now need to buy a photocopy of an individual CB Fotofacts model from them, or try to find your info elsewhere online. The index from Volume #293 lists every CB they ever covered. This index is also on my Web at: www.cbcintl.com/sams.htm

The last time I checked, SAMS would sell you photocopies for out-of-print Fotofacts. But be prepared to pay about $25 each; there's no other way to get them now unless somebody has put a model online. SAMS schematics are much easier to read than those microscopic Asian drawings, so it's well worth using them. Since they are probably the biggest American publisher of electronics books, a search will probably show many titles of interest to electronic techs.

Many newbies ask me where they can find books on things like how to read schematics, how to use an oscilloscope, etc. SAMS and the other firms here offer titles on these and many other electronic subjects, whether beginner or expert.

SEMICONDUCTOR PARTS SUBSTITUTION MANUAL. Always keep a copy of this handy. The ECG/SK parts lines were bought by NewTone Electronics (NTE), so that's where you need look now. (This also applies to any other ECG/SK references in this book that I might have forgotten to change!)

NTE ELECTRONICS
44 Farrand St., Bloomfield NJ 07003
(973) 748-5089 • (800) 683-6837
www.nteinc.com

JAPANESE TRANSISTOR SPEC/SUBSTITUTION MANUALS. These are great little books straight from the source, updated every year. In many cases this is the only way to get the specs or lead basing on a particular Asian device. If you're an experienced tech you know that many times the TCG/ECG/SK replacement has the same electrical characteristics but different lead basing. With these books you can figure out the basing and the electrical specs for correct substitution. There's also a Japanese Substitution Book, a Japanese FET Book, etc.

One minor problem: the books are written in Japanese, with just enough English words to get by. What I did to figure out their basing diagrams was to use a known Japanese transistor like a 2SC2312 and look up its base drawing; then I wrote the letters E, B, C next to the Japanese characters for these terminals. Now whenever I have to look up an unknown transistor, I compare that Japanese script with the one previously marked.

The only good source I know of now for these great little Asian device books is at Amazon, but there are probably others. I recently saw a 6-book online deal that included not only bipolar devices, but also FETs, diodes, etc.

This section wouldn't be complete without mentioning one of the biggest and most useful CB sites that's ever been online, namely:

www.cbtricks.com

They went to a lot of trouble to put schematics, board layouts, and a lot of other handy info into a huge, all-in-one Web site. Check it out.

CB RADIO MANUFACTURERS

You'll often get a CB where the manufacturer is now out of business, or the customer has no service manual. Many CBs never appeared in SAMS, and newer models have come along since the Fotofacts ended. Following are those companies still in the business, who can provide certain parts and service manuals for their CB radios.

It's not impossible to find a rare part from an extinct CB model, if the main chassis had an equivalent made by a current manufacturer. For example, suppose you need the Audio IC for a Lafayette HB740 radio, a nice chassis (Cybernet PLL02A 2-crystal AM) that's been sold under dozens of other brand names. Midland is still around and has used that very same chassis, so try to get it by specifying <u>their</u> corresponding model number. You can learn which models are identical from the information listed in our **TUNEUP & MODIFICATION REPORTS**, or send a stamped SASE or email. (Cont'd on next page.)

CB RADIO MANUFACTURERS, cont'd

NOTE: You won't find exact replacements for any Uniden or Cybernet export models, unless they're the same parts used in the American versions. The main non-standard parts are the broadband tuning coils; if you need one and can't take one from a junker, you'll have to use the stock narrow-bandwidth American coil. These guys will deny any knowledge of "export" radios, even though their name's on it!

ALAN ELECTRONICS GmbH
(Includes **Albrecht** & some **Midland** models)
www.alan-electronics.de
Daimlerstrasse 1k • 63303 Dreieich, Germany
A very popular brand name all over Europe.

COBRA ELECTRONICS CORP. (DYNASCAN CORP.)
6500 W. Cortland, Chicago IL 60607
Customer Service: (773) 889-3087
Main: (773) 889-8870 • **www.cobra.com**

GALAXY INC.
Repairs: (760) 480-8800 • **www.galaxyradios.com**
Email: techsupport@galaxyradios.com
They only service radios having a "DX" prefix, like "DX-959" or similar. If there's no "DX" on it, it's a cheap copy and they will not fix it! Their address is a big secret too, only revealed when you call to ship your radio to them.

MIDLAND INTERNATIONAL
5900 Parretta Dr., Kansas City MO 64120
(816) 241-8500 • **www.midlandradio.com**
Midland's another possible source for Cybernet parts, which were used a lot in their earlier models. The current AM models use the Korean Maxon chassis, and SSB models are Unidens.

BEARCAT, PRESIDENT, REGENCY – See UNIDEN

RADIO SHACK (Nationwide)
(800) 843-7422 • www.radioshack.com
You can often order a specific service manual or part from your local R/S store, assuming the item's still available. In the last few years R/S has made very few new CBs under their own name, instead choosing to sell some other main CB brands like Cobra, Midland, and Uniden.

RANGER COMMUNICATIONS INC. (RCI)
(Includes Ranger, RCI, Texas Ranger, & some Galaxy)
867 Bowsprit Rd., Chula Vista, CA 91914
www.rangerusa.com

Parts & Service	**Amateur & CB**
Local: (619) 426-6440	Local: (702) 262-0772

UNIDEN AMERICA CORP.
4700 Amon Carter Bl., Ft. Worth TX 76155
(800) 297-1023, (817) 858-3300 • **www.uniden.com**
Includes many rigs with the Bearcat, Cobra, President, Stalker, Teaberry and Uniden labels, plus the main inside guts of many other models like the Midland 79-260, Radio Shack TRC451, TRC453, TRC465, etc.

CB ANTENNA MANUFACTURERS

Quality CB antennas are getting harder to find, since there are fewer distributors other than CB specialty shops. This is a real problem if you live in a small town and have no local sources. The following are known major manufacturers. Contact them to see about buying their products through distributors, or sometimes directly. NOTE: Some of the Websites listed (2013) are old and may be gone by now. Keep searching!

ANTENNA SPECIALISTS CO.
They merged so many times, I cannot find them! But they're out there, still selling CB stuff.

ANTTRON ANTENNA CO.(SOLARCON)
1426 E. Indianola Av., Youngstown OH 44502
(330) 788-9404

FIRESTIK ANTENNA CO. (PAL Firestik)
2614 E. Adams, Phoenix AZ 85034
(602) 273-7151 • **www.firestik.com**

FRANCIS INDUSTRIES INC.
431 W. Broad, Pataskala OH 43062
(740) 927-4091

HUSTLER INC. (Includes **NEW-TRONICS** and **ANTLER**)
#1 New-Tronics Pl, Mineral Wells TX 76067
(817) 325-1386

JO GUNN ENTERPRISES
3138 County Road 30, Ethelsville AL 35461
(205) 658-2229 • **www.jogunn.com**

K-40 ELECTRONICS
Contact them through:
DAS: (800) 228-1291
www.k40.com

SHAKESPEARE CO.
6111 Shakespeare Rd., Columbia, SC 29223
P.O. Box 733, Newberry SC 29108
(800) 845-7750, (803) 227-1590

SIGNAL ENGINEERING
1172 Aster Av.
Sunnyvale CA 94086
(408) 247-2300
www.signalengineering.com

(cont'd on next page)

CB ANTENNA MANUFACTURERS, cont'd

WILSON ANTENNA
724 Lawn Rd., Palmyra PA 17078
(800) 542-6263
www.wilsonantenna.com

CB DISTRIBUTORS & SPECIALTY SOURCES

SCANNER WORLD USA
17 Interstate Av., Albany NY 12205
(800) 476-8050, (518) 436-9606
All major brands of CBs, scanners, & accessories

GC ELECTRONICS
1801 Morgan St., Rockford IL 61102
(815) 316-9080
Best known for their CB accessories like DC power plugs, dummy loads, antenna hardware, chemicals, mike connectors, tuning tools, etc. Get the name of your local distributor.

RF PARTS CO.
435 S. Pacific St., San Marcos CA 92069
(800) 760-744-1943 • **www.rfparts.com**
Huge stock of RF transistors and tubes, Ranger line of 10-Meter transceivers, many CB-related accessories, Antron antennas, etc. Also the best source around for linear amp schematics when yours blows up. Schematics, NOT the amps!

TALLEY COMMUNICATIONS
12976 Sandoval St., Santa Fe Springs CA 90670
(800) 949-7079, (562) 906-8000
www.talleycom.com
One of the few reputable CB wholesalers left, for serious dealers only. Brand lines include Cobra, Uniden, and many others.

CONTINUING EDUCATION & CORRESPONDENCE COURSES

FREE ELECTRONICS COURSES & TUTORIALS
By IAN C. PURDIE, VK2TIP
plus U.S. NAVY TRAINING SERIES (NEETS)

www.electronics-tutorials.com/site-tree.htm
www.fcctests/neets/neets.htm

Great self paced, online electronics training. These are FREE and online to fit your schedule and convenience. Separate modules for each subject to quickly choose only those you need. Over 120 topics last time I checked. Plus kit projects to help you learn, and some sample FCC license tests from the latest question pool. The price is right, and you'd be crazy not to check this out. Most were written by an Australian Ham named Ian C. Purdie, VK2TIP. Plain English, easy to read and understand!

TEXAS INSTRUMENTS "UNDERSTANDING ELECTRONICS"
The famous computer chip giant also made a very well written series of books. The basic book "UNDERSTANDING SOLID-STATE ELECTRONICS" is an excellent self-study work, with quizzes for each chapter. They also offer cassette courses to go along with the books. You can still find these used on Google and Amazon.

TEST EQUIPMENT - NEW

MFJ ENTERPRISES
300 Industrial Park Rd., Starkville MS 39759
(800) 647-1800, (662) 323-5869
www.mfjenterprises.com

CONTACT EAST
P.O. Box 786, N. Andover MA 01845
(508) 682-2000

POMONA ELECTRONICS
1500 E. 9th St., Pomona CA 91766
(909) 623-3463.
Perhaps the biggest specialty source of test accessories. Regular and SMD clipleads, probes, connectors, coax adapters of all family types.

TUCKER ELECTRONICS
1717 Reserve St., Garland TX 75042
(800) 527-4642, (214) 348-8800
All the major brands of new and used test equipment, professional tools, repairs and calibrations, hobby radios and scanners.

TEST EQUIPMENT - USED

FAIR RADIO SALES COMPANY INC.
2395 St. Johns Rd., Lima OH 45804
(419) 223-2196, 227-6573 • **www.fairradio.com**
Here's where to find one of those vintage URM25 RF signal generators, RF ammeters, etc. A huge warehouse crammed full of surplus electronic parts, used HP and Tektronix test equipment, etc. Many hard-to-find items you'll never see in the usual chain stores. Free catalog.

NUTS & VOLTS MAGAZINE
430 Princeland Ct., Corona CA 92879
(951) 371-8497 • **www.nutsvolts.com**
Subscriptions: (800) 783-4624, (877) 525-2539
Another big (monthly) swap sheet read by about 50,000 Hams and other electronic scroungers. You just might find what you need here, or sell off your unwanted junk. Ask for a sample.

GENERAL REPAIR PARTS

You're much better off buying from these guys than the manufacturers, who mark up everything about 500%. Unless you need a really special part (Channel Selector switch, dual-ganged pot, etc.) use the following companies. Over the years I've dealt with all of them personally. Most carry a wide range of test equipment and tools too. We've been buying all the parts for our CBC catalog kits from **DIGI-KEY, MOUSER,** and **CIRCUIT SPECIALISTS** for over 20 years now. All have fast delivery, and almost never seem to be out of stock on catalog items. The other companies listed are smaller, but just as good.

ALL ELECTRONICS CORP.
14928 Oxnard St., Van Nuys CA 91411
(888) 826-5432, (818) 904-0524
www.allelectronics.com
A large mailorder supplier for new and surplus parts and test equipment. Free catalog.

ALLIED ELECTRONICS CORP.
7151 Jack Newell Blvd. South
Ft. Worth, TX 76118
(866) 433-5722 • **www.alliedelec.com**
I remember these guys from when I was a kid, drooling over catalog products from their single huge store in Chicago. Their catalog is still a few inches thick but it's free, so they probably have what you're looking for nowadays. Contact the corporate office shown above, then you can search their Web for a sales branch near you.

CIRCUIT SPECIALISTS INC
P.O. Box 3047, Scottsdale AZ 85271
(800) 528-1417 outside AZ, (602) 464-2485
Excellent source for all general replacement parts like semiconductors, chokes, capacitors, resistors, trimmers, etc. Free catalog.

DALIS ELECTRONICS
3645 E. Atlanta Av. #2, Phoenix, AZ, 85040
(800) 888-1408, (602) 275-2626
www.daliselectronics.com
All general new replacement parts, including NTE semiconductors, GC Electronics items, Amphenol and Belden coax, etc. Accepts small orders.

DIGI-KEY CORPORATION
P.O. Box 677, Thief River Falls MN 56701
(800) 344-4539, (218) 681-6674
www.digikey.com
Huge inventory of general parts, particularly the cheaper Asian types. Also some of the CB type Toko coils and transformers. Free catalog.

GENERAL REPAIR PARTS, cont'd

MCM ELECTRONICS INC.
405 S. Pioneer Bl., Springboro OH 45066
Sales: (888) 235-4692
Tech Support: (800) 824-8324
www.mcmelectronics.com
Major source for Japanese transistors and ICs. Large selection of connectors and major test equipment. Free catalog.

MOUSER ELECTRONICS
1000 N. Main St., Mansfield TX 76063
National sales: (800) 346-6873
www.mouser.com
Like **CIRCUIT SPECIALISTS** and **DIGI-KEY**, with a giant parts inventory. They also stock the NTE semiconductor replacements, some exotic hardware (like those special metric cabinet screws), test equipment, etc. Free catalog.

NEMAL ELECTRONICS INC.
12240 NE 14th Av., Miami FL 33161
(800) 522-2253, (305) 899-0900
www.nemal.com
A major Amphenol distributor when you need any type of coax cable or special coax connectors. And they are willing to accept small or individual orders.

RAMSEY ELECTRONICS
590 Fishers Station Dr., Victor NY 14564
www.ramseyelectronics.com
(800) 446-2295 • (585) 924-4560 EST
A great place that's been around for about 40 years. Sells all kinds of electronic parts for the hobbyist, and especially some cool kits to build yourself.

TOKO AMERICA
1250 Feehanville Dr., Mt. Prospect IL 60056
(847) 297-0070 • **www.toko.co.jp**
The major manufacturer of virtually all CB-type tuned coils and transformers. Certain parts are sold by **DIGI-KEY** and **AVNET.** Get their complete inductor catalog, as this may be the only way to find replacements for the low-Q tuned coils used in the export models, or for broadbanding the USA versions. Strictly wholesale; you can't buy directly, so get the contact info for their U.S. distributors from the above Web site, or:

DIGIKEY: At left. **AVNET EXPRESS:** (800) 332-8638

CRYSTALS

The following companies still cater to individuals, and are willing to sell small quantities of special-order crystals. Expect to wait two weeks or longer for such orders.

CRYSTEK CORP.
12730 Commonwealth Dr., Ft. Myers FL 33913
(800) 237-3061, (239) 561-3311
NOTE: They sell some crystals through Mouser and Digikey, no minimum order, fast shipping, etc.

INTERNATIONAL CRYSTAL MFG.
10 N. Lee Av., Oklahoma City OK 73102
(800) 725-1426, (405) 236-3741
www.icmfg.com

JAN CRYSTALS
P.O. Box 60017, Ft. Myers FL 33906
(239) 936-2397
www.jancrystals.com

PETERSEN RADIO
2735 Av. A, Council Bluffs IA 51501
(712) 323-7539

RADIO RESOURCE PAGES
www.af4k.com/mega/xtals.htm
This guy keeps a long list of Ham radio type parts resources, including crystal sources from all over the world. There are lots more than we can list here. Check it out!

VACUUM TUBES & OLD PARTS

ANTIQUE RADIO CLASSIFIED
P.O. Box 802
Carlisle MA 01741
TEL: (508) 371-0512
FAX: (508) 371-7129
www.antiqueradio.com
Big monthly magazine that specializes in articles and ads on this subject. Restoration parts, tubes, services, early TV, Ham, telegraph, books, and much more.

ANTIQUE ELECTRONIC SUPPLY
6221 S. Maple Av.
Tempe AZ 85283
TEL: (480) 820-5411
FAX: (480) 820-4643
www.tubesandmore.com
Similar to above.

POWER & AUDIO TRANSFORMERS, or FILTER CHOKES for all CBs, especially old Tube type rigs

The source listings on the next page and on Page 302 are a good place to start. Here's where to look for those iron-core parts you thought were impossible to find. Whether just repairing or completely restoring old vintage radios, check these out. You don't need exact replacements to make old CBs work again

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FOREIGN PARTS SOURCES

Foreign readers should first check the ads in their local CB and electronics magazines, since buying from the U.S. can be slow and expensive.

Here's a quick foreign dialing lesson. The international access code from the U.S. is "011." Using a Touch-Tone phone to direct dial from the U.S., the sequence would be:

011 + [country code] + [city code] + [local number]

EXAMPLE: Suppose you want to direct-dial a VISA card order to AVERA in Holland. You'd press:

011 + 31 + (0)76 596-3820

Don't include the "0" in the city code part of the number (shown in parenthesis above), such as (0)76 above for Holland.

AUSTRALIA:

DICK SMITH ELECTRONICS PTY. LTD.
P.O. Box 321, North Ryde 2113 NSW
AUSTRALIA
Tel: +61 + (02) 888-3200

EUROPE/NETHERLANDS:

AVERA bv
Hazeldonk 6259, 4836 LG Breda
NETHERLANDS
www.avera.eu
Tel: +31 + (0)76 596-3820

EUROPE/GREAT BRITAIN:

TRUCK KING
P.O. Box 8913
Newark, Notts. NG24 9BX
UNITED KINGDOM
www.truck-king.co.uk/index.html
Tel: 44-01636-676-898

2 BASIC TROUBLESHOOTING TECHNIQUES

Most techs don't use a logical approach to CB repairs. Many of these people wouldn't know a vacuum tube from a vacuum cleaner. They looked in a radio once or twice and now they're experts! Instead they try the methods usually reserved for amateurs, which you probably know as "shotgunning," "hit and miss," and of course, "guess." Occasionally such methods are lucky but to be professional and successful you must develop a systematic approach.

USE OF LOGICAL METHODS

The CB transceiver is an electronic system, and a very sophisticated one at that. Starting from scratch you'll be overwhelmed by everything going on inside unless you fully understand each function.

The functions are best understood by viewing each as a block or "black box" for the moment. When you connect all the blocks together you have a "block diagram." Later we'll break the blocks down into stages, stages into circuits, and circuits into component parts. The block diagram phase is so important to developing a logical troubleshooting approach that you'll never succeed without it. Therefore your first task should be to memorize the functional block diagrams shown. Memorize them and understand them to the point where you can easily draw them yourself.

Figure 2-1 shows block diagrams of typical AM and FM CB transceivers. (SSB is covered in CHAPTER 6.) I strongly suggest you spend some time studying them, especially if you're a relative newcomer to CB servicing. Once you understand a block diagram, the logical sequence is to find the faulty block, then the faulty stage, then the faulty circuit, and finally the faulty part within the circuit. To follow this sequence you need certain basic knowledge:

1. What the overall system does in normal operation.
2. What the functions are, and how adjustments affect them.
3. What each component part does to affect the circuit operation.

PHYSICAL FEEDBACK

A basic way to locate blocks which aren't working right is to figure out which ones are working right. One of the best ways to get such feedback is to simply look at the radio's various indicating devices like SWR Meter, Modulation Meter, S-Meter, RF Meter, tube filaments, dial lamps, fuses, LED channel display, etc. You can use sight, smell, hearing and touch a lot more than you realize.

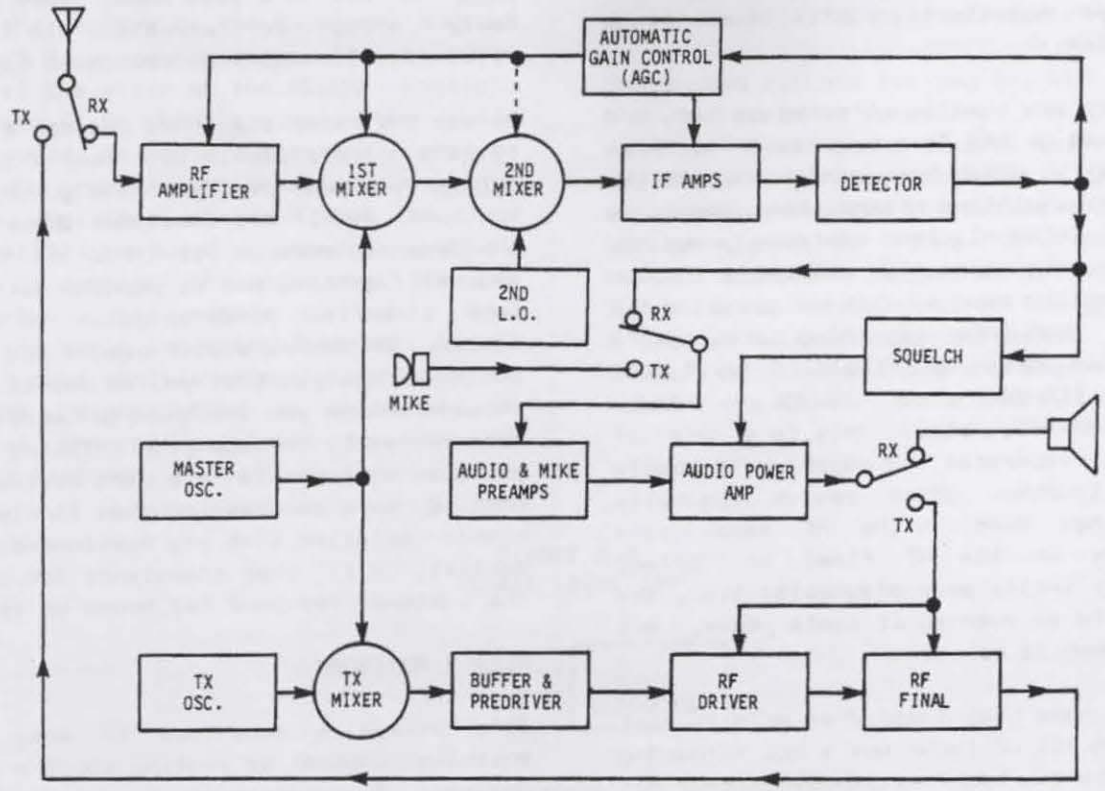
For example, you can see a broken wire or component lead, broken PC foil trace, smell a burned resistor, feel a power transistor or IC that's overheating or not heating normally. A speaker hum or buzz might tell you the audio section is working OK. Generous use of your senses will often lead to a fast and profitable fix.

Physical checks are a logical first step, especially with intermittents. Intermittents are the bane of most technicians and will drive you crazy if you let them. The first question in such cases is, "What conditions cause the intermittent problem?" Does it happen when you tap on the frame or push on the PC board? Does it happen only when the set is warm (or cold)? These are all clues which form a pattern when you understand each circuit function and how they relate to each other.

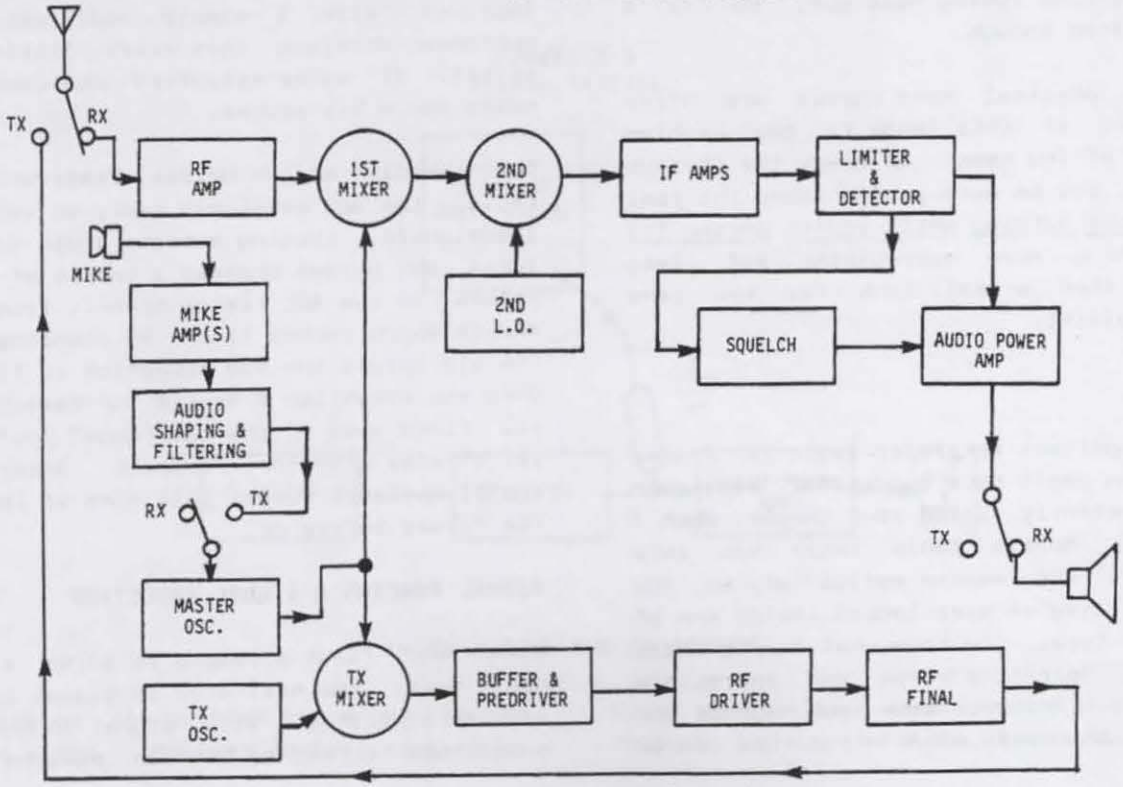
Example: Suppose the receiver volume pops up and down when tapping on the chassis. A finger on the VOLUME control causes a hum which doesn't change. This tells you the audio section is working right. You can hear an on-the-air signal or the one from your generator, and the S-Meter needle remains constant during the tapping, which eliminates the RF circuits. That narrows it down to the IF or detector sections, so from that point it's a matter of finding the part that's loose, poorly soldered, etc. Beginning to see how this works?

FIGURE 2-1
AM & FM TRANSCEIVERS

AM TRANSCEIVER BLOCK DIAGRAM



FM TRANSCEIVER BLOCK DIAGRAM



So much for mechanical intermittents. "Thermal" intermittents are also very troublesome. You key the mike, the transmitter is fine for a few seconds, then suddenly quits. Once you've confirmed that flexing or tapping the case or PC board has no effect, you're down to a thermal problem.

Semiconductors are greatly affected by heat and cold, and can go bad from excesses of either. You need a way to check both conditions. Maybe the RF power amplifier transistor opens a junction or internal lead contacts when it heats, but acts normally otherwise. Power devices especially have a habit of doing this. How do you test this? By using some stuff called "Freeze Spray" or "Chill Spray." (GC Electronics #10-8668 or 10-702, Miller-Stephenson #MS-240, etc.) This is a can of Freon which evaporates so quickly it cools whatever it touches. Since you've logically narrowed things down to the RF amps, some freeze spray on the RF Final or Driver transistor may verify your diagnosis; i.e., the radio transmits as soon as it cools down, but stops again when it reheats.

Sometimes you need heat instead of cold to test a component. A lot of techs use a hot soldering iron but you've got to be extremely careful not to damage an otherwise good part! There are commercial thermal spot testers available which concentrate the heat in a very small area. Don't use a shrink tubing heat gun; the heat's not concentrated enough.

Summing up, physical spot checks are often justified and if this leads to the problem you're ahead of the game. So check the obvious things first, but be sure you've found the real problem. Assume nothing until you've proven it! There's nothing more aggravating and less profitable than a call-back for the same customer complaint.

ATTITUDE

Almost as important as proper logic is proper attitude. You can't be a successful repairman if you're constantly losing your temper. When I was at G.E. Mobile Radio there was this oldtimer, Al, who worked exclusively on the hand-helds. If you've ever looked inside one of those $1500 toys, you know what a nightmare they can be. Hair-fine wires and incredible parts density. Anyway, each tech had his own little room; the walls of Al's room had large chunks of plaster missing from where he'd thrown the radios at the wall whenever he got disgusted with them. The reason he never got fired was because he was a really great tech, when he was in a good mood. They needed him badly enough to tolerate his occasional outbursts. However your customers may not!

Al was the exception. And CBs don't cost $1500 so it's not profitable to invest a lot of time unless you can fix them. I'm guilty of temper tantrums myself and sometimes think of CBs as the Japanese revenge for Hiroshima. If you find yourself getting mad or running out of ideas, take a coffee break or go on to an easier repair. An easier repair psychs you up, since it convinces you that you're not as stupid or incompetent as you thought you were. Besides, temper really clouds your thinking and makes you miss what should have been obvious. There's nothing more embarassing than finding a very simple solution that you overlooked two hours earlier. Will your conscience let you charge the customer for your two hours of steam?

KEEP A NOTEBOOK

It's always a good idea to keep notes of anything unusual or routine about a particular chassis. That way you save a lot of time whenever you see that chassis again. If installing an extra part prevents another one from failing prematurely, or performance can be improved with a simple modification, the customer deserves this extra little bit of effort. It makes satisfied customers, which makes you a bit richer.

For example on the Uniden President Jackson radio, the AGC overloads badly on very strong SSB signals, causing extreme audio distortion. Turns out Uniden changed a couple of resistor values in the AGC timing circuit from previous models which worked fine. By changing back to the old values the SSB reception is fine again. Once you establish a system for remembering how you fixed some of the old "dogs" you'll save a lot of time when they reappear. After a while you'll collect a real gold mine of information for future reference.

SIGNAL TRACING & SIGNAL INJECTION

When your first attempts to solve a problem don't work, the next step is signal tracing or signal injection. With signal injection you substitute a signal from an external source

like a signal generator or another radio. If you get the right signal output with the test injection, the circuits between the injection point and the output point are probably OK.

Let's say the problem is "No Receiver Audio." See Figure 2-2. Inject a signal from an audio generator at the wiper of the VOLUME control. If you heard it in the speaker, the audio amplifier could be ruled out as the problem. This means the problem must be somewhere before the audio amplifier stages. But if the injection still produced no speaker output, you'd have to consider the audio chain as the problem area. This method can be used throughout the radio including Transmit. If you suspected a dead oscillator or mixer, inject the correct signal from an external RF generator at the proper point to see if operation is restored.

Signal tracing involves the connection of some other indicating device like a 'scope, signal tracer, frequency counter, or VOM/RF probe to see if the signal is reaching a particular circuit point. Figure 2-3 shows this idea applied to the "No Receiver Audio" problem.

These two methods let you quickly localize the circuit area to determine the problem more exactly. Some techs like to inject signals at the front and follow them until lost. Others work backwards from the output end until the proper signal is found. I've done both at various times and there's no preferred choice. The point is not to start in the middle without a clear idea of which direction to proceed. Unless of course there's a logical reason to believe the middle is the faulty area.

FIGURE 2-2
SIGNAL INJECTION

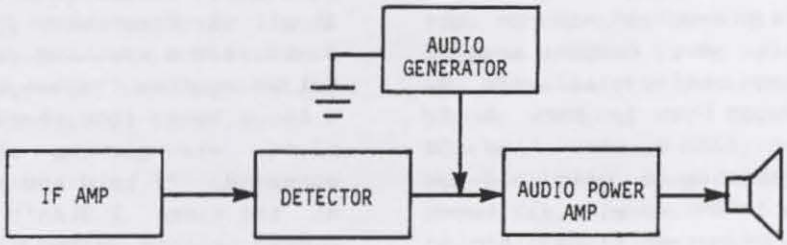
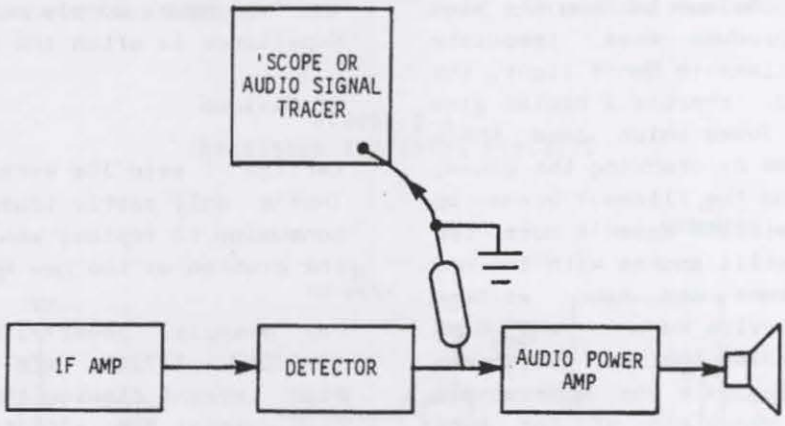


FIGURE 2-3
SIGNAL TRACING



INTERPRETING THE DC BIASES

After isolating the problem to a particular circuit or stage, the next logical step is to make some voltage measurements of the active devices; i.e., the tubes, transistors, or ICs.

The service manual should specify the voltages at each terminal and the operating conditions that produced them. (You do have the service manual, right?)

Your interpretation also requires an understanding of the various amplifier operating "classes" used (A, B, AB_1, C), since voltage changes might be a lot more subtle than outright shorts and opens. For example, distortion in a Class A audio amplifier might be due to a resistor change that effectively changes its bias to another operating class. Amplifier classes are defined by the amount of forward bias relative to the input signal. Bias affects amplifier efficiency (the output level for a given input) and the purity of the amplified signal. Amplifier classes are described in more detail later.

Tubes

Tubes are relatively easy to check by direct substitution. A tube tester isn't always reliable, since it runs them at greatly reduced operating voltages to prevent injury to the operator. Tubes aren't very common anymore except for a few vintage radios still used by some oldtimers. (Browning Mark 3, Mark 4/4A, Tram D201, Dak X, Robyn T240-D, etc.) Like old cars, tubes can function even with old-age problems. It's common to find many or all tubes testing less than "GOOD" but still maintaining the radio up to specs. At the low levels used in CB circuits, there's often a tremendous reserve gain that's not even being used.

Most tube problems are obvious because the high operating voltages produce more immediate physical signs. The filaments don't light, the plate glows cherry red, there's a bluish glow when gassy or leaky. Tubes which lose their vacuum rapidly, such as by cracking the glass, turn a milky color and the filament burns up immediately. If a substitute doesn't cure the problem or the radio still smokes with the new tube, unplug the tube and make voltage measurements. Most service manuals and SAMS Fotofacts for tube radios include resistance measurements. These indicate the approximate ohms-to-ground across each pin of the tube socket. This is a great troubleshooting aid, so use it when available.

Because of the heat generated, components like resistors and capacitors eventually break down. Aside from tube filaments burning out, these component breakdowns represent about 90% of tube equipment repairs. You'll occasionally find some exotic problem like a transformer impedance changing from shorted turns, but this is rare.

Tube substitution is the fastest way to test faulty stages, unless an obvious physical symptom (like smoke!) is present. When tube substitution doesn't work, pull the tube and measure the voltages (or resistance-to-ground) on the socket pins for clues to the problem.

If small parts like resistors, coils, or capacitors burn open, the circuit simply doesn't work. But if they short, other symptoms appear that make the tube look bad when the real problem is the part connected to the tube.

Here's a personal example, Lou Franklin age 12: I was building a high-level plate modulator for my old Heathkit DX-40 Ham rig. (It used screen modulation, cheap but without the real punch of high-level AM.) Anyway, I built this Class B push-pull modulator with a pair of 6L6s, got it all wired correctly, and turned on the rig. I keyed the mike and got a normal RF carrier. But as soon as I spoke into the mike, there was a large bang, lots of smoke, and the 6146 Final plate was glowing cherry red. My father screamed, "I told you so!" What happened? Well at the time, I didn't realize that the Final plate voltage with high-level AM at 100% modulation can theoretically swing to double the resting plate voltage. The existing plate bypass capacitor was naturally underrated and blew up in my face, shorting out and passing the full power supply current through the tube! Experience is often the best teacher...

IC Devices

Earlier I said ICs were easy to troubleshoot. That's only partly true. Since an IC is time-consuming to replace you must be very sure it's the problem or the new one may also burn out.

For example, power ICs like audio outputs (TA7205P, TA7222, etc.) often fail due to the high current flowing through them. This same high current also affects shunt components like the bypass capacitors connected to them. If they were bad and you didn't notice, the new IC might smoke too.

IC diagnosis is limited to measuring the listed voltages and looking for the input and output

signals. If the signals are present and at their indicated levels, you can be 99% sure the IC is good. Using a 'scope to check for inputs and outputs is the first thing I do. If the signals are missing, greatly reduced, or distorted, then I measure the pin voltages. If all or some of the voltages are grossly different than specified, then I temporarily assume the IC is bad. After removing it, I recheck the voltages at the empty pin foil traces again, and try to interpret which differences are normal and which might mean a problem external to the IC. With no IC in the board I 'scope the input trace again to confirm that a normal input signal is present. With these precautions I'm reasonably sure the new device will fix the problem. When in doubt, always proceed slowly!

TRANSISTOR BASICS

Most active devices in modern CBs are discrete bipolar NPN transistors. PNP types are used when polarity differences are advantageous, like in DC switching and voltage regulator circuits. FETs (Field Effect Transistors) are also found, but are limited to receiver or mixer stages. There are lots of ICs throughout the transceiver, but they're easy to troubleshoot since there's nothing you can do about fixing them internally anyway.

The tricky part for most repairmen is the plain old bipolar transistor, so we'll briefly review some things about them. If you don't understand how transistors work in the first place, go back to the suggested reading list in CHAPTER 1 and study that material first.

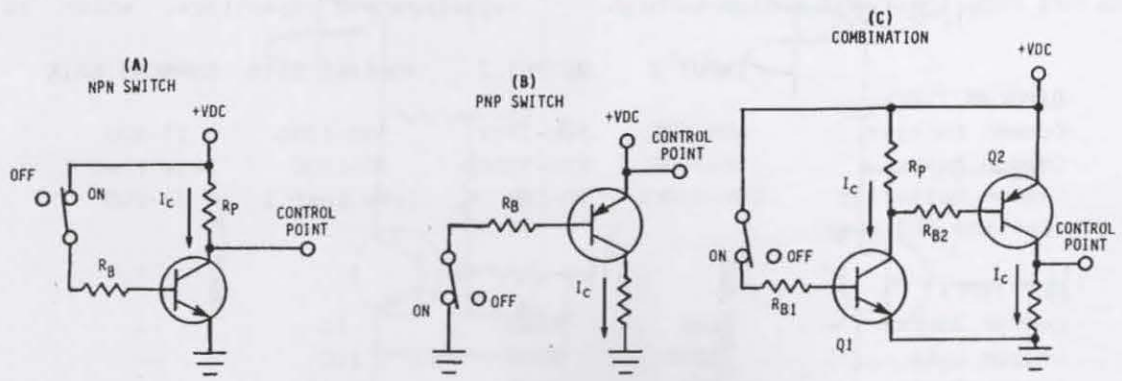
TRANSISTORS AS SWITCHES

Many CB circuits use transistor switches, mostly to control various T/R voltages and signal paths, or to control mode functions which are different among the AM, FM, USB or LSB (or both SSB) modes. The base of the NPN or PNP device controls current flow through its emitter and collector. With no base current flow there's no collector current, and the transistor is cut off. As more base current is applied, the collector current also increases until at some point further base current no longer increases the collector current. This is the "saturation" point. Between the extremes of cutoff and saturation is the linear operating region. Most amplifiers work in the linear region to prevent distortion, but switches generally must avoid this region.

Figure 2-4A shows a basic NPN switch of the type common to CBs. In the "ON" state, a voltage applied to R_b causes current to flow in the base-emitter junction. This causes a much bigger current to flow from collector to emitter. Because heavy collector current flows its voltage drops very low, near ground potential. In the "OFF" state, no base voltage is applied and the transistor remains cut off. Its collector voltage is pulled up near V_{cc} by R_p.

A PNP switch, Figure 2-4B, is commonly used when control is needed in the high-to-low base

FIGURE 2-4
TRANSISTOR SWITCHING CIRCUITS



voltage direction rather than the low-to-high NPN condition. In this case when the base voltage falls to about 0.6 V less than the collector, the transistor turns on and its collector is pulled down near zero volts again.

CBs also use combinations of NPN and PNP devices, Figure 2-4C. This has the advantages of more gain and no signal inversion between input and output. As Q1 turns on its collector is pulled lower and turns on Q2. This complementary-pair arrangement is very common to amplified squelch and AGC circuits, and to voltage regulators and AM modulators in the newer AM/SSB radios. In such circuits they function more like variable resistors than hard ON-OFF switches.

TRANSISTOR AMPLIFIER CIRCUITS

Refer to Figure 2-5 and the following table. Bipolar transistor circuits are classified as Common Emitter, Common Base, and Common Collector. The "common" element is the one shared by both the input and output circuits. FETs can also be defined by their common elements and are included here too. Each type has different characteristics, and each can be found throughout a CB transceiver. Values are approximate and will depend upon operating voltages, currents, external load values, and input signal levels.

Note from Figure 2-5 that only the Common Emitter and Common Source have in/out signal relationships 180° out of phase; all others are in phase.

The Common Emitter is the most widely used configuration for CB circuits like RF, IF, and audio amplifiers, and for DC amplifiers and switches. (The FET equivalent is the Common Source, which has high input and medium-to-high output impedance and is usually chosen for that reason.) The input signal is applied between base and emitter, and the output is taken between emitter and collector. It has the highest power gain of all classes, up to 40 dB.

The Common Base circuit is used for voltage regulation of the "series-pass" type, functioning as a variable resistor where the amount of base current controls the amount of output current. It's often used for the RF amplifier stage in the receiver front end, where the low input impedance makes a good coupling match for a standard 50Ω antenna with better linearity than the Common Emitter. The Common Base also has a higher cutoff frequency, but less power gain. The power gain, which is up to 30 dB, is due to the high ratio of input/output impedances. Since input/output signals are in phase, it oscillates easily and is often used for just this purpose.

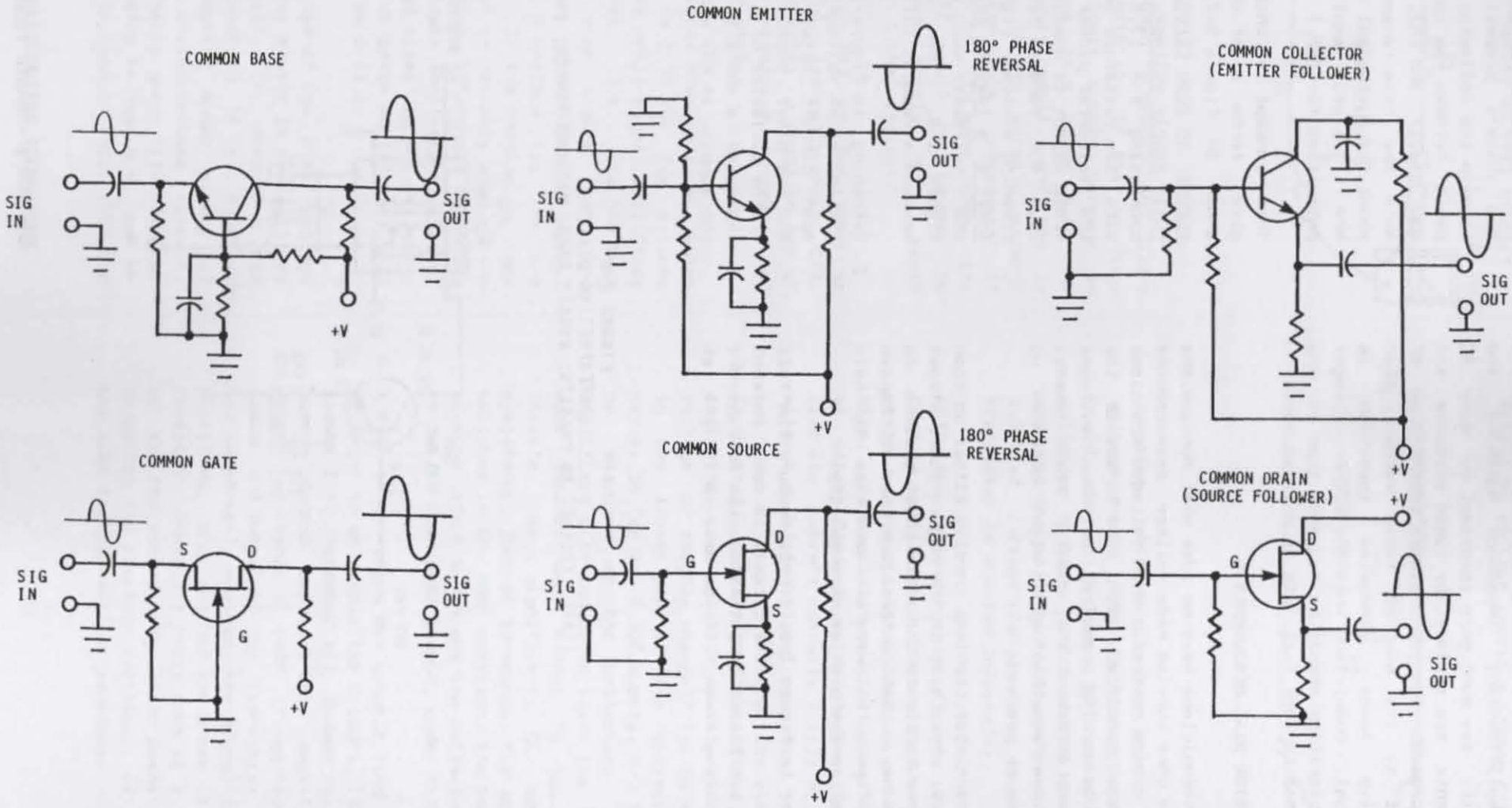
The Common Collector or "Emitter Follower" is rarely used in CBs. The main purpose is for impedance matching, high input to low output. It might be applied in a mike input circuit, where a high-impedance ceramic or crystal mike is being matched to a low-impedance preamp input. It's also found in most Uniden AM/SSB IF strips to DC-couple between IF stages. It has some power gain, up to about 16 dB.

All three circuits may be found in the NPN or PNP configuration, and the only difference is the polarity of the supply voltages. Learn the differences. Memorize them! Whenever you get confused about which way current flows, just follow the arrows; they always point in the direction of conventional (not electron) current flow. "Conventional" means from the more positive to the more negative terminal.

The circuits shown in Figure 2-5 used only resistors and capacitors, which is normal for

	INPUT Z	OUTPUT Z	VOLTAGE GAIN	CURRENT GAIN
BIPOLAR TYPE:				
Common Emitter	400-5KΩ	30K-75KΩ	300-1000	25-200
Common Base	50-300Ω	20K-500KΩ	50-1500	less than 1
Common Collector (Emitter Follower)	20K-500KΩ	50-1KΩ	less than 1	25-200
FET TYPE:				
Common Source	1MΩ	15KΩ	50	--
Common Gate	300Ω	35KΩ	100	--
Common Drain (Source Follower)	2MΩ	300Ω	0.95	--

FIGURE 2-5
BASIC TRANSISTOR AMPLIFIERS



audio, DC, or switching purposes. However for RF amplification, impedance matching and stability are much more important so many RC components are replaced by tuned circuits and transformers. You can always identify an RF circuit by its use of tuned rather than resistive loads. Otherwise operation is identical. Understand what the proper voltages and polarities should be for each type so you know what to look for. This is covered next.

TRANSISTOR BIAS MEASUREMENTS

Many technicians have no idea what conclusions to draw once they've made voltage measurements on the active devices. When voltages are close to those specified, it's safe to assume the stage is working properly. But when voltages are very different they scratch their heads. They know "somethin' ain't right" but have no idea how to proceed.

Most transistor problems involve either an open or short, especially in the higher power stages since manufacturers underrate power devices to save money. Leakage problems tend to happen less often. Following are some tips to help you analyze the problem more exactly.

1. Refer to Figure 2-6. If you measure the full supply voltage, the circuit is open between the two measuring points because no current is being drawn. If you measure 12.71 V at the collector of Q12, Q12 isn't turned on and there's probably an open component between the collector and ground. The only parts between the collector and ground are Q12 itself and R43, so check them first. Note the base-to-emitter voltage drop of about 0.6 V, typical of all properly working NPN transistor amplifiers. (Reverse the polarities for PNP.)

   This concept of shorts and opens seems to give techs a lot of trouble though. As shown in Figure 2-7, <u>any time you read across an open circuit, you will read the full supply voltage.</u> Try this yourself by connecting the 13.8 VDC supply in series with two resistors of any value. Connect the voltmeter probes as shown. Many techs would expect to measure something less than 13.8 VDC because resistors are voltage-dropping devices, right? Yes, <u>but only when there's a load to consume power.</u> If R2 and the voltmeter were reconnected as shown in Figure 2-8, then you would expect to measure a reduced voltage.

2. Returning to Figure 2-6, if you measured little or no voltage, there's probably an open circuit between the measuring points and the power supply, or a short to ground. If the collector of Q12 measures 0 V, this indicates a short to ground or an open to the supply. If C71 shorts it would pull the

FIGURE 2-6
INTERPRETING BIASES
(LATE CYBERNET AM CHASSIS: HYGAIN 2702, MIDLAND 77-888, ETC.)

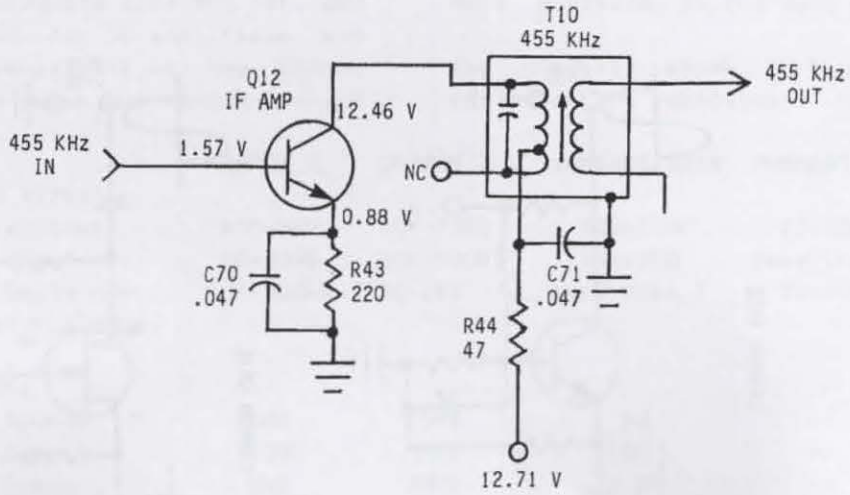


FIGURE 2-7
MEASURING VOLTAGE ACROSS AN OPEN CIRCUIT

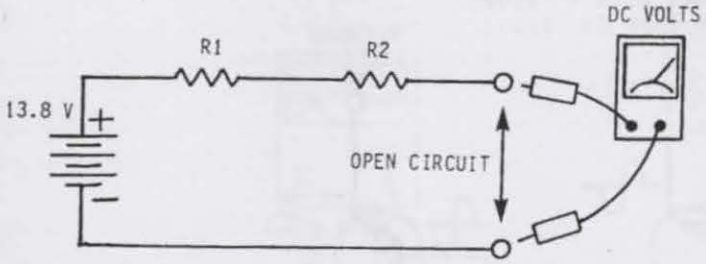
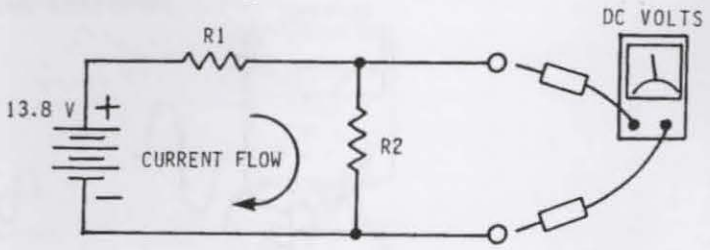


FIGURE 2-8
MEASURING VOLTAGE ACROSS A LOADED CIRCUIT



top end of R44 down to ground and Q12's collector along with it. If R44 is high enough it will limit supply current so nothing as obvious as a blown fuse or burned resistor would result, and this is the usual case. If R44 weren't present you'd definitely see smoke somewhere! If R44 or the primary of T10 were open, the collector of Q12 would no longer be connected to the power supply, so it would then read 0 V. Wasn't that logical?

3. If you find either R43 or R44 open or burned, you should logically check Q12, C70, and C71 for shorts; a short in any of them would pass excessive current and probably smoke the part.

4. Check the base-emitter bias voltage, which should be 0.6 VDC to 0.75 VDC for silicon transistors used as small-signal amplifiers or saturated switches. (I.e., the NPN base should read this much higher than the emitter, regardless of absolute voltages.) When less than 0.5 V replace it; the b-e junction is leaky. If the reading is near 1.0 V, the junction is probably open. There are minor base voltage differences depending on circuit functions; a small-signal type of amplifier will read close to 0.6 V, while saturated switches or power amplifiers will often read as high as 0.75 V.

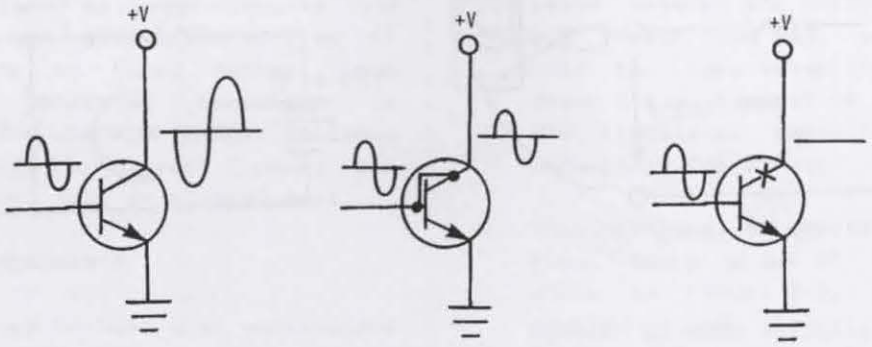
   The most common cause of low bias voltage (assuming the power source is correct) is the transistor itself. Try measuring the collector-emitter junction. If it's equal to V_{cc} but the schematic shows plenty of resistance in the collector-base circuit, the junction is probably open. (Like Step #1 above.) If the reading is near 0 V, use an insulated-hook clip lead to short the b-e junction, which kills the bias. The c-e voltage should instantly rise. Likewise, you could also clip-lead a 10KΩ resistor from collector to base, which should bias it on and pull the collector voltage down. If the expected voltage changes don't happen, the transistor is shorted internally.

   NOTE: The preceeding step is only useful for Class A amplifiers. These tests won't work where there's either no bias or reverse-bias, like oscillators, clipping circuits, or other Class B or C stages. In those circuits there's normally little or no bias without a driving signal present.

5. In general, small-signal amplifiers with a collector load resistor operate with a c-e voltage of roughly one-half V_{cc} to keep it in the linear part of its characteristic curve. So for a 9.0 VDC supply, 4-5 VDC will be measured at the collector. For RF amplifiers with inductive loads the voltage will measure much closer to V_{cc}, since there's no significant DC collector resistance, just AC impedance. For saturated switches in the "ON" position, the base will measure about 0.7 V and the collector will be pulled down near ground, under 0.5 V.

6. A dual-trace 'scope can quickly find shorts or opens in an amplifier circuit. Refer to Figure 2-9. Remember all Common Emitter or Common Source amps not only amplify, but <u>invert</u> the signal by 180°. If you 'scope the input and output of the transistor you'll see immediately whether the signal is being amplified, and whether the phase is being inverted. Obviously there must be a signal up to the tested stage which means signal injection for receiver problems, or keying the mike for transmitter problems.

FIGURE 2-9
TESTING TRANSISTORS WITH A 'SCOPE
(Courtesy Hayden Book Co. Inc.)



NORMAL
SIGNAL AMPLIFIED
AND INVERTED

B-C SHORT
NO AMPLIFICATION

B-C OPEN
NO SIGNAL OUTPUT

Summary Of Transistor Failure Conditions
(Courtesy Heinemann-Newnes Books)

1. Base-Collector short: Base and collector voltage measure the same. Base-emitter junction is still good, giving normal 0.6 V difference reading. Supply voltage falls slightly due to higher current draw.

2. Base-Emitter short: Both terminals read the same, and lower than normal. Collector voltage rises near V_{CC}, since no collector current is flowing.

3. Collector-Emitter short: Both terminals read the same. Device turned off, since emitter rises higher than the base. Supply voltage falls due to excess current draw. Fuse may blow, especially in power circuits.

4. All junctions shorted: All terminals read the same. Supply voltage falls due to excess current draw.

5. Base-Emitter open: Base rises well above normal difference of 0.6 V. Collector rises near V_{CC}, and emitter falls near ground.

6. Collector-Base open: Collector rises near V_{CC}. Emitter falls near ground. Base still reads normal 0.6 V difference, since b-e junction is still good.

TESTING SEMICONDUCTORS WITH THE OHMMETER

Since most faulty semiconductor devices in a CB will be either open or shorted, you can follow bias measurements with simple VOM checks using the resistance scales. This section describes how to make such tests.

Testing Diodes

A diode is a simple switch. When the polarity of the applied voltage forward-biases it, the diode turns on and current flows. "Forward bias" means the anode is at least 0.6 V more positive than the cathode for silicon devices, and 0.2 V for germanium devices. In CB circuits silicon diodes are used almost exclusively; germanium diodes are used only for AM detection, S/RF metering, AGC, and RF overload protection where the lower conduction voltage is desirable. When the semiconductor junction is reverse-biased, no current flows so the switch is effectively turned off. Most VOMs on the resistance scale use a 1.5 V battery, more than enough to turn on a diode junction.

As shown in Figure 2-10, if the negative lead of the meter is connected to the cathode and the positive lead to the anode, the diode will be forward-biased. When this happens there's very little resistance, indicated by a low resistance reading. For silicon devices this reading is typically about 500-600Ω (200-300Ω for germanium) using the Rx100 scale.

If you then switch the meter leads as shown in

FIGURE 2-10
FORWARD BIAS DIODE TEST

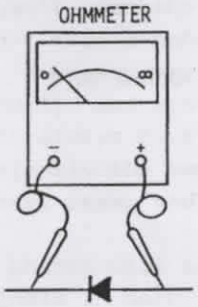
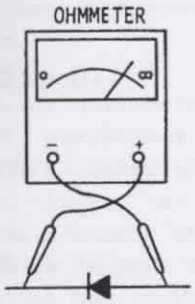


FIGURE 2-11
REVERSE BIAS DIODE TEST



(Courtesy McGraw-Hill Book Co.)

Figure 2-11, the diode is now reverse-biased so very little current flows. The small current that does flow results from the high "back" resistance which causes either a very high resistance reading or none at all, depending upon the scale used. So to test a diode, attach ohmmeter leads first one way and then the other. In one direction you'll read very high resistance and in the other very low resistance. But note the following precautions, which also apply to testing transistors:

1. The actual ohms reading is different from meter to meter and for different range scales. To increase the accuracy of your readings, compare them to a known good device of the same type.

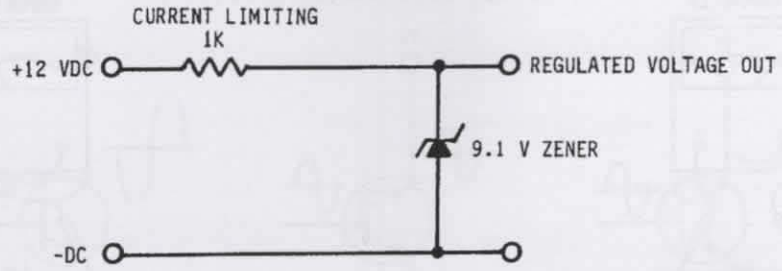
2. You'll generally have to disconnect one device lead before measurements. In-circuit tests can be very misleading, since there may be low-resistance components in parallel with the diode which make it appear shorted. For example, relay coils have shunt diodes to protect against voltage spikes as the relay switches. You couldn't test this diode without unsoldering one lead, because it would have a low resistance reading both ways. How often have you been fooled into thinking you found a bad diode, only to discover upon lifting a lead that it tests good?

   When testing transistors the ohmmeter battery often has enough voltage to turn on the junction, giving a false reading. Electrolytic capacitors of the type used in CBs can also provide low resistance paths when accidentally reverse-polarized with an ohmmeter. A VOM that uses several volts to operate can damage a junction if the reverse breakdown voltage is exceeded. For these reasons, play it safe by using a VOM powered only by a 1.5 V battery, and limit current by using the Rx100 or higher scale. Many meters have a special "LOW OHMS" scale to measure resistances without turning on the junctions, a good feature to consider.

3. Make sure you know which meter lead is positive and which is negative, especially when testing transistors. Yes, I'm serious! The BLACK lead on many VOMs may only be negative for voltage measurements, not necessarily for resistance readings! Many people don't realize this. It's easily checked by testing some known good diodes out of circuit; if placing the BLACK lead on the cathode (the banded end) and the RED lead on the anode reads a high rather than low resistance, the meter polarity is reversed. (BLACK is [+], RED is [-].) This doesn't mean the meter's bad; it's just the way they designed it. My little Radio Shack 22-201A multimeter works this way, and yours may too.

To test for leakage or shorts, switch to a higher resistance scale like Rx1000 and connect the leads in the reverse-bias order. With a low resistance this way you have a shorted or leaky diode, assuming you removed one lead from the circuit first. Silicon diodes show reverse resistances greater than 1MΩ. Germanium diodes have higher leakages, about 100KΩ to 1MΩ. Some diodes may function OK in certain applications even with lower leakage resistances. For example, rectifiers have physically larger junctions and may show higher leakage currents.

FIGURE 2-12
TESTING ZENER DIODES

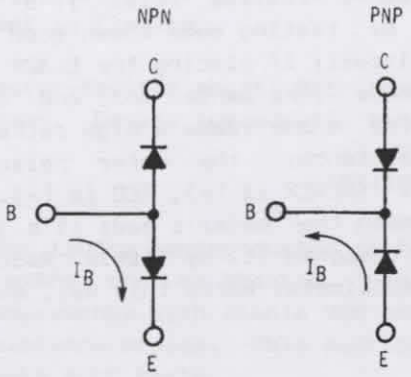


You can check Zeners like any other diode for opens, shorts, or leakage. But that doesn't tell you if it's regulating at the specified value. Check them as shown in Figure 2-12 by applying a DC voltage at least 2 volts higher than the Zener voltage through a series limiting resistor.

Testing Transistors With An Ohmmeter

Transistors can be checked like diodes but need a bit more caution. Think of a bipolar transistor as two back-to-back diode junctions like those shown in Figure 2-13.

FIGURE 2-13
BIPOLAR TRANSISTOR EQUIVALENTS



The common element is the base. By connecting a VOM as shown back in Figure 2-10 and 2-11, the junctions will be forward-biased one way and reverse-biased the other way. Like diodes, there's very little current flow with reverse bias so you get a high resistance reading. With forward bias current flows so the resistance reading is low. You can check PNP and NPN transistors exactly the same way, except that polarities are reversed so the meter leads must also be reversed for readings to make sense.

NPN or PNP?

The NPN/PNP subject confuses many techs, so let's try to clear this up. First of all, about 95% of the discrete transistors in a CB are NPN types. The only reason PNP types ever appear is when it's convenient to take advantage of their opposite polarities. Examples are DC switching, voltage regulation, and squelch circuits. For almost every other function, the NPN is used.

How do you figure out which one is which? If you have a schematic, just look which way the arrow points on the emitter lead. Here's a simple memory trick I was taught:

"NPN = No Point In"
"PNP = Point In Please"

Sounds corny but does make you remember! Now assume you don't have a schematic, or the schematic is printed wrong, which does occasionally happen. Check the voltage relationship between the collector and emitter. If the collector voltage is more positive than the emitter, it's an NPN device; if the collector voltage is negative with respect to the emitter, it's a PNP transistor. An easy trick to remember collector polarity is:

NP positive N
PN negative P

If you can't remember any of this, just follow the arrows; the arrows <u>always</u> point in the direction of conventional (not electron) current flow, from the more positive terminal to the less positive terminal. This is also true for diodes.

Identifying The Leads

Now suppose you can't read the number on the case and you don't have a schematic, even a misprinted one. Suppose you don't have a Japanese spec manual, and you know American replacements don't always have the same basing even though electrically the same. How can you identify the emitter, base, and collector?

Simple ohmmeter checks will tell you. Check each pair of terminals in both directions. Two of the six combinations will give low forward resistance readings. Of those two combinations, one lead will be common to making the other two leads read low resistance. This common lead is the base. If the positive meter lead on the base gave the low readings, it's an NPN type; if the negative lead it's a PNP type. The meter polarities are the true ones, regardless of RED or BLACK color. With the base known, you can figure out the others by studying their connections within the circuit.

Leakage Tests

Transistors when reverse-biased with an ohmmeter should show very high resistance readings. For silicon transistors, forward bias will read under 500Ω on the Rx1000 or Rx10K scale. When reverse-biased they probably won't register at all. I just tried both a small signal and power type and couldn't get a twitch even on the 10M scale of two different meters. Germanium transistors are non-existent in CB radios these days so don't worry about them unless you're fixing some ancient rig from the early 1960's. (Germanium tests much higher leakages than silicon, so don't be too quick to decide it's faulty.)

Testing FETs

You can also use a VOM for FETS, but you must be more careful. Use only a VOM with a "LOW OHMS" scale as previously mentioned. MOSFETs in particular are easily damaged by static, so always keep them in a conductive carrier and use a grounded soldering iron.

The plain old JFET (2SK19, 2SK49, MPF102, etc.) can be tested like a bipolar transistor. Use the Rx100 or Rx1K scale for forward resistance readings. Only N-channel FET types are used in CBs, so connect the (true) positive meter lead to the gate and the negative lead to the drain or source. Typical JFET forward resistances are 200-1KΩ. When reverse-biased there should be almost infinite back resistance; otherwise it's leaky or shorted.

For the single- or dual-gate MOSFET, use the meter's highest resistance scale to minimize the current. MOSFET gates are insulated by an incredibly thin layer, so tests between the gate(s) and drain/source should show almost infinite resistance in both directions. If not, the gate insulation has broken down.

Understanding Device Markings

Here's a brief lesson in understanding the EIAJ (Electronic Industries Association of Japan) markings on diodes and transistors. The first number ("1," "2," or "3") is the number of electrical connections, minus one. Thus diodes all start with the number "1," bipolar transistors with "2," and dual-gate MOSFET transistors with "3." The next item is a letter "G" or "S". The "G" means germanium material, the "S" means silicon. Next is a letter "A," "B," "C," or "D" for bipolar transistors or "J" or "K" for FETs, which identifies the polarity and application. The "J" means a P-channel FET, the "K" means an N-channel FET. The "A," "B," "C," and "D" for bipolar transistors are grouped as follows:

A = PNP, high frequency
B = PNP, low frequency
C = NPN, high frequency
D = NPN, low frequency

The next number group is the actual registered device number, such as 2SA733. Suffix letters (2SC1674L) after the device number refer to an improved production version of that device. (An "A" suffix means the first improvement, "B" is the second improvement, and so on.) Unless you're using an exact replacement this makes no difference, since SK or ECG subs don't differentiate that precisely. For exact replacement you can always use an improved device for its earlier version, but the reverse isn't necessarily true for every circuit.

If you think about where you've seen all these device numbers on a CB schematic, it starts to make some sense, right? The following examples help clarify this numbering system.

BIPOLAR TRANSISTOR APPLICATION EXAMPLES:

2SC945 = NPN silicon high frequency (low power)
2SC1307 = NPN silicon high frequency (high power)
2SB525 = PNP silicon low frequency (medium power)
2SA733 = PNP silicon high frequency (low power)
2SD325 = NPN silicon low frequency (high power)
2SK19 = N-Channel JFET
3SK45 = N-Channel dual-gate (MOS)FET

In CB applications "low frequency" generally means audio, switching, or voltage regulation uses. "High frequency" means everything else, like RF and IF amplifiers and mixers. There are always a few exceptions. For example the 2SA733 and 2SC945 are often used in switching or squelch circuits where cheap, low power PNP or NPN devices are needed. You can use a high-frequency transistor for a low-frequency application, but not the other way around.

Transistors have standard industry markings and you can't necessarily tell who made it unless the package is physically large enough to have the manufacturer's logo on it. The "TO" prefix which defines its physical case (TO-220, TO-92, etc.) means "Transistor Outline." ICs are usually identifiable by their markings, which are read, left to right: manufacturer, generic family (digital or linear), registered device number, package material, and special factors like reliability or temperature range.

Each manufacturer has its own letter prefix. Full details are found in the IC MASTER yearly catalog. (Available from Hearst Business Communications, 50 Charles Lindbergh Bl. #100, Uniondale NY 11553. TEL: 516-227-1300.) However before you spend a bunch of money on that, you should know there's a free download at: **http://ptf.com.**

Use their Web search box and just type "IC Master."

Sometimes proprietary or "in house" numbers are assigned to transistors and ICs, making replacement more difficult. Following is a brief prefix ID summary for the companies whose chips you're most likely to find in CB radios.

The IC suffix letter is especially important, because it refers to some physical package characteristic which you'll probably need to know for exact replacement. This may refer to the package material like plastic or ceramic, or the lead configuration. Many manufacturers use the letter "P" for plastic (MC14510<u>6P</u>), but not always. NEC uses a "C," as in µPD2824<u>C</u>. A common dual op-amp is the 4558D or 4558S. The "D" means dual-in-line pins, the "S" means single-in-line. Obviously they're not going to be interchangeable!

COMMON CB MANUFACTURERS' IC PREFIXES:

AN, MN = Panasonic (Matsushita)
BA = Rohm
CA, CD = RCA
HA, HD = Hitachi
LA, LB, LC = Sanyo
LM, MM = National Semiconductor
M = Mitsubishi Electric
MB = Fujitsu
MC, MRF = Motorola
NE = Signetics
NJM = New Japan Radio Co. Ltd.
SN = Texas Instruments
TA, TC = Toshiba
TDA = European Association: SGS, Siemens, Telefunken, etc. May be second-sourced from some others on this list.
µPC, µPD = NEC Electron

Many ICs use the same device number with only the manufacturer's prefix being unique, like <u>NJM</u>4558, <u>µPC</u>4558, etc. They're the same. Sometimes you'll find a bunch of other numbers often mistaken for the device number. Usually these are control or batch numbers so the manufacturer can trace a production problem on a run of bad ICs. For example, the chip may have markings like "LM324N" and "8307" on it. We smart technicians of course recognize the "LM-324-N" as National Semiconductor's linear monolithic device #324 in molded DIP epoxy package. The "8307" means "the 7th week of 1983," when it was made.

YOUR BUILT-IN TESTERS
(EYES, EARS, NOSE, FINGERS)

You'll discover a lot of CB repairs don't require fancy test equipment. When you learn to be observant and logical, ask the right questions, and use your own senses, the cause of many common problems will jump right out at you. On the next page is a brief summary of some cause and effect problems that can be analyzed by using sight, sound, smell and touch, and good old common sense.

LIGHTS & LED DISPLAYS:

1. Doesn't light up = burned out bulb(s), bad power connections, faulty power source, burned out fuse.
2. Lights dimly = power supply problem, wrong lamp previously installed.
3. Lights too brightly = power supply problem, wrong lamp previously installed.
4. LED segment(s) out = poor solder connection of LED pin(s) or associated pull-up resistor(s), bad 7-segment display block.

RESISTORS:

1. Burned, charred, blistered, cracked, or smoking = excessive current.
2. Cold or cooler than normal = open, broken lead, lower than normal current, resistance value increased.
3. Hot, hotter than normal = excessive current.

CAPACITORS:

1. Bulging, discolored, charred, hotter than normal = leakage.
2. Loose connection(s), noisy output = intermittent or complete circuit failure, defective part, frequency shift.

CHOKES & TRANSFORMERS:

1. Burned, charred, arcing, smoking, hotter than normal, smell of tar = high current, faulty shunt component, turns shorted.
2. Cold to touch = open transformer, no input voltage, no load connected to output.
3. Buzzing sound = laminations or windings loose, excess current.
4. Output changes = intermittent part or connection.
5. Smell of ozone = internal arcing.

SPEAKER:

1. Distortion, buzzing, rattle = broken cone, voice coil rubbing, loose mounting, faulty audio amp.
2. Loud hum or buzz with signal = poor power supply filtering.
3. No signal sound, buzzes or hums = open voice coil, open coupling from amplifier, open connection.
4. Buzz or hum but no signal sound = open signal path to speaker.

S/RF METERING:

1. No deflection = open signal path, faulty meter, bad sampling diode.
2. Too much or too litte deflection = improper adjustment.

TUBES:

1. Doesn't light up = bad tube, filament voltage missing.
2. Glows red hot = bad tube, incorrect bias or short, no drive, shorted shunt component on socket.
3. Arcing = faulty tube.
4. Filament dimmer than normal = filament voltage problem, bad tube, wrong tube type.
5. Noisy or intermittent output, arcing, or microphonic when tapped = bad tube, loose connection in socket, elements shorting.
6. Cold to touch (except gas voltage regulators) = bad tube, low filament voltage.
7. Visible purple haze = gassy tube (except voltage regulator types which are supposed to glow when conducting).
8. Milky color = vacuum missing due to cracked glass.

TRANSISTORS:

1. Smoking, arcing, split, cracked, feels hotter than normal = junction shorted, excessive current, voltage or bias.
2. Output intermittent when tapped = bad device, bad connection.
3. Cold or cooler than normal = junction open, no current draw, improper bias, supply voltage missing or low.

PC BOARDS, CONNECTORS:

1. Output change when flexed or pulled = intermittent connection, poor solder joint, cracked PC trace.
2. Warm or hot = dirty connection, high current, shorted.
3. Burned, smoking, open PC trace = shorted series device, resistive connection, high current.

(List courtesy McGraw-Hill Book Co.)

NOTES

3 GENERATING THE SIGNAL FREQUENCIES

Figure 2-1 showed basic CB transceiver block diagrams. In the diagrams were blocks called the "Master Oscillator" which fed both the Receive and Transmit mixer stages. The Master Oscillator is the subject of this chapter. It's the heart of any CB transceiver, the point from which all other signals are developed, mixed, or amplified. The modern Master Oscillator is one of two types: the multiple crystal synthesizer, or the PLL (Phase Locked Loop) synthesizer. Walkie-Talkies (except 40-channel types) and old tube CBs with plug-in crystals use direct generation rather than synthesizers.

CRYSTALS & CRYSTAL OSCILLATORS

The crystal oscillator is found in virtually every CB radio. If a piece of quartz is cut a certain way, sandwiched between two metal plates, and the proper electrical voltage applied, a molecular strain develops which causes the quartz to vibrate or "oscillate." The reverse is also true: if a crystal (like that in a crystal mike) is mechanically strained, it produces an AC output voltage. This is known as the "piezoelectric effect." The oscillation occurs at a very precise frequency. It's this stability which makes quartz crystals so useful as control devices; the oscillator's frequency can be controlled within a very tight and predictable range.

Figure 3-1 shows the electrical equivalent of a quartz crystal, and its internal construction. A crystal is the equivalent of a series-resonant circuit having high inductance and low capacitance. "R" represents the crystal's mechanical resistance to vibration; the higher this resistance, the harder it is to make it vibrate. A crystal with good "activity" has a low resistance, while one with high resistance will be sluggish and may not even oscillate. Sometimes a crystal loses activity with age and eventually fails. $C_{parallel}$ represents the capacitance of the holder and any other external shunt capacitance in the circuit.

Crystals are grown artificially from a sample of quartz material. Like diamonds, quartz crystals have several possible cutting angles relative to the major axis. The specific cut depends upon the intended operating frequency and has a great effect on performance. Most common for CB use is the "AT" cut. It has a very small temperature coefficient, which means it's not as affected by temperature as some other cuts. This makes it especially useful for high frequency circuits, where stability is a major concern. Figure 3-2 shows the AT cut on a typical bar of cultured crystal.

FIGURE 3-1
ELECTRICAL EQUIVALENT OF QUARTZ CRYSTAL AND ITS CONSTRUCTION

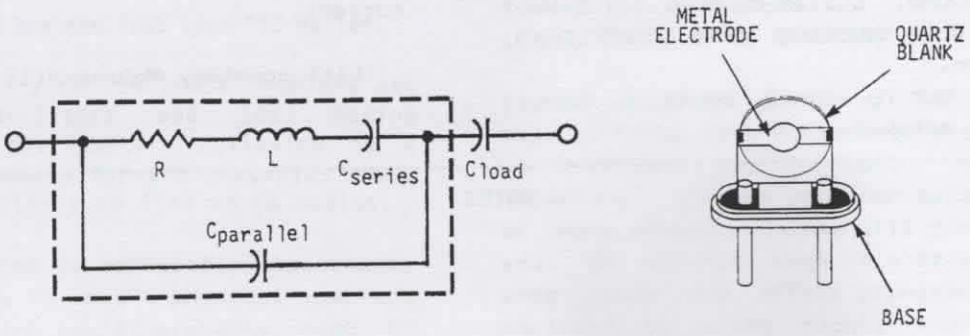
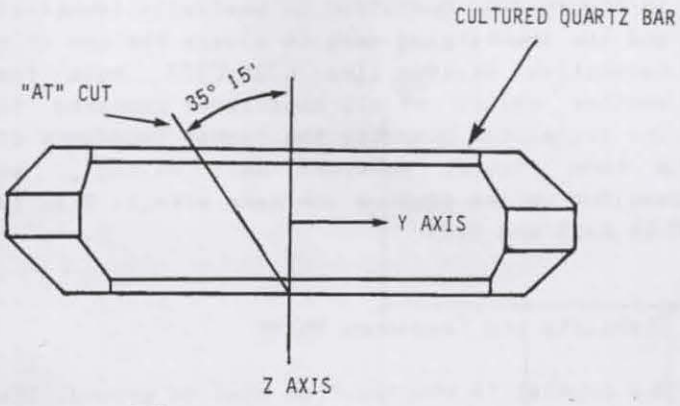


FIGURE 3-2
THE AT CRYSTAL CUT



Series and Parallel Resonance

A crystal can oscillate with either series or parallel resonance, depending upon the cut and its placement in the circuit. The series-resonant circuit has a slightly lower natural frequency than the parallel-resonant or "anti-resonant" circuit. For example, surplus FT-243 crystals have about a 2.2 KHz mode difference at 5 MHz. If a parallel-mode crystal in used in the series mode, it oscillates at the series-resonant frequency and will appear to be lower than its marked frequency.

A series-resonant circuit has the lowest impedance, and its frequency is determined only by the crystal's vibration. In Figure 3-1, if C_{load} weren't present, the crystal would be series-resonant and would look purely resistive to the circuit; no load capacitance would need to be specified. As it's tuned off resonance the circuit becomes parallel-resonant, since the inductive reactance of L becomes greater than the capacitive reactance of C_{series}. So it looks inductive to the circuit.

When this reactance is in parallel with the crystal holder or any other external parts (represented by $C_{parallel}$), it forms a parallel-resonant circuit. The resonant frequency of such a circuit is determined by mechanical vibrations and external capacitance; the load capacitance must be specified for such crystals. This partly explains why you may get misleading frequency measurements when using an out-of-circuit crystal tester compared to the actual oscillator operating conditions.

A parallel-resonant circuit has a much higher impedance than a series circuit. Because it's extremely sharp tuning (high Q), moving the oscillator slightly off frequency decreases its feedback voltage, discouraging it from oscillating at any but the intended frequency. That's what makes a quartz crystal such an excellent and stable frequency source. CB crystal oscillators use several methods to maintain this stability.

Transistor Oscillators

Transistor oscillators are patterned after the same circuits used by vacuum tubes, and the same general rules apply. The main differences are the input/output impedances and voltages involved. Bipolar transistors have much lower impedances than tubes, and input/output capacitances are usually higher. In choosing oscillator transistors, a rough rule-of-thumb is that they should high gain ("beta") and an f_T (point where gain = 1) at least 10 times higher than the intended operating frequency. That's why devices like the 2N2222A, 2N3904, 2SC710, 2SC945, or 2SC1675 are used as CB oscillators, even though they're also capable of certain VHF/UHF applications too.

What makes a circuit oscillate in the first place? If part of an amplifier's output is connected back to its input so the signals are in phase, this extra input adds to the existing input to further increase the gain. This is known as "positive feedback." There must be at least enough feedback to compensate for the circuit losses; otherwise the oscillations would eventually die out just as friction makes mechanical vibrations die out. Once the gain passes a certain point the circuit can sustain itself with no help from the original input, in a sort of perpetual motion.

The crystal (or any similar control element like an LC network) sets the frequency at which this happens. You can think of an oscillator as a sort of high-gain amplifier that's gone out of control. In this case it's exactly what we want to happen, but there'll be other times when self-oscillation is very undesirable and must be prevented at all costs, like in RF and audio amplifiers. Oscillators are often biased Class C for its very high efficiency. Both a regulated supply voltage and voltage-divider bias methods are used to increase stability.

The Colpitts Oscillator

There are several types of oscillators, and their main differences are in the way the feedback is applied. For CB use the Colpitts circuit is standard, probably because capacitors are much cheaper than coils. One side of the crystal is grounded, which also simplifies the problem of stray capacitance in crystal switching circuits. The crystal is normally used in its parallel-resonant mode except in certain SSB circuits.

Refer to Figure 3-3. The Colpitts oscillator is identified by a capacitive voltage divider (C1/C2) which provides the feedback. Feedback is via C2 which couples back about 25-35% of the output voltage. Thus the value of C2 is generally chosen to be roughly 1/4 or 1/3 of C1 for best stability. If the feedback is too small it won't oscillate; if too large it won't give good amplification, lowering the output voltage and possibly fracturing the crystal. You'll see oscillators using ratios from 10:1 to 2:1 depending upon the particular circuit, crystal cut and frequency; the minimum feedback value for reliable oscillator starting is always chosen. R3 provides a DC emitter return while keeping Q1 above RF ground. Sometimes you'll see an RF choke used here but a resistor works fine. Biasing is by the voltage divider R1/R2, and the main supply is always well regulated; both measures insure good stability.

A tube version of the Colpitts circuit is shown in Figure 3-4. Operation is basically identical and the identifying mark is always the use of a capacitive divider like C326/C327. Note the smaller values of all capacitors compared to the transistor circuit; the higher impedance of a tube circuit develops more voltage, so smaller values produce the same effect. Bias is via R321 and R323.

Stability and Frequency Shift

The crystal is shunted from base to ground. Its frequency is often made adjustable by a small value of inductance or capacitance, as shown below. Because the bipolar Colpitts circuit already has a fairly high input shunt capacitance, the trimmer is always placed in series with the crystal for maximum effect. Sometimes you'll see an additional small fixed capacitor (under 10 pF) in parallel with the trimmer; this helps stabilize the frequency for temperature drift by dampening the effect of the trimmer and distributing the heating effects of the RF currents more evenly. While this isn't always done in AM radios, SSB requires the extra stability measures.

FIGURE 3-3
COLPITTS CRYSTAL OSCILLATOR

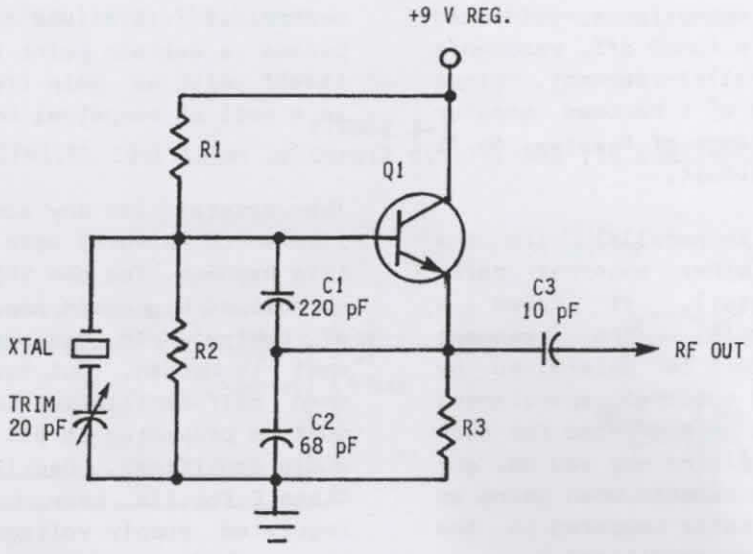
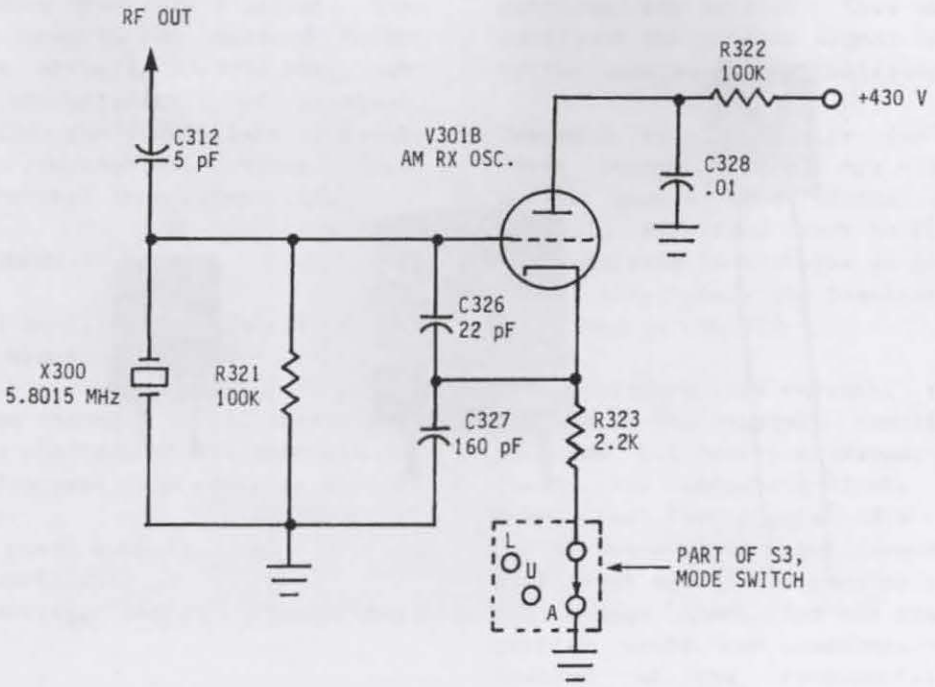


FIGURE 3-4
VACUUM TUBE COLPITTS OSCILLATOR
(Tram D201/D201A)



For best stability the trimmer is always a high-quality ceramic rather than a mica compression type. Voltage-divider bias is used for stability. In addition oscillator V_{cc} is kept to a minimum, under 9.0 VDC, and always Zener- or transistor-regulated by a separate branch of the power supply.

Sometimes the frequency is purposely shifted, like in Delta Tune and SSB Clarifier controls. The standard AT cut crystal will "slide" very nicely, as will third-overtone types used in their fundamental modes. To minimize stray capacitance they're usually soldered directly to the PC board without sockets. The most common CB crystal holder types are the HC18/U, HC6/U, and HC25/U, Figure 3-5. The larger (and more expensive) HC6/U was used mostly before the 23-channel era. It has the largest tuning shift, which is why it's still used in the Cobra 148/2000GTL chassis Clarifier circuit.

Overtone Oscillators

Crystals of less than about 20 MHz are of the "fundamental" type, meaning they vibrate directly at the cut frequency. Above 20 MHz, the crystal wafer becomes physically too thin and fragile to be practical. For higher oscillator frequencies an "overtone" crystal is used. This is specially cut to oscillate at an approximate odd harmonic like the 3rd, 5th, 7th, etc. The third overtone is most common. Overtone crystals have much higher Q than fundamental types of the same frequency, making them more stable and less affected by external circuit capacitance. Many CB synthesizers require signals in the 33-37 MHz range, generated from third overtone crystals. For example, in Figure 3-6 the desired AM output is 33.3350 MHz; an 11.1125 MHz third overtone crystal and tripler stage are used. In overtone oscillators, the crystal is always used in its series-resonant mode.

Notice that a separate tripler stage (TR23) follows the 11 MHz oscillator. While a harmonic oscillator could be used directly (and is, in cheaper designs), its fundamental note and other undesired harmonics would also appear in the output and would have to be filtered. Overtone crystals don't have this problem. But

FIGURE 3-5
CRYSTAL HOLDER TYPES
(Courtesy McGraw-Hill Book Co.)

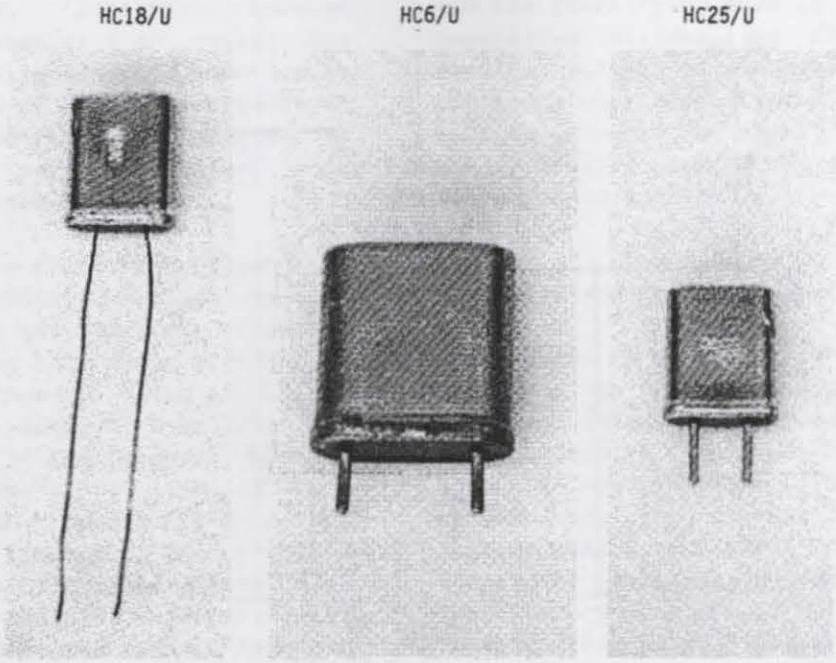
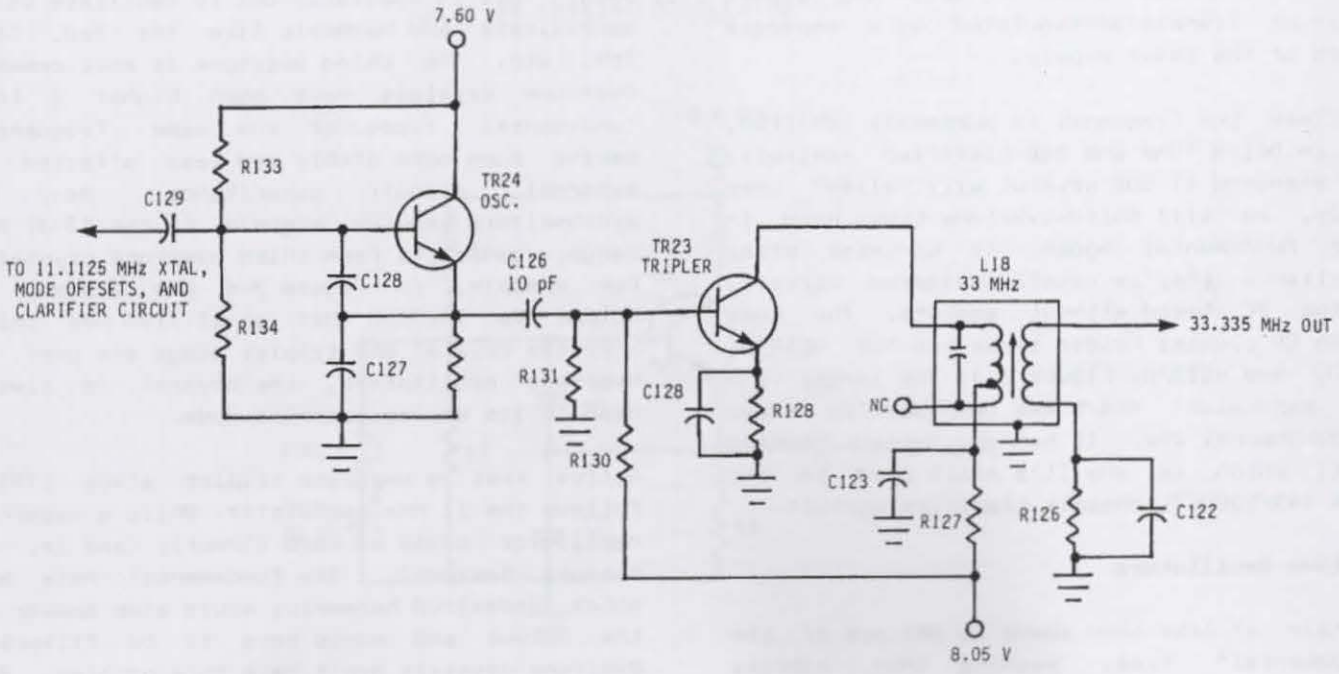


FIGURE 3-6
OVERTONE CRYSTAL OSCILLATOR
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



they're extremely fragile, only a few mils thick, and are generally operated with the minimum feedback that will sustain oscillation. The rest of TR24 is a standard Colpitts circuit. R133 and R134 provide voltage-divider bias. Output coupler C126 is purposely kept small to avoid loading down TR24's output. The output at L18 is tuned to the desired third harmonic, which is actually 33.3350 MHz, not 33.3375 MHz. One characteristic of overtone crystals is that they don't oscillate on exact multiples of the fundamental, since their action is more mechanical than electrical.

OSCILLATOR TROUBLESHOOTING

Repairing a crystal oscillator is fairly easy. Oscillator failure symptoms include:

1. No Transmit, some channels or all channels.
2. No Receive, some channels or all channels.
3. No Receive or Transmit, and radio is a PLL-synthesized type.
4. Low transmitter power output.
5. Weak receiver sensitivity.
6. Intermittent receiver and/or transmitter operation.

Transistor and tube-type oscillators are not much different except for the operating voltages. A gassy oscillator or mixer tube will account for many problems in tube circuits. The high voltages used in tube circuits tend to break down other parts faster too, especially electrolytics which dry out with heat and age. Crystals are a common failure point in both oscillator types.

The first step is to determine if the oscillator is running. A 'scope or frequency counter at its output reveals this immediately, although the counter is preferred since it gives the exact frequency. Since an oscillator develops base (or grid) bias when oscillating, check for this with the crystal removed or shorted by a capacitor; the voltages should be different. If not, the problem is either a bad crystal or insufficient feedback from an open or leaky capacitor.

The amplitude of a Colpitts transistor crystal oscillator is about 1.5-2.5 VAC when measured directly at the actice device. Otherwise use very loose coupling or you may load it down and get false readings or kill it completely. A couple of turns of wire is usually enough. I prefer the "RF Sniffer" probe described in CHAPTER 1, since there's no physical contact.

If you're reasonably sure the oscillator isn't running, you can try coupling in a stable signal source like that from a signal generator. If operation is restored you've confirmed the problem. This method can be used to inject the carrier signal in the transmitter or the receiver Local Oscillator(s).

Assuming the oscillator isn't running, the first things to check are the power to the active device, the device itself, and the crystal. Referring back to Figure 3-3, check the specified DC voltages on Q1. If they're way out of line, check the transistor using methods described in CHAPTER 2.

When voltages are correct, the most likely problem is the crystal. Sometimes the crystal is good but poorly soldered; that's all it takes. Try reheating first; if that doesn't work, test the crystal in a crystal checker. Don't worry about exact frequency readings in your test oscillator because stray capacitance can change them. And the placement of your counter probe can sometimes read a harmonic instead of the fundamental. Conversely, overtone crystals may read their fundamental frequency instead. (Many CB oscillators operate in the 33-37 MHz range, which means you might read the 12 MHz fundamental note.)

If you have another crystal handy in the same frequency range, try it in place of the original. If the circuit has a series trimmer like a capacitor or coil, check for RF continuity from the crystal low side to ground. This is especially important in SSB radios because the Clarifier circuit is often between the crystal and ground. (Eg, Cobra 140/142GTL chassis, Cobra 148/2000GTL chassis.) If there's a tuning adjustment on a crystal oscillator, recheck it. Some older radios had an oscillator coil. If it's adjusted right at the critical peak it may not start every time. Such coils should always be set just past the peak on the inductive (slow-tuning) side. Screw the slug into the coil a bit further.

If none of these things work, check the individual resistors and capacitors; if a capacitor in the feedback circuit opened or changed enough, it could kill the oscillator even though the DC transistor voltages are correct. (One nice use for a capacitance meter!) And excess feedback from an increased

coupling value can fracture a crystal.

How To Order Crystals

Assuming you need a replacement crystal, or the customer wants other frequencies installed, you must know some basic technical and mechanical specs or you'll feel like a dummy when you contact crystal companies; they'll ask those questions. Specs are left out of service manuals, so here they are for future reference:

FREQUENCY: As desired. (Fundamental under 20 MHz, third overtone over 20 MHz.)

HOLDER TYPE: See the photos in Figure 3-5; solder leads (HC18/U), plug-in (HC25/U), etc.

ACCURACY: .005% or better. You'll pay a lot more for higher accuracy. Some crystal circuits have no trimmer, so you may need the better one if stray capacitance affects it. Determine by the specific circuit.

RESONANCE: Specify parallel resonance for fundamental Colpitts types, and series resonance for overtone applications.

LOAD CAPACITANCE (C_L): Standard AM or FM circuits used for synthesizers, receiver Local Oscillators, transmitter oscillators, etc. are 32 pF. For SSB Carrier Oscillators or Clarifiers, where several KHz shift is needed, use a smaller value like 20 pF. The smaller the load capacitance, the more the external circuitry affects it.

Some recommended crystal suppliers are listed in CHAPTER 1. Expect to wait 2-4 weeks for it.

Miscellaneous Oscillator Problems

Strange things can happen in high-frequency circuits, especially when stray capacitive coupling exists. Usually you find this in radios where somebody tried to install a crystal switch using long wires, or some other non-standard "improvement" to the radio.

Here's a classic example: I was fixing a President Adams. It worked fine in all modes until the bottom cover was attached. When attached, it wouldn't transmit correctly on SSB; AM was OK. Keying the mike on SSB produced a solid carrier which was obviously self-oscillation. It was clear nothing on the PCB was shorting to the cover.

This baffled me until I investigated further. Turns out some fool tried to broadband a mixer coil near the Balanced Modulator IC by cutting the coil traces and rejumpering. This would have been OK, except he used #16 solid wire for the jumpers, which were bent over into "U" shaped loops parallel to the chassis and therefore the cabinet cover. With the cover attached, there was enough capacitive coupling from the loops to the metal cover to feed the signal right back where it didn't belong, causing self-oscillation. Rewiring the jumpers cured the problem. But it took that closer inspection and the old "Never overlook the obvious" to even get me thinking about it!

In 23-channel radios it's possible for one crystal to take over the function of another crystal that's dead or weak. The oscillator wants to start and will, if given the slightest encouragement. The RF power output may be normal, but off frequency. Or the power and sensitivity may be lower than normal but channels are duplicated; for example, you can receive and transmit Ch.11 from both the Ch.11 and from the Ch.15 positions. This means the crystal common to Ch.15 Receive and Transmit is probably bad. Corrosion or dirty switch contacts can also cause this.

If the problem is limited to a single channel the switch is the most likely cause; bad synthesizer crystals affect several channels at once, usually in groups of four or six channels. (Unless it's an older radio with separate crystals for each channel.) Only the position of the Channel Selector switch is unique to a single channel.

Another problem among older radios having less shielding is that a broadband signal can be transmitted covering a lot more than just one channel within the 27 MHz band! Confirm with another receiver or a spectrum analyzer.

Some RF power amplifiers, again in the older 23-channel models with their easier technical standards, are capable of transmitting a full power signal even if one of the synthesizer oscillators is dead. It might not be on 27 MHz though. For example, a 23 MHz signal might be transmitted in a radio that uses the 23/14 MHz crystal synthesizer circuit. I discovered this the hard way while trying to adjust a mobile antenna. The SWR just wouldn't come down, even though the coax was good and the radio showed a perfect match into a dummy load. I was positive

the antenna was good. The rig was transmitting a beautiful 4-watt signal, on 23 MHz! In those days I couldn't afford a frequency counter or I would have caught this immediately. Be aware!

Non-Synthesized Circuits

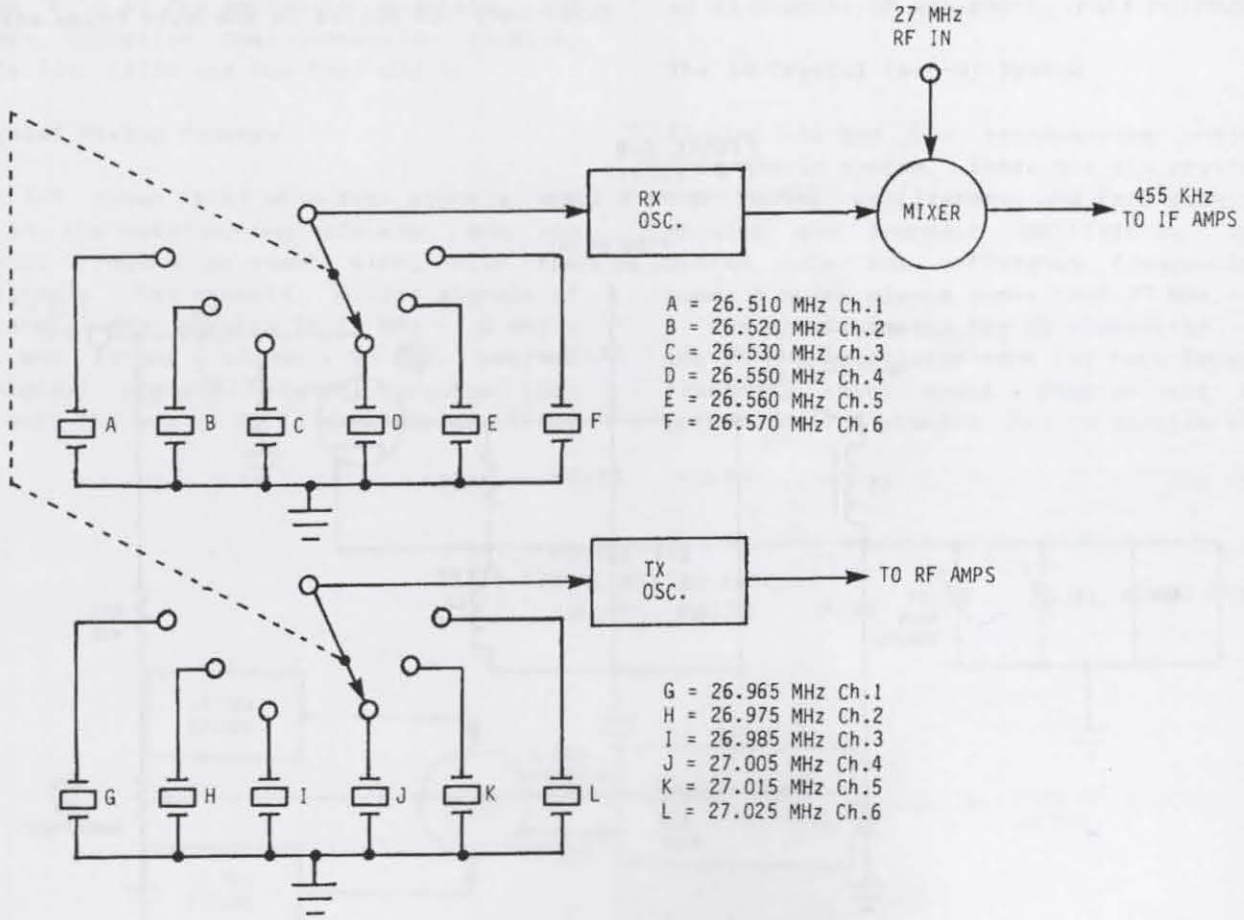
In the early days CB radios didn't have a Master Oscillator stage; they used individual oscillators for Receive and Transmit, which meant one pair of crystals per channel. The crystals were plug-in types so the user could change channels easily once the crystal socket capacity was exceeded. The pair was separated by 455 KHz to provide one receiver intermediate frequency (IF) in a simple single-conversion circuit. This allowed some selectivity, but not much. The idea worked fine back then because few people had CBs, so they didn't need many channels or any great selectivity. Imagine what that situation would be like today!

Figure 3-7 shows the basic idea. The Transmit crystal is always the direct 27 MHz frequency, and the Receive crystal is 455 KHz lower. From the oscillator, signals go directly to the transmitter amplifier or receiver mixer stages respectively. A typical example was the old "white face" Johnson Messenger II. Since many oldtimers still use these rigs and want them maintained, you should know how they work.

The very same idea is still used today for simple 3- or 6-channel Walkie-Talkies. Except for their simplified single-conversion crystal scheme, handhelds have all the same circuits as synthesized radios whose operation is explained throughout this book.

Speaking of Walkie-Talkies, a simple way to improve performance is to reverse the Transmit/Receive crystal pair. This allows operation on a frequency which is 455 KHz below

FIGURE 3-7
CRYSTAL MIXING FOR 6-CHANNEL SINGLE-CONVERSION WALKIE/TALKIE



the marked channel, on a "0" frequency rather than a "5." For example, reversing a Ch.19 pair (27.185 MHz) means Transmit is now on 27.185 MHz - 455 KHz = 26.730 MHz instead. The required 455 KHz Receive IF offset remains, except now it's high-side injection rather than low-side injection. (See P. 99.) No retuning is usually needed, the range is improved since it's on a quiet (but illegal) channel, and the customer will think you're a genius.

The VFO

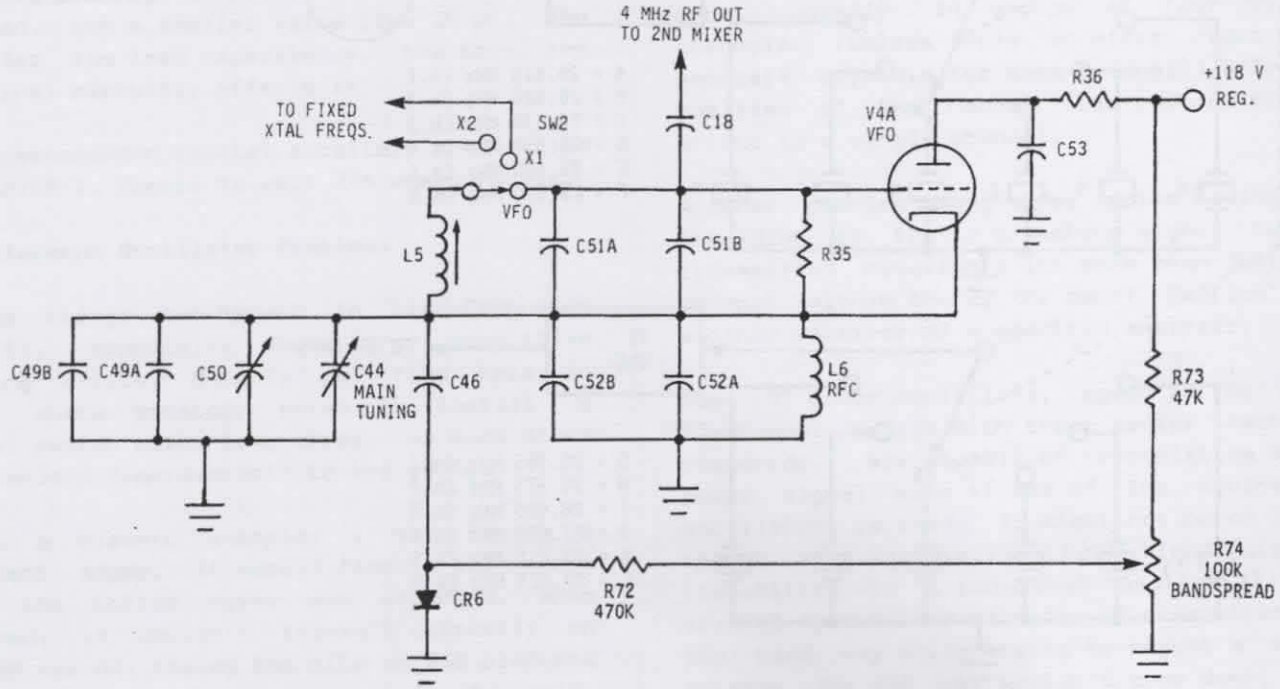
The VFO (Variable Frequency Oscillator) is a circuit you won't find much anymore, but I've included it to show its similarity to the crystal-controlled oscillator. (Don't confuse this with a Variable Crystal Oscillator or VXO, which is the technical name for a Delta-Tune or Clarifier circuit.) Some of the classic old Trams and Brownings included VFOs before FCC rule changes prohibited them. And a few VFOs were sold as add-on accessories. Many people are still interested in them. The serious builder should consult the DeMaw book or THE RADIO AMATEUR'S HANDBOOK for detailed theory and construction tips.

Figure 3-8 shows the popular Browning and Tram type VFO, minus the switching for simplicity. This is another Colpitts circuit, now series-tuned. (Most crystal oscillators are parallel-tuned.) A triode tube is used here, similar to the bipolar transistor except for biasing and impedances. Note the same use of a capacitive feedback divider, C51b/C52a. The frequency controlling elements are L5, C44, C49a, C49b, C50, C46, and the Bandspread circuit.

The parallel tank circuit isn't practical in a VFO. The high combined shunt capacitance of C51a/C51b and C52a/C52b would require the inductance of L5 to be an unreasonably low value. Even if it works right, the smallest changes in lead length or PC traces would cause electrical and mechanical instability. These problems are solved by using a series-tuned tank circuit, with L5/C44 (and the associated shunt trimmers and stabilizers) in series from grid to ground. The reduced shunt capacitance allows a larger and more practical coil value for L5, which in turn reduces the effects of stray circuit capacitance.

This coil is bolted to the main frame with a

FIGURE 3-8
VFO CIRCUIT
(Browning Mark III)



locking nut for good mechanical stability. Multiple parallel trimmers (C49a/C49b, C50) are used across the Main Tuning capacitor. These add thermal stability by distributing the RF currents among several capacitors rather than just one. The +118 VDC supply is Zener-regulated from the main HV supply.

The Bandspread circuit is a simple way to fine-tune the VFO. As the voltage to CR6 is increased via R74 the diode turns on, shunting the additional capacitance of C46 into the circuit. The capacitance is controlled by the forward bias on the diode. The high value of R72, R73, and R74 is for RF isolation from the power supply, similar to modern Clarifier circuits. By using a regulated voltage for the Bandspread control, there's no initial power-up drift caused by diode junction heating when switching from standby to active use.

CRYSTAL SYNTHESIZERS

As CB radios gained popularity, all of the original 23 channels were quickly filled up. Crystals are very expensive relative to other components and it wasn't practical to use 46 separate crystals to cover the band, let alone 80 crystals when the band was expanded to 40 channels. And as overcrowding became the rule, more selective receiver circuits were needed.

The answer to the problems of cost, physical chassis space and greater selectivity was a process called "crystal synthesis" or "crystal-plexing." This allowed complete 23-channel AM coverage with as few as twelve crystals, and the more selective dual-conversion receiver circuits too. Let's see how they did it.

The Crystal Mixing Process

Figure 3-9 shows that when two signals are mixed in the heterodyning process, sum and difference frequencies result along with the two originals. For example, mixing signals of 15 MHz and 10 MHz results in 15 MHz - 10 MHz = 5 MHz, and 15 MHz + 10 MHz = 25 MHz, besides the original signals. Tuned circuits then select only the sum or difference frequency for further processing. In CB synthesizers both sum and difference signals may be used.

Forget the additional crystals used in SSB equipment for the moment, since this is completely covered in CHAPTER 6. This leaves basically two crystal synthesis methods for most AM radios: the 12-crystal scheme, and the 14-crystal scheme. In both cases, three oscillators are used: a Master Oscillator, a Transmit Oscillator, and a Receive Oscillator. There are subtle differences between the two mixing methods, and each was used about equally in 23-channel AM equipment.

The 14-Crystal (6-4-4) System

Figure 3-10 and the accompanying chart show this basic system. There are six crystals in the Master Oscillator, and four each in the Receive and Transmit oscillators. In this system only the difference frequencies are used; a quick glance shows that 37 MHz - 10 MHz = the 27 MHz needed for CB operation. Notice the 37 MHz oscillator runs for both Receive and Transmit, which means a problem here affects <u>both</u> modes. A problem only on Receive or only

FIGURE 3-9
BASIC SIGNAL MIXING PROCESS

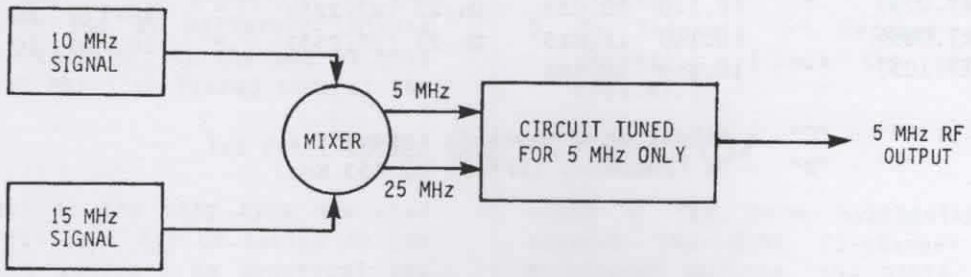
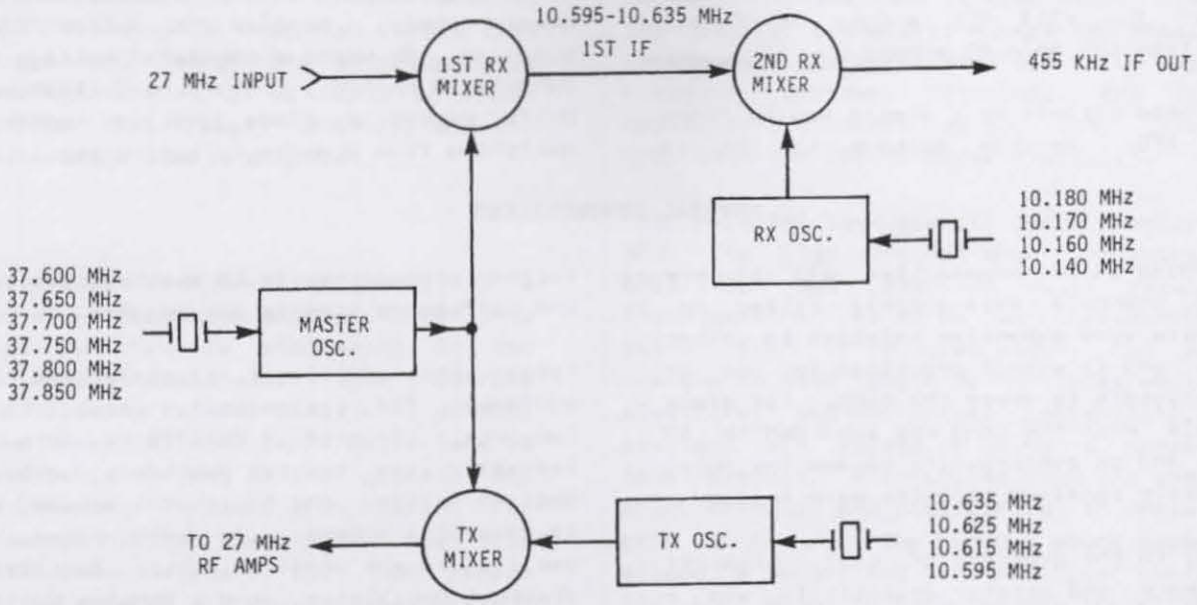


FIGURE 3-10
THE 14-CRYSTAL (6-4-4) AM MIXING SYSTEM



THE 14-CRYSTAL AM SYNTHESIZER

	BOTH RX&TX	RX ONLY	TX ONLY		BOTH RX&TX	RX ONLY	TX ONLY
	"A"	"B"	"C"		"A"	"B"	"C"
Ch. 1 (26.965)	37.600	10.180	10.635	Ch.13 (27.115)	37.750	10.180	10.635
Ch. 2 (26.975)	"	10.170	10.625	Ch.14 (27.125)	"	10.170	10.625
Ch. 3 (26.985)	"	10.160	10.615	Ch.15 (27.135)	"	10.160	10.615
Ch. 4 (27.005)	"	10.140	10.595	Ch.16 (27.155)	"	10.140	10.595
Ch. 5 (27.015)	37.650	10.180	10.635	Ch.17 (27.165)	37.800	10.180	10.635
Ch. 6 (27.025)	"	10.170	10.625	Ch.18 (27.175)	"	10.170	10.625
Ch. 7 (27.035)	"	10.160	10.615	Ch.19 (27.185)	"	10.160	10.615
Ch. 8 (27.055)	"	10.140	10.595	Ch.20 (27.205)	"	10.140	10.595
Ch. 9 (27.065)	37.700	10.180	10.635	Ch.21 (27.215)	37.850	10.180	10.635
Ch.10 (27.075)	"	10.170	10.625	Ch.22 (27.225)	"	10.170	10.625
Ch.11 (27.085)	"	10.160	10.615	Ch.23 (27.255)	"	10.140	10.595
Ch.12 (27.105)	"	10.140	10.595				

Synthesis: "A" - "C" = direct on-channel TX frequency;
"A" - "B" = RX frequency (offset by 455 KHz)

on Transmit means you should consider the separate Transmit and Receive oscillators, not the Master Oscillator.

This system is divided into six major groups. The last group (Ch.2½2/23) has one less frequency than the others; we only need 23 channels, and the missing combination would generate the 24th channel. The jump of 30 KHz between Ch.22 and Ch.23 later became Ch.24 and Ch.25 in the expanded 40-channel FCC band.

For example, Channel 1 (26.965 MHz) mixes the 37.600 MHz crystal with both the 10.180 MHz crystal on Receive, and the 10.635 MHz crystal on Transmit. The transmitter mixing produces the direct channel frequency of 37.600 MHz - 10.635 MHz = 26.965 MHz. However the receiver mixing results in 37.600 MHz - 10.180 MHz = 26.510 MHz. Note this is 455 KHz lower, which provides the required 2nd IF for the dual-conversion receiver circuit.

Use this information whenever you suspect oscillator-related problems. The most common causes will be faulty crystals, a faulty mixer, poor soldering of a particular crystal, or poor contact(s) for a particular crystal at the Channel Selector switch.

Symptoms of 6-4-4 synthesizer failure are:

1. No Transmit or Receive on any channel. (Check active devices, mixer, and switch wiring.)
2. No Transmit or Receive on four consecutive channels. (Check the associated 37 MHz crystal.)
3. No Receive on every fourth channel. (Check the associated 10 MHz crystal.)
4. No Transmit on every fourth channel. (Check the associated 10 MHz crystal.)

There are some variations on the 6-4-4 crystal system using frequencies other than the common 37-10-10 MHz scheme, and you may occasionally encounter these. Examples are most Johnson radios, which use 32-6-6 MHz, and the SBE scheme of 17-9-9 MHz. The principle is the same, although both sum or difference mixing frequencies may be chosen. At the end of this chapter (Pp. 87 and 88) I've listed some of the other common AM-only mixing schemes for your reference. Also go to my Web link reference shown at the bottom of Page 85 to see all the known AM and SSB schemes.

The 12-Crystal (6-4-2) System

This system differs in the way the mixing signals are generated. See Figure 3-11 and the accompanying chart. There are now two Master Oscillators running at 14 MHz and 23 MHz. The resulting sum of 38 MHz is chosen and then mixed with separate 11 MHz Receive and Transmit oscillators. When subtracted from the 38 MHz composite signal, we get the required 27 MHz. Like the 14-crystal system with its 10 MHz Receive/Transmit crystal pairs that are separated by 455 KHz, in this system the 11 MHz crystals are also separated by 455 KHz to generate the required offset for dual-conversion receivers.

Example: For CB Channel 1 (26.965 MHz) the 23.290 MHz crystal mixes with the 14.950 MHz crystal. This gives 23.290 MHz + 14.950 MHz = 38.240 MHz. The Transmit oscillator is always 11.275 MHz, which results in 38.240 MHz - 11.275 MHz = 26.965 MHz, the channel frequency. For Receive, the result will be 38.240 MHz - 11.730 MHz = 26.510 MHz. This is the same as the 14-crystal scheme; we simply got there by a different route. This 6-4-2 synthesizer method was very popular in Uniden AM radios sold under the Cobra, Courier, HyGain, Lafayette, Midland, and Realistic names, among many others.

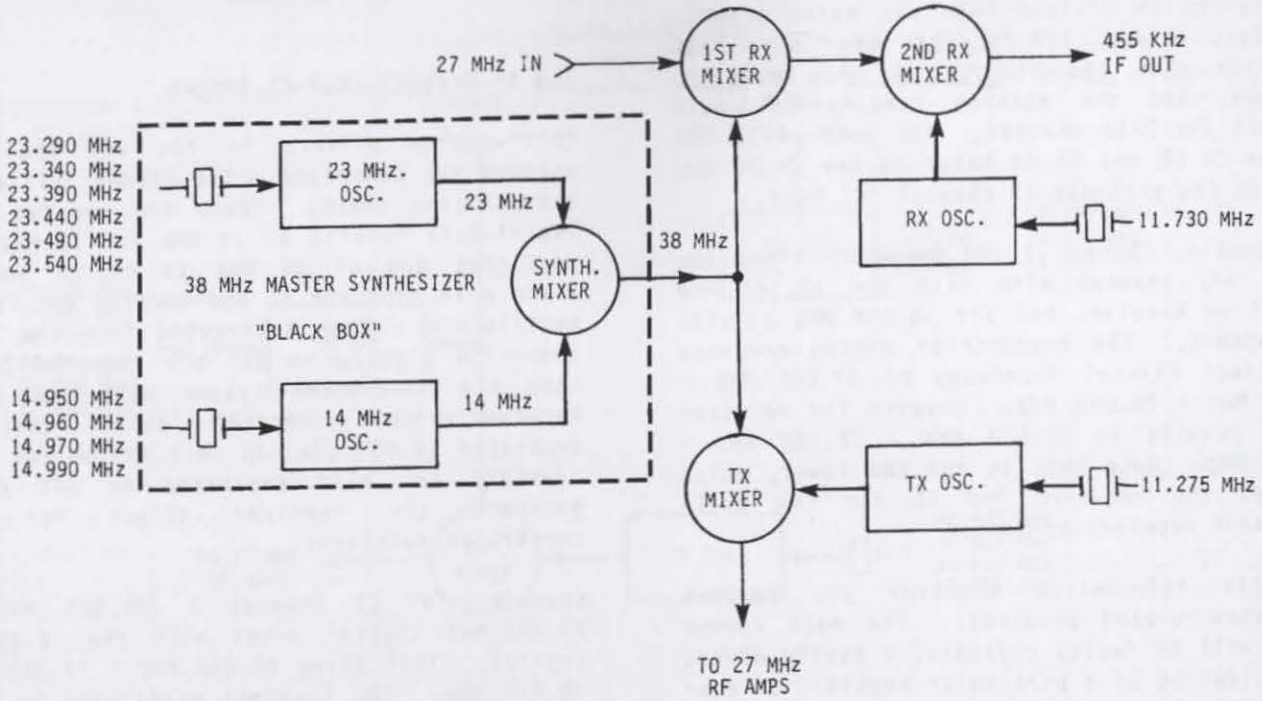
Symptoms of synthesizer failure in the 6-4-2 crystal system are:

1. No Transmit, all 23 channels. (Check the 11.275 MHz oscillator circuit.)
2. No Receive, all 23 channels. (Check the 11.730 MHz oscillator circuit.)
3. No Transmit or Receive, all 23 channels. (Check the 38 MHz mixer stage.)
4. No Transmit or Receive on four consecutive channels. (Check the associated 23 MHz crystal.)
5. No Transmit or Receive on every fifth channel. (Check the associated 14 MHz crystal.)

THE PHASE-LOCKED-LOOP (PLL) SYNTHESIZER

The PLL synthesizer is the only type now used for CB radios worldwide. Any CB having 40 (or more) channels just wouldn't be practical any other way because of the extra crystal expense. One exception was the Tram D201A, which simply added a few more synthesizer crystals to convert the D201 23-channel radio to the 40-channel version, the D201A. It had plenty of room, and was a very expensive rig anyway. A handful of late 23-channel American CBs like

FIGURE 3-11
THE 12-CRYSTAL (6-4-2) AM MIXING SYSTEM



THE 12-CRYSTAL AM SYNTHESIZER

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	23.290	14.950	Ch.13 (27.115)	23.440	14.950
Ch. 2 (26.975)	"	14.960	Ch.14 (27.125)	"	14.960
Ch. 3 (26.985)	"	14.970	Ch.15 (27.135)	"	14.970
Ch. 4 (27.005)	"	14.990	Ch.16 (27.155)	"	14.990
Ch. 5 (27.015)	23.340	14.950	Ch.17 (27.165)	23.490	14.950
Ch. 6 (27.025)	"	14.960	Ch.18 (27.175)	"	14.960
Ch. 7 (27.035)	"	14.970	Ch.19 (27.185)	"	14.970
Ch. 8 (27.055)	"	14.990	Ch.20 (27.205)	"	14.990
Ch. 9 (27.065)	23.390	14.950	Ch.21 (27.215)	23.540	14.950
Ch.10 (27.075)	"	14.960	Ch.22 (27.225)	"	14.960
Ch.11 (27.085)	"	14.970	Ch.23 (27.255)	"	14.990
Ch.12 (27.105)	"	14.990			

Synthesis: "A" + "B" - 11.275 = direct on-channel TX frequency;
"A" + "B" - 11.730 = RX frequency (offset by 455 KHz)

the SBE Formula D, Realistic TRC57, Royce 601, Midland 13-857B and similar Cybernet chassis used PLL circuits, often composed of many discrete ICs. Today's IC technology reduces the PLL circuit to just one or two chips, a few external components, and 1-7 crystals. Besides the obvious advantages of cost and space reduction, performance is also improved because every channel has the same degree of accuracy; the same crystal is being used to generate every mixing frequency.

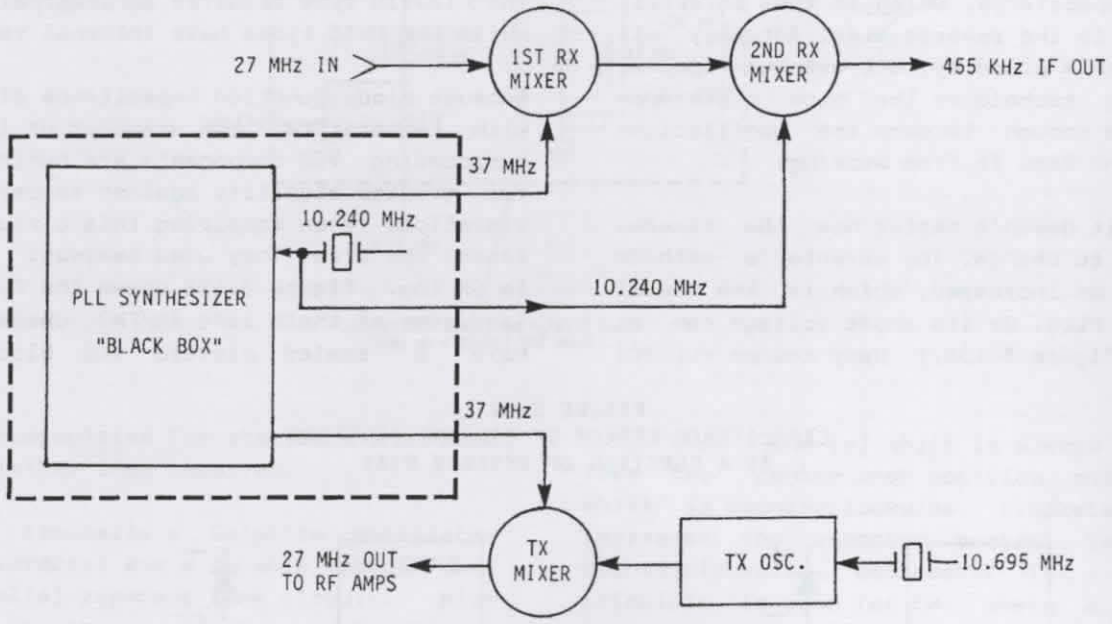
PLL circuits look more complicated than crystal synthesizers, but really aren't when you compare their end results; i.e., generating a specific set of mixing signals. The main distinction is that the PLL is a digital rather than analog system. Let's compare both in a very general way to see how they evolved.

Comparison of PLL and Crystal Synthesizers

Return to the 12-crystal 6-4-2 synthesizer on the preceeding page. For the moment ignore whatever's going on inside the dotted lines. The important point is that coming from this area is a set of 38 MHz frequencies, one for each CB channel, which when mixed with the associated 11 MHz Receive/Transmit oscillators will produce the required signal frequencies.

Now compare this to the equivalent PLL synthesizer of Figure 3-12. Again, the area inside the dotted lines can be considered a "black box" for the moment. Its output is a group of 37 MHz frequencies, plus a 10.240 MHz signal. When mixed with the appropriate Receive/Transmit circuits, the same signal frequencies are generated. Note the 10.240 MHz oscillator is sampled and also used to supply the injection for the 2nd receiver IF. This eliminates the extra cost and complexity of another crystal oscillator, and also helps reduce the number of spurious signals generated within the radio. Except for some other minor changes for SSB, there's little difference between the function of either "black box."

FIGURE 3-12
EQUIVALENT SYNTHESIZER OF FIG. 3-11 USING A PLL



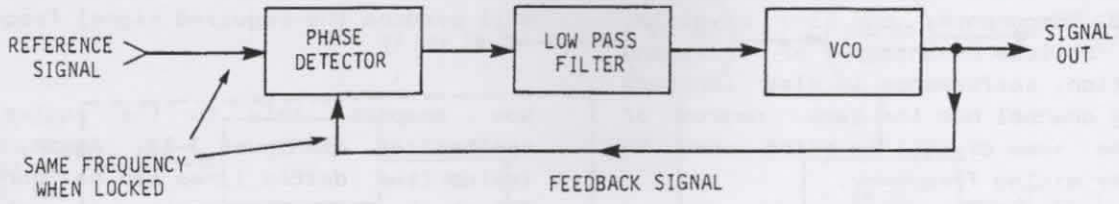
ELEMENTS OF THE PLL SYSTEM

Now let's dissect the PLL "black box" to see what's happening inside that makes it produce the needed mixing signals. Figure 3-13 shows its three basic elements: a Voltage-Controlled Oscillator or VCO, a Low-Pass Filter, and a Phase Detector or Phase Comparator.

The VCO

The VCO is an oscillator whose frequency change

FIGURE 3-13
BASIC PLL SYSTEM



depends not upon coils, capacitors, or quartz crystals, but on a special semiconductor device called a "varactor," "varicap," or "VVC" (Voltage-Variable Capacitance) diode. This has the ability to change its capacitance at a predictable rate as its reverse-bias voltage changes. The concept makes more sense when you consider the construction of a typical silicon PN junction. See Figure 3-14.

The two halves of the PN junction can be thought of like the two plates of a capacitor separated by the junction barrier. Near the junction are [+] and [-] charged particles. The varactor operates with reverse-bias, and as this bias increases, the charged particles are forced further away from the junction. This lowers the capacitance, which is thus inversely proportional to the reverse bias. Actually all diodes have this property, but without special manufacturing techniques the back resistance could be low enough to damp the oscillations completely and keep it from working.

Note that it doesn't matter how the reverse bias is made to change. The varactor's cathode voltage can be increased, which is the usual case in most PLLs. Or its anode voltage can be decreased. (Figure 3-15B.) Many common PLL ICs like the PLL02A, SM5104, and MC145106 use a negative-going Phase Detector output in which the higher the input frequency, the lower the DC output voltage to the varactor.

The most common varactor diodes for CBs are the 22 pF or 33 pF types. (1S2339G, ITT310, ECG613, ECG614, etc.) This is the capacitance value at a specific reverse bias, typically 4.0 VDC. In practice a fixed DC bias is first applied to establish operation in the diode's linear range, and the changing control voltage is added to this. Figure 3-15A shows a VCO circuit using a discrete varactor. Many newer chassis use ICs containing most of the VCO circuit, and often part of the mixer too. Examples are the TA7310/AN103/C3001, and the UHIC005 or UHIC007. The TA7310 type requires an external varactor, while the UHIC types have internal varactors.

Because diode junction capacitance also changes with temperature, the varactor or IC and the surrounding VCO components are buried in wax for greater stability against temperature and vibration. When repairing this circuit, always reseal the area. They used beeswax; candle wax is OK too. Figure 3-15B shows the Cybernet SSB (and some of their late AM/FM) chassis, which have a sealed plastic VCO block that's

FIGURE 3-14
CAPACITANCE EFFECT OF SILICON JUNCTION
AS A FUNCTION OF REVERSE BIAS

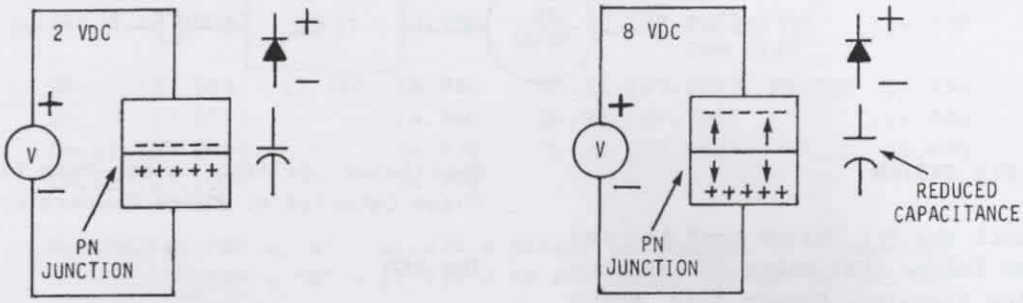
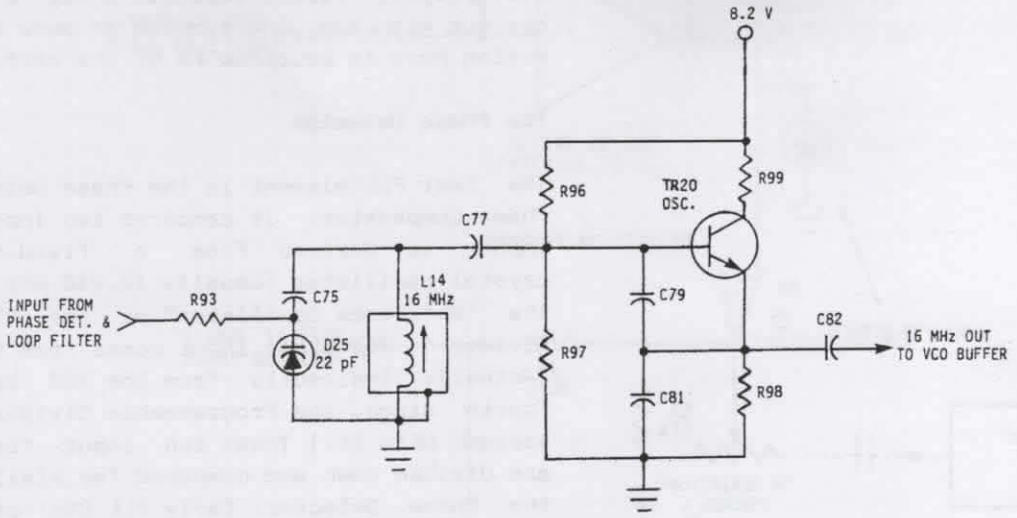
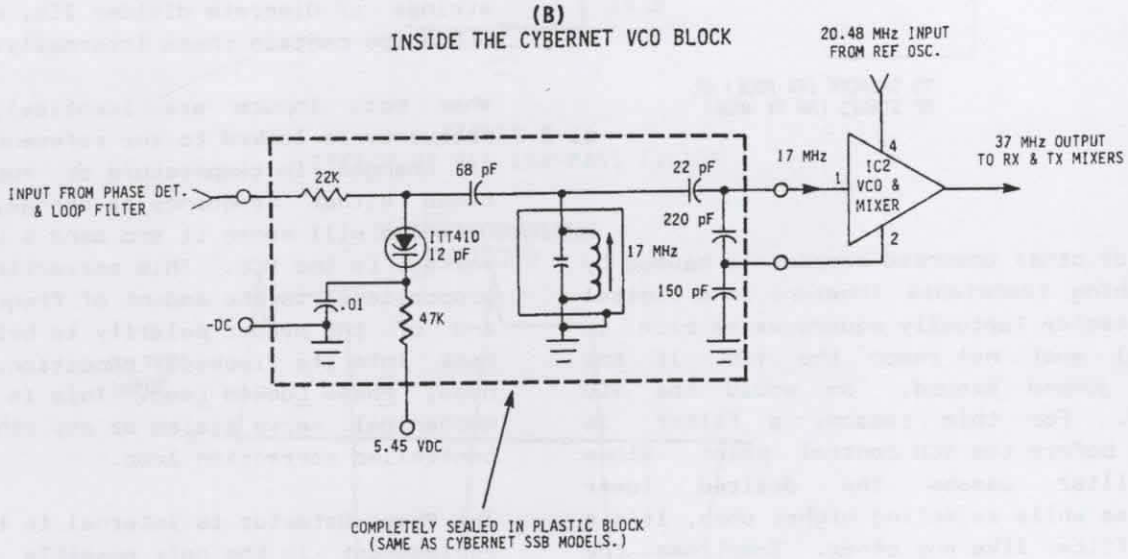


FIGURE 3-15
VCO CIRCUITS

(A)
COLPITTS VCO USING DISCRETE COMPONENTS
(Cobra 146GTL, President AR144, Realistic TRC451, Uniden PC244, etc.)



(B)
INSIDE THE CYBERNET VCO BLOCK



completely encapsulated for stability and must be replaced rather than repaired.

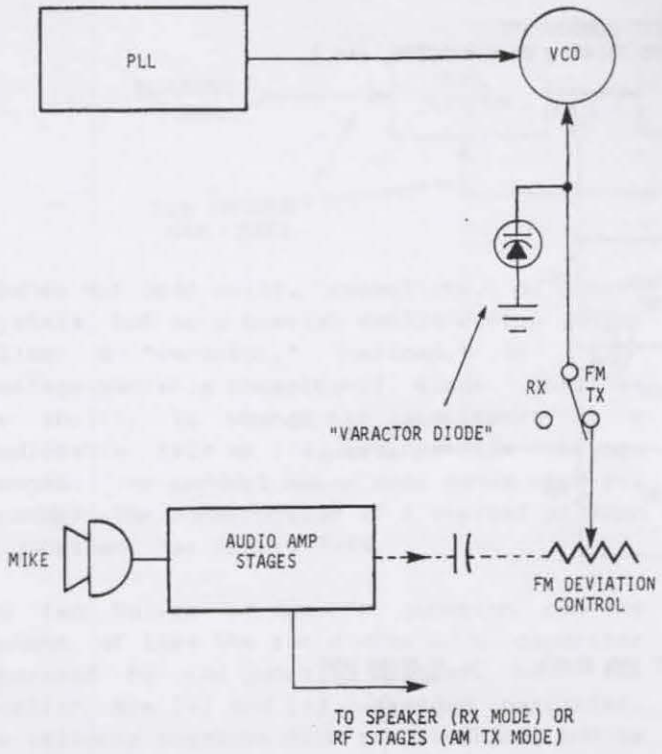
The VCO is typically a Colpitts oscillator where the varactor and a tunable shunt coil form its parallel-resonant tank circuit. With a varactor in the oscillator tank circuit (Figure 3-15A), any change in its reverse bias changes the capacitance, which in turn changes the frequency. The higher the applied voltage, the smaller the capacitance and hence the higher the frequency, and vice-versa. This is precisely the circuit idea used in the Delta Tune or Clarifier control of a modern CB radio.

Note that the [+] shift is always clockwise from the center knob position and the [-] shift is counterclockwise. Clockwise rotation increases the varactor control voltage and counterclockwise decreases it. The same principle is used for FM, where a sample of the mike audio is applied to the VCO varactor and causes it to change frequency at an audio rate. See Figure 3-16.

The Low-Pass Filter

Since the VCO is driven by a DC control voltage, its purity is critical. Ripple,

FIGURE 3-16
USING A VARACTOR TO PRODUCE FM



spikes, or other unwanted components caused by the switching transients inherent in a digital Phase Detector (actually square waves rich in harmonics) must not reach the VCO. If the voltage jumped around, so would the VCO frequency. For this reason, a filter is inserted before the VCO control point. Since this filter passes the desired lower frequencies while rejecting higher ones, it's a Low-Pass filter like any other. Sometimes the filter is called a "Charge Pump" on the schematic, since its capacitors charge up from the Phase Detector output and then "pump" the filtered DC voltage out to the VCO.

The Low-Pass Filter may be of a simple RC type, or nowadays, an active filter inside the PLL chip. See Figure 3-17. The op-amp type filter has a lower output impedance, making it easier to drive a VCO. This filter's also called an "integrator," since it integrates or rounds off the sharp corners of the digital square wave. Think of it as a Digital-to-Analog Converter.

When the filter's RC time constant is long enough, the voltage spikes disappear and the waveform is similar to pulsed DC. Figure 3-18 shows this graphically. The top trace has a small glitch, which is removed by the filter in the bottom trace. You can check the effectiveness of the LP filter using a fast dual-trace 'scope at the input and output. Its electrolytic filter capacitors may eventually dry out with age. One symptom of poor filtering action here is spurious FM of the carrier.

The Phase Detector

The last PLL element is the Phase Detector or Phase Comparator. It compares two inputs: one input is derived from a fixed-frequency crystal oscillator (usually 10.240 MHz) called the "Reference Oscillator" or the "Reference Divider." The other input comes from the VCO. (Actually indirectly from the VCO because a fourth stage, the Programmable Divider, is in series with it.) These two input frequencies are divided down and compared for similarity in the Phase Detector. Early PLL CBs used long strings of discrete divider ICs, while modern PLL chips contain these internally.

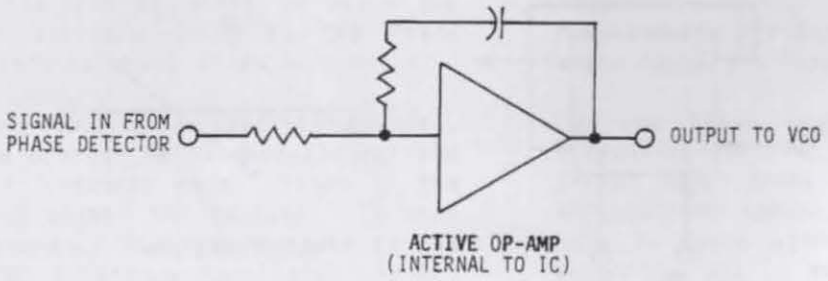
When both inputs are identical, the VCO frequency is locked to the reference frequency. If changes in temperature or supply voltage cause either frequency to change, the Phase Detector will sense it and send a DC correction voltage to the VCO. This correction voltage is proportional to the amount of frequency change and of the proper polarity to bring the loop back into its "locked" condition. Hence the name, Phase Locked Loop. This is similar to a mechanical servo system or any other feedback-controlled correction loop.

The Phase Detector is internal to the IC, and replacement is the only possible repair. The actual circuit is an edge-triggered RS flip-flop of the type shown in Figure 3-19. The circuit is reset once each cycle by the reference signal, and toggled once each cycle by the feedback signal from the VCO. (The SET line isn't used.) Also shown is the characteristic sawtooth output waveform as a function of the input phase difference. The output goes to an integrator (Low-Pass Filter), which provides the proper VCO varactor bias.

PLL Capture & Lock Conditions

Once the VCO begins to shift frequency, it's in the "capture" state. It stays this way until its output frequency is the same as its input.

FIGURE 3-17
LOW-PASS FILTERS



ACTIVE OP-AMP
(INTERNAL TO IC)

PASSIVE RC CIRCUIT

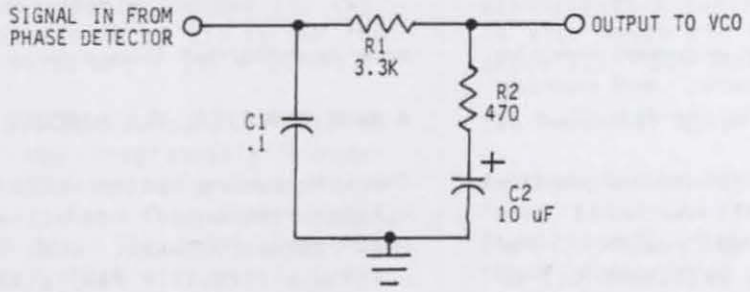
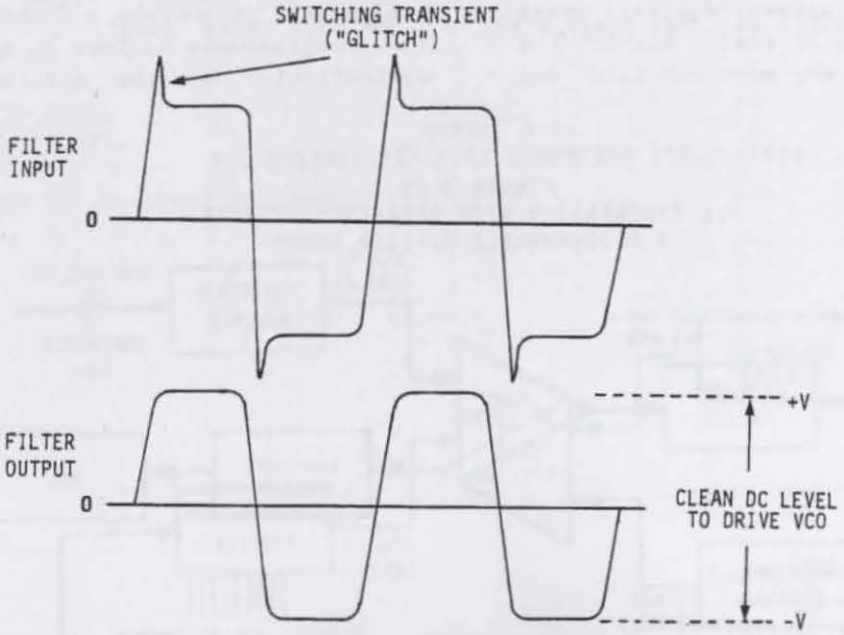


FIGURE 3-18
EFFECT OF PLL LOW-PASS FILTER

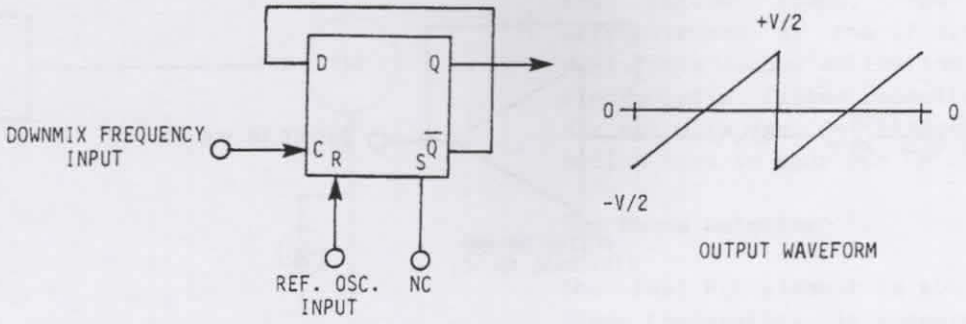


At that point it's locked. So the PLL has three possible operating conditions:

1. Free-running.
2. Capture.
3. Locked or "tracking."

Each PLL circuit has an associated capture range, which defines how far off frequency the error can be and still lock up. If the two frequencies are outside the capture range, the VCO will free-run at a frequency determined by the LC components in the oscillator circuit.

FIGURE 3-19
PHASE DETECTOR USING R-S FLIP-FLOP
(Courtesy Hayden Book Co.)



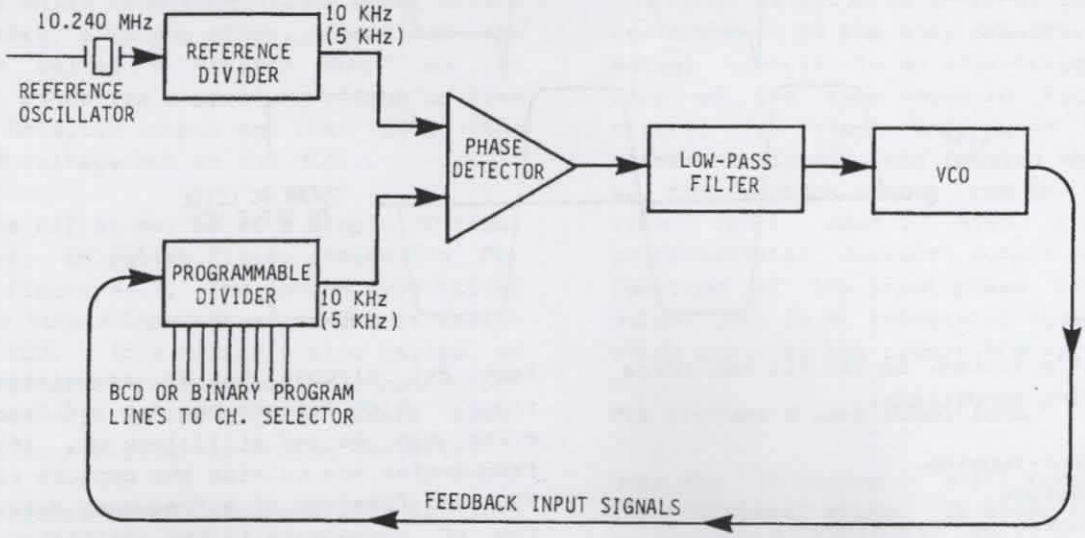
This out-of-lock condition is a common symptom in malfunctioning CB synthesizers, and usually indicates a problem external to the PLL IC.

When the error is within the capture range, the capture process begins and continues until the locked or tracking condition is reached. The actual lock-up time takes only milliseconds, as you've no doubt observed when switching CB channels. The frequency range over which the VCO can remain locked is much wider than the range actually needed for capture, similar to the AFC circuit in an FM stereo receiver. These ranges are determined by RC timing within the PLL, and help explain why some circuits are more broadbanded than others.

A MORE PRACTICAL PLL CIRCUIT

The preceeding system works quite well for a single frequency, but allows no way to change the frequency other than by changing the reference itself. For a 40-channel band of frequencies, it's not good enough. Figure 3-20 shows two more blocks added to the basic loop: a Reference Divider, and a Programmable Divider. The Reference Divider is internal in the modern IC and has a fixed division ratio. The Programmable Divider is also internal but controllable at the outside world by the

FIGURE 3-20
PLL SYNTHESIZER WITH REFERENCE DIVIDER
& PROGRAMMABLE DIVIDER ADDED



Channel Selector switch, which changes the division ratio as needed. It's the key to synthesizing many channels from one oscillator signal. The objective is still to match the output of both dividers going to the Phase Detector so there's no phase error to correct.

In addition to selecting a specific channel, the Programmable Divider helps down-convert the VCO signal to a frequency range closer to the divided reference signal for capture. In most PLLs the VCO frequency isn't even close to the normal 10.240 MHz Reference Oscillator signal. For example, if 10 KHz was the required Phase Detector comparison frequency, a Reference Oscillator frequency of 10.240 MHz divided by the number 1,024 produces a 10 KHz signal. If the signal to the Programmable Divider is, say, 1.35 MHz, then it must divide by 135 to get the same 10 KHz result. (1.35 MHz ÷ 135 = 10 KHz.)

When the Reference Divider outputs 10 KHz to the Phase Detector, the Programmable Divider must also output 10 KHz or an error voltage will be generated. For the Programmable Divider to output 10 KHz, its input from the VCO must be a frequency which will equal 10 KHz when divided by the currently-programmed divisor. If this divisor is, for example, the number "330," the input signal must have been 330 x 10 KHz = 3.30 MHz. A signal other than exactly 3.30 MHz would produce an error voltage. If the VCO signal were 3.10 MHz instead, the result would be 3.10 MHz ÷ 330 = 9.39393 MHz. This error would generate a correction voltage to drive the VCO higher in frequency again, until the input to the Programmable Divider reached 3.30 MHz, which would cause the loop to be locked once again.

For you heavy technical types, an excellent discussion of PLLs and related synthesizer design was found in the SIGNETICS ANALOG APPLICATIONS MANUAL. Signetics is now located only in Korea with the contact info on their Web site, and it may be worth a try. I saw a few still for sale from Amazon.com or else you should search the 'Net using Google, etc.

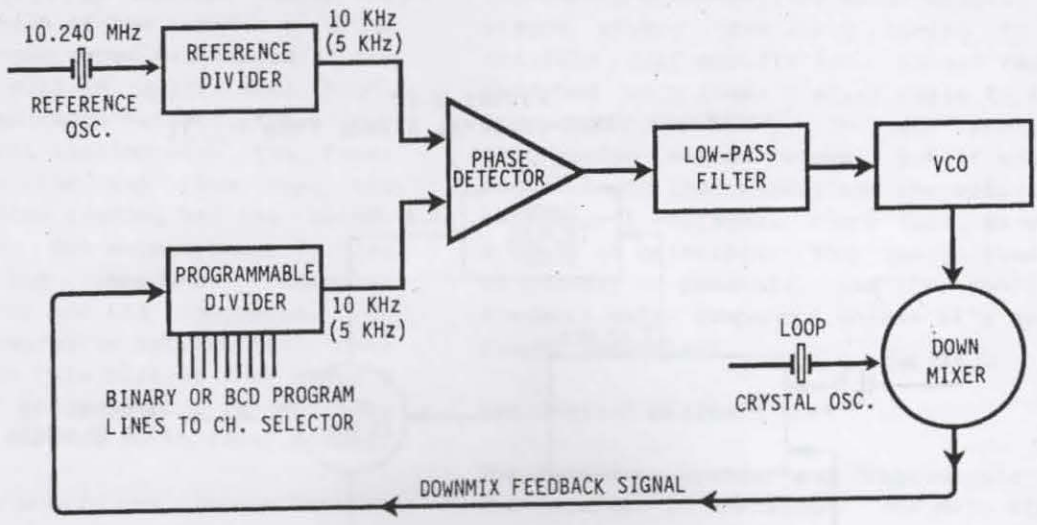
The SAMS book, DESIGN OF PHASE-LOCKED-LOOP CIRCUITS WITH EXPERIMENTS, by Howard M. Berlin is also worth checking. (ISBN #0-672-21545-4, about $15. See SAMS address in CHAPTER 1.)

The Downmixer Stage

Another common PLL synthesizer element is the "Loop Mixer," "Loop Oscillator," "Offset Oscillator," "Offset Mixer," "Down Mixer," "Down Converter," or "Down Oscillator." All mean the same thing when indicated on a schematic. Figure 3-21 below shows this stage added to the loop; note it's otherwise identical to the basic circuit of Figure 3-20.

This stage must be added to many PLL circuits

FIGURE 3-21
PLL SYNTHESIZER WITH DOWNMIXER STAGE ADDED



because the Programmable Divider isn't fast enough to directly divide the VCO signal, generally in the 16 MHz or 35 MHz range. Its purpose is to mix the VCO signal down to a lower frequency, usually under 4 MHz, which the PLL can handle. The result is the "downmix" signal, which goes to the Programmable Divider input. The newer AM-only or FM-only chips like the C5121, LC7130/31, LC7132, LC7136/37, SM5123A, SM5124A, or TC9106/9109/9119 are fast enough to divide a VCO up to 20 MHz directly, completely eliminating the Downmixer stage.

Sometimes included in the chip is an additional circuit which divides the 10.240 MHz reference frequency in half, to 5.120 MHz. This signal is available at one of the IC pins and is coupled to an external tripler coil to generate a 15.360 MHz signal used for loop downmixing. (5.120 MHz x 3 = 15.360 MHz.) See Figure 3-22. This saves the cost of an extra discrete oscillator which would otherwise be needed. Chips which have used this option include the LC7120, SM5107, µPD858, µPD861, µPD2810, µPD2812, µPD2814, µPD2816, and µPD2824.

Frequency Multiplication

Just as the Downmixer lowers a frequency, sometimes it's necessary to raise an oscillator frequency. The most common frequency multiplication for CB synthesizers is the doubler or tripler stage. Many VCOs run in the 34-37 MHz range to take advantage of high-side mixer injection. It's often cheaper and more convenient to take an existing crystal oscillator and sample part of its signal, rather than to add another discrete active stage at the higher frequency. Another reason is that the Delta Tune or Clarifier is connected to one of the crystal oscillators. Since it's difficult to pull a crystal very far off frequency, a multiplier stage automatically multiplies the frequency shift too. If a crystal can be pulled 1 KHz directly, a doubler or tripler would make the total shift 2 KHz or 3 KHz respectively.

Multiplier stages are always biased Class C, a condition that encourages distortion (i.e., harmonics) and greater efficiency. Generally speaking a doubler will be about 50% efficient, a tripler about 30%, etc. At first glance many commercial circuits appear to be Class A stages, since some forward bias may exist. A perfect example is the MB8719/8734 synthesizer (Page 83) whose tripler circuit is repeated in Figure 3-23. The TR23 tripler stage has about 1.45 V forward base bias, since R128 raises the emitter 1KΩ above ground. Regardless of this positive bias, the input signal is even higher and will drive it into Class C operation. (Class C power stages are directly grounded for DC; see CHAPTER 5.)

The reason for some forward bias is to make the stage easier to drive. Transistors sometimes need this; vacuum tubes rarely do, since their high input impedances discourage loading and power loss. The 11 MHz oscillator can still drive TR23 into the Class C region on RF voltage peaks. With transistor multipliers the harmonics result not only from the inherent Class C envelope distortion, but also from non-linearities in the transistor junction capacitance as the driving signal swings

FIGURE 3-22
DOWNMIXER USING INTERNAL SIGNAL FROM PLL IC

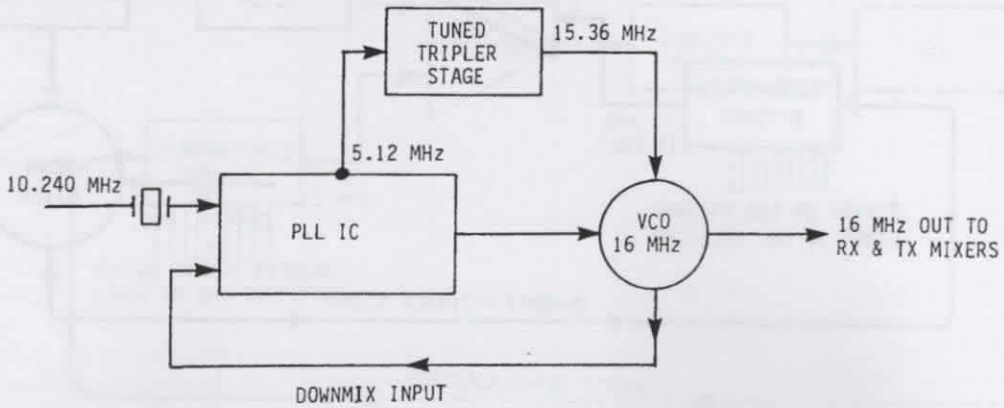
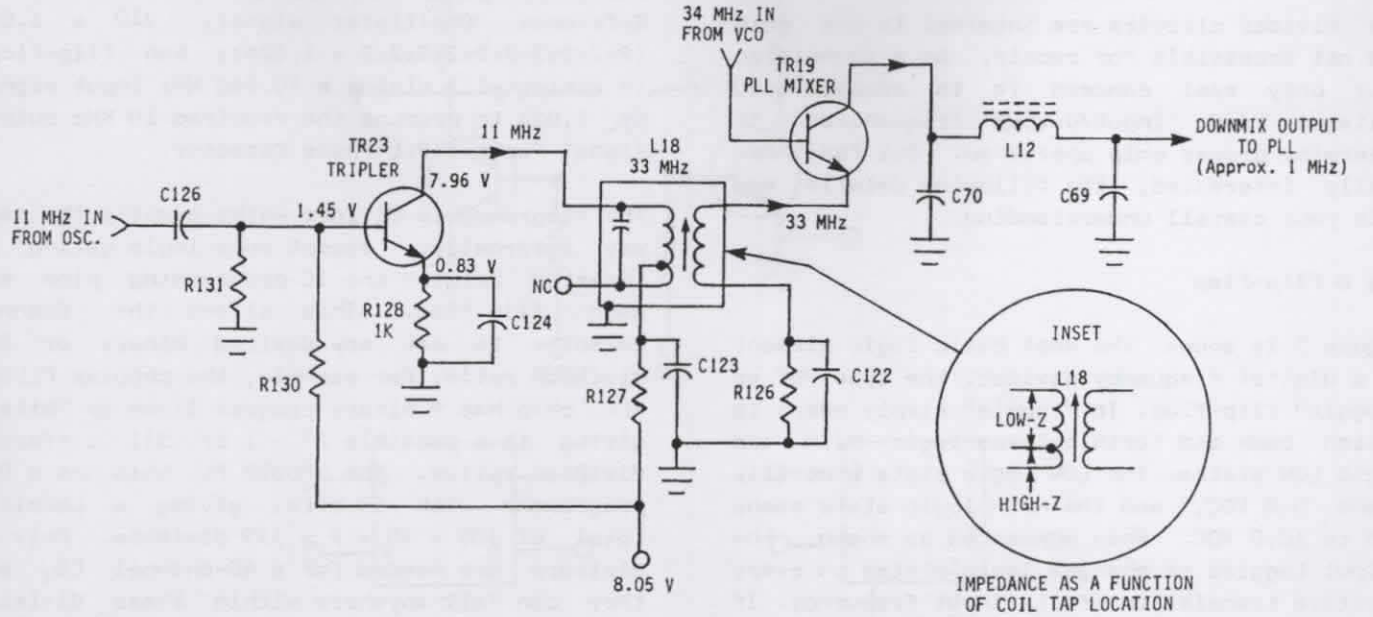


FIGURE 3-23
TUNED MULTIPLIER STAGE
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



through its amplitude and phase changes. Again, this doesn't happen with vacuum tubes. Besides the desired 3rd harmonic (33 MHz) which is peaked by L18, there will also be undesirable harmonics in the output. These are removed by the Pi section filter C70/L12/C69.

Controlling Coil Q & Coupling Impedances

Note L18 has a tapped primary with one end unconnected. This is very common in CB RF circuits. The position of the tap has a great effect on performance. When not tapped at the exact center the coil is split into high-impedance and low-impedance halves; the higher impedance is the coil section with the fewer turns. The further the tap from V_{CC}, the lighter the collector loading and the better the filtering action. But output power is also reduced because the impedance mismatch between the collector and L18 increases. The tap location is a compromise between efficiency and signal purity. In this circuit they chose a lower impedance for the collector to maximize gain; harmonics are cleaned up in later stages.

As a technician you should pay close attention to possible changes made to these tuned circuits by previous repairmen. Like the above example, many tapped RF transformers have an unconnected end. In modifying CBs for channel expansion and greater bandwidth, people sometimes cut the tapped foil trace and rejumper its circuit to the unused end. This has the effect of lowering its Q, since a bigger coil means lower impedance. But it also lowers the stage gain. This may or may not matter, depending upon the particular circuit.

You'll find hi-Z/low-Z coil splits used in the receiver and transmitter mixer stages; RF power stages always have low-Q tuning to prevent possible self-oscillation. Export radios are designed with lower Q mixer coils to cover the increased bandwidth. In some radios this rejumpering method works, but if stage gain seems lower than normal and the active device has correct voltages, check this. Never forget a basic CB principle: they design these things as cheaply as possible, and they don't include a single extra component unless it's needed for proper operation!

How Digital Dividers Work

The Reference Divider and Programmable Divider are similar in operation. The main difference is that the Reference Divider uses a fixed reference frequency, while the Programmable Divider works on a variable frequency that

changes with the division ratio set by the Channel Selector. The reference signal itself is generated either by a separate transistor oscillator, or by an internal chip oscillator needing just an external crystal to oscillate.

The divider circuits are internal to the chip and not accessible for repair. As a technician your only real concern is to measure IC voltages and input/output frequencies to determine proper chip operation. But for those really interested, the following details may help your overall understanding.

The D Flip-Flop

Figure 3-24 shows the most basic logic element of a digital frequency divider, the type "D" or "Toggle" flip-flop. To "toggle" simply means to switch back and forth between logic HIGH and logic LOW states. The LOW logic state generally means 0.0 VDC, and the HIGH logic state means 4.5 to 10.0 VDC. When connected as shown, the output toggles or changes logic states on every positive transistion of its input frequency. If the input frequency is a pure square wave (which it would be when the oscillator signal is properly shaped), then the output will also be a square wave whose frequency is exactly half that of the input frequency. Thus we can say that the D flip-flop is a $\div 2$ circuit.

By "cascading" or stringing a number of such flip-flops in series, division is possible by any power-of-2 factor. If the flip-flops are cascaded such that the output of one is used to trigger the input of the succeeding one, it's called a "ripple carry" or asynchronous divider. Input changes must ripple through the entire divider chain, a relatively slow process, to produce the divided-down output. Tying all inputs together in parallel so each flip-flop is driven from a single input and changes simultaneously creates a "synchronous" divider or counter. This is much faster and also eliminates the problem of glitches due to the propagation delays inherent in the asynchronous type of divider.

Using the previous example of the 10.240 MHz Reference Oscillator signal, $2^{10} = 1,024$ ($2x2x2x2x2x2x2x2x2x2 = 1,024$); ten flip-flops in series will divide a 10.240 MHz input signal by 1,024 to produce the required 10 KHz output signal for the PLL Phase Detector.

The Programmable Divider works exactly the same way internally, except some logic gating is inserted between the IC programming pins and each flip-flop. This allows the Channel Selector to set any desired binary or BCD division ratio. For example, the popular PLL02A PLL chip has 9 binary program lines or "bits," giving it a possible $2^9 - 1$ or 511 different division ratios. The µPD858 PLL chip has a BCD programmer with 10 bits, giving a possible total of 300 + 90 + 9 = 399 divisors. Only 40 divisors are needed for a 40-channel CB, and they can fall anywhere within these division ranges convenient for the circuit design.

The RS Flip-Flop

A refinement of the basic flip-flop allows more precise synchronization. Figure 3-25 shows the "RS" or Reset-Set flip-flop. The two inputs are called SET ("S") and RESET ("R"), and the outputs are called "Q" and "Q-NOT." (The bar or "NOT" mark over the Q is a special digital logic symbol meaning, "the opposite or complimentary logic state of whatever Q is.") Complimentary logic signals are always applied to the SET-RESET inputs. Thus a logic HIGH at R makes Q-NOT HIGH and Q LOW. The S signal will be LOW under this condition. When S switches HIGH, Q goes HIGH and Q-NOT goes LOW, and R will be LOW. The two transistor outputs literally flip-flop back and forth when square

FIGURE 3-24
TYPE "D" FLIP-FLOP

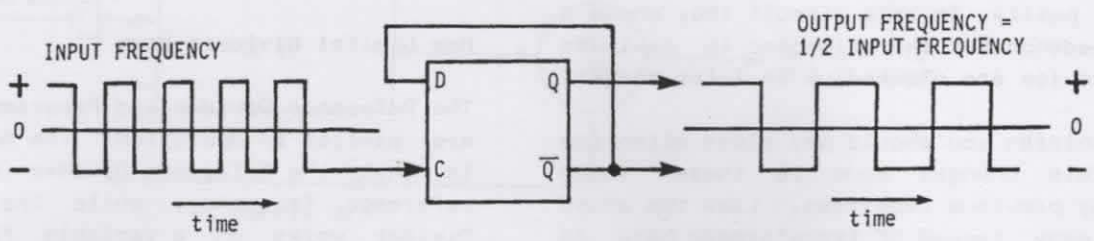
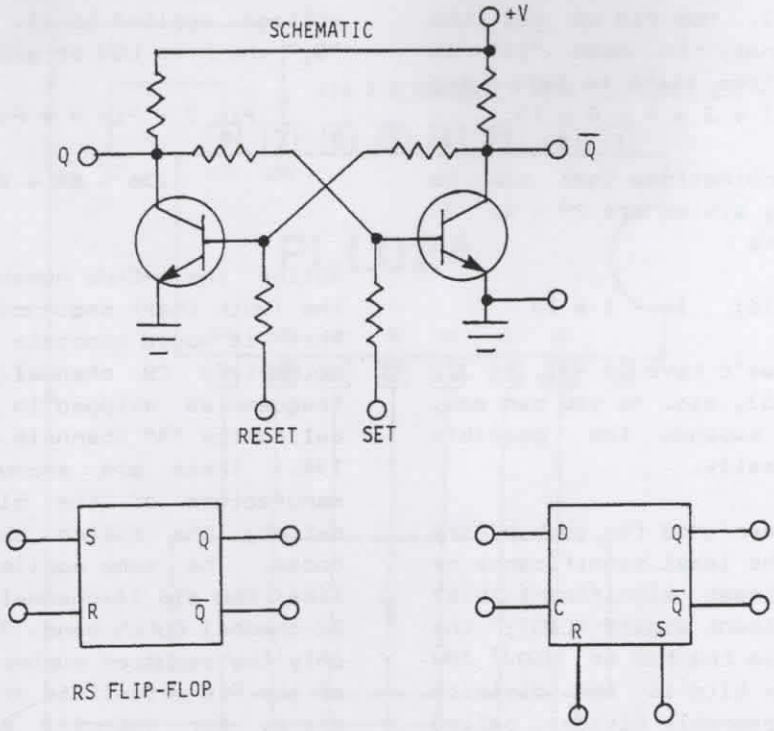


FIGURE 3-25
THE "RS" FLIP-FLOP



wave inputs are applied. You may recognize the schematic as a variation of the basic multivibrator circuit.

A simple flip-flop is not synchronized to any particular signal. By adding CLOCK ("C") and DATA ("D") inputs to the basic RS flip-flop, a more sophisticated "D" flip-flop is created. This allows inputs and outputs to be clocked or synchronized at a desired rate. Each positive logic change at C toggles the circuit, making it a convenient frequency divider.

If the D flip-flop is wired as shown earlier in Figure 3-19, the CLOCK input becomes a voltage sampling input, in this case one input of the Phase Detector. The other Phase Detector input is the RESET line. (The SET line isn't used.) Thus we get a device capable of sampling at a digital rate. Its switching operation is called "edge-triggered" because the transition of the leading edge of a square wave from logic LOW to logic HIGH triggers the output logic change.

Binary Programmable Dividers

Since ÷2 flip-flops are the heart of digital synthesizers, the binary type of numbering system (Base 2) is used rather than the decimal system (Base 10) used by people. That's because electronic switches have at least two useful conditions, "ON" and "OFF." In a binary number system only two conditions are needed to represent a decimal number. These conditions are called "HIGH" and "LOW," "ON" and "OFF," or "1" and "0," and represent two different voltage or logic levels. In CBs the LOW logic state is usually close to 0.0 volts, and the HIGH state varies from about 4.5-10.0 VDC, since PLL ICs are all CMOS devices.

Binary numbers are written like decimal numbers, except only combinations of 1s and 0s are used. The most significant digit is on the left, and the least significant digit on the right. Each digit or "bit" (binary digit) of a binary number has a weight or value twice that of the bit to its immediate right. Compare this to the human decimal system, where each digit

has ten times more weight than the digit to its right. (Hundreds, Tens, Ones, etc.) So if four bits are available, you can represent all decimal numbers from "0" ("0000" in binary) to "15" ("1111" in binary). How did we get the number "1111" in binary to mean "15" in decimal? By reading from right to left and adding up each weight: 1 + 2 + 4 + 8 = 15.

The total possible combinations that can be represented in a binary system are $2^n - 1$. So in a 4-bit system we have

$$2 \times 2 \times 2 \times 2 = 16; \quad 16 - 1 = 15$$

By adding a fifth bit, we'd have $2^5 - 1$, or 31. With $2^6 - 1$, we'd have 63, etc. As you can see, each additional bit expands the possible combinations logarithmically.

The PLL IC has one pin assigned for each binary weight. The pin with the least significance or weight is called the "least significant bit" (LSB) or "least significant digit" (LSD); the heaviest weighted bit is the MSB or MSD. The sum of all HIGH binary bits is the division ratio of the PLL's Programmable Divider, called the "N-Code" or "÷N" number. A chart listing the binary logic states of each pin, by CB channel number, is called a "Truth Chart." Shown below is part of the actual Truth Chart from the PLL02A late-generation AM circuit.

The chart shows the N-Code number for CB Ch.1 is "330." How was this number derived? Simple! Just add up the binary weight of each IC pin with a logic HIGH state of "1," meaning it has voltage applied to it. Ignore any pin with a "0," which is LOW or grounded. Thus,

Pin 7 + Pin 9 + Pin 12 + Pin 14, or

256 + 64 + 8 + 2 = 330

Notice the N-Code number "327" was skipped in the Truth Chart sequence, because the frequency that it would generate (26.995 MHz) isn't an authorized CB channel. There are five such frequencies skipped in the FCC band, commonly called the "A" channels. (3A, 7A, 11A, 15A, 19A.) These are accounted for during the manufacture of the binary Channel Selector switch; the switch skips the non-CB binary codes. The same applies to other CB services like the old 18-channel Australian band or the 22-channel Dutch band. The Channel Selector has only the required number of positions; the rest of the PLL circuit is otherwise identical. This means, for example, many of the 18-channel Australian CBs can be changed to 40-channel versions simply by replacing the Channel Selector switch and connecting all the correct binary programming pins that would normally be connected for the 40-channel versions.

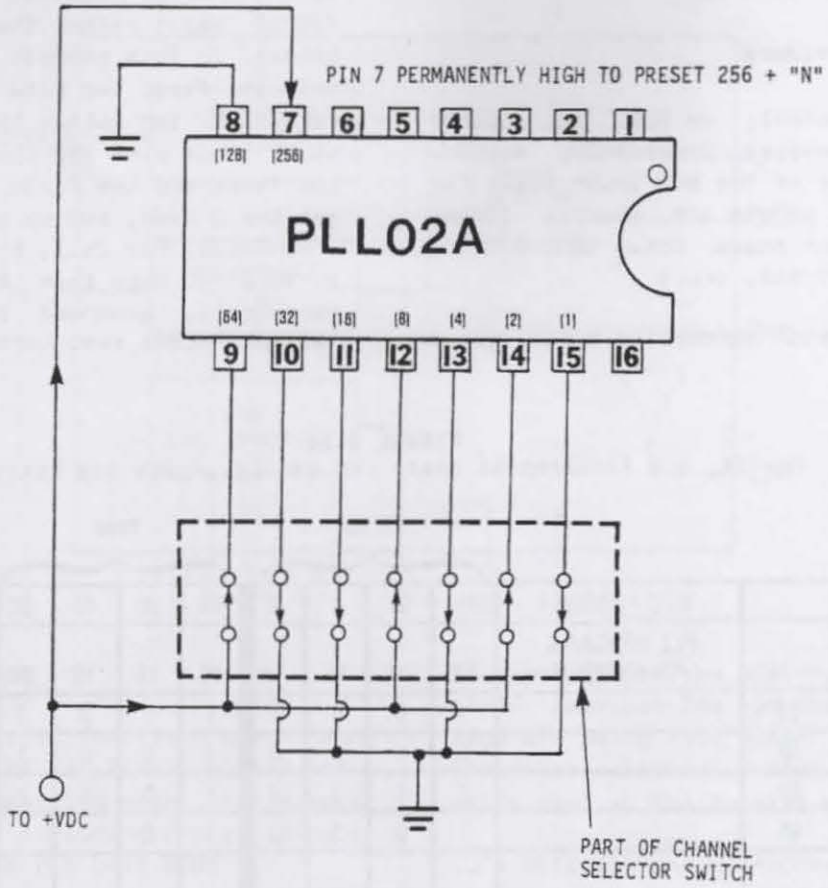
BINARY POWERS-OF-2:			(256)	(128)	(64)	(32)	(16)	(8)	(4)	(2)	(1)
			IC PROGRAM PINS								
			7	8	9	10	11	12	13	14	15
CH.#	(FREQ. MHz)	N-CODE									
1	26.965	330	1	0	1	0	0	1	0	1	0
2	26.975	329	1	0	1	0	0	1	0	0	1
3	26.985	328	1	0	1	0	0	1	0	0	0
4	27.005	326	1	0	1	0	0	0	1	1	0

Generating The Program Codes

Figure 3-26 shows the actual voltage switching which occurs in the previous example of the PLL02A binary PLL chip. It shows the number "330" being generated by forcing pins 7, 9, 12, and 14 to logic HIGH while pulling the other program pins LOW. The chips generally have internal pull-up or pull-down resistors on every pin that's programmable. In a few cases, like some early Uniden µPD858 SSB radios, external resistor packs were needed because the chip didn't have internal resistors.

The Channel Selector is a multi-layered detent wafer switch capable of producing 40 different binary or BCD N-Codes. The non-CB channel positions are skipped entirely. In some CB services like that of Great Britain having 40 consecutive channels, the switch will also be arranged consecutively with no skips.

FIGURE 3-26
GENERATING THE BINARY N-CODE THROUGH SWITCHED VOLTAGES & GROUNDS



N = 256's BIT + 64's BIT + 8's BIT + 2's BIT = "330" FOR CH.1

FIGURE 3-27
INTERNAL FUNCTIONS OF PLL02A PLL IC

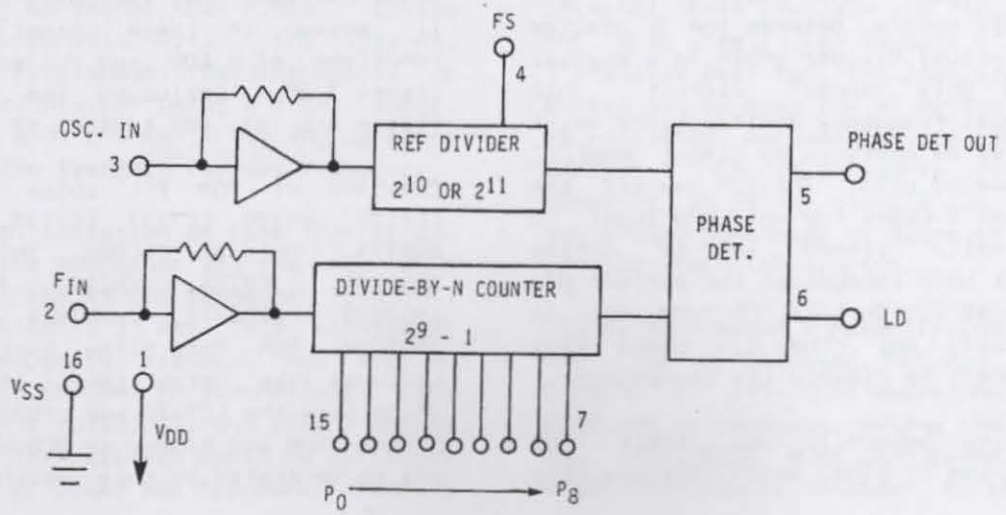


Figure 3-27 shows a block diagram of the PLL02A synthesizer we've been discussing. It shows how the main PLL elements of Reference Divider, Programmable Divider, and Phase Detector are all contained in one IC chip.

BCD Programmable Dividers

The Binary Coded Decimal, or BCD, is another common PLL synthesizer programming method. Figure 3-28 is part of the BCD Truth Chart for the popular Uniden µPD858 SSB chassis (Cobra 138/139XLR, President Adams, Robyn SB510D/520D, Realistic TRC449/457/458, etc.)

In the BCD system, each successive 4-bit group has a weight ten times greater than the group to its left. (Our chart is reversed though.) In each group the usual binary doubling occurs; the highest possible number in any 4-bit group is "9" or its decimal multiple ("9," "90," "900," etc.) rather than the "15" possible in binary. In this example the Hundreds group has only the first two bits because the chip has a total of ten rather than twelve programming pins: four pins for the Ones group, four for the Tens, and the first two of the Hundreds. To get the N-Code, add up each group: Ones + Tens + Hundreds. For Ch.1, this is 1 + (10 + 80) = 1 + 90 = 91. Note that Pin 22 (200's group) is permanently grounded (logic "0"), since the largest N-Code ever needed is "135" for Ch.40.

FIGURE 3-28
PARTIAL BCD PROGRAMMING CHART FOR UNIDEN µPD858 SSB CHASSIS

			Ones				Tens				Hundreds	
		BCD POWERS	1	2	4	8	10	20	40	80	100	200
	÷ N	PLL PROGRAM PIN NUMBER	13	14	15	16	17	18	19	20	21	22
Ch. 1	91		1	0	0	0	1	0	0	1	0	0
Ch. 2	92		0	1	0	0	1	0	0	1	0	0
Ch. 3	93		1	1	0	0	1	0	0	1	0	0
Ch. 4	95		1	0	1	0	1	0	0	1	0	0
⋮	⋮											
Ch. 40	135		1	0	1	0	1	1	0	0	1	0

NOTE: Pin 22 permanently grounded to chassis ("0") for all 40 channels.

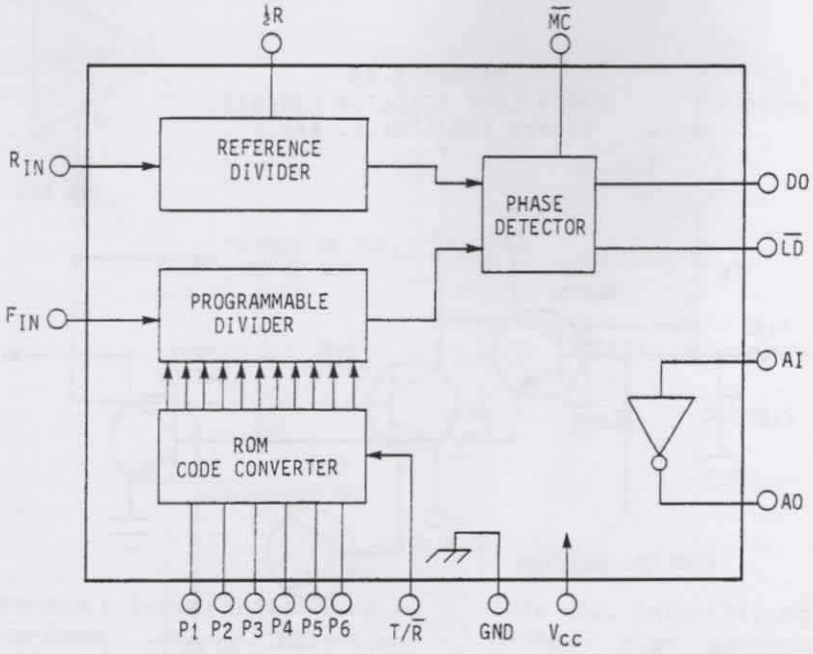
ROM Programming

A third type of synthesizer programming is used in all the new AM-only American radios, the newer AM/SSB types, and most British and European FM-only models. Between the IC program pins and the actual divider chain is a special ROM or "Read Only Memory" circuit. This prevents illegal frequency modifications which would otherwise be possible by direct control of the programming pins. The ROM has all the required channel N-Codes for only the legal CB band permanently stored in it during manufacture. It only recognizes the correct pin codes for Ch.1-40 (or Ch.1-18, Ch.1-22, etc. in other countries); any other pin codes will either be ignored, or disable the transmitter.

The ROM chips generally use 6-bit BCD programming at the IC pins, since only six bits are needed to represent the 40 channel numbers "0" to "39" in BCD. The TC9106/09/19 and LC7132 purposely use a special random 8-bit code to prevent guessing the numerical programming sequence. (Not that you could do anything about it anyway in these chips!) The internal functions of a ROM type PLL are summarized in Figure 3-29, including the active Low-Pass filter amp (AI, AO) typical of the newer chips.

Examples of ROM PLL chips are the C5121, LC7120, LC7130, LC7131, LC7132, LC7136, LC7137, MB8733, PLL03A, PLL08A, SM5123A, SM5124A, SM5125B, TC9106, TC9109, TC9119, µPD861, µPD2810, µPD2812, µPD2814, µPD2816, and µPD2824. ROM does allow certain convenience features like instant recall of Ch. 9 or Ch.19. Chips like the LC7120 and µPD861 are switchable between ROM and binary or BCD programming; one pin is dedicated to this option.

FIGURE 3-29
INTERNAL FUNCTIONS OF ROM TYPE PLL IC



Additional PLL Functions

There are several other IC functions which can add to the flexibility of PLL synthesizers. These are briefly summarized next. For a more complete discussion, including the IC pinout information, see **THE CB PLL DATA BOOK.**

T/R SHIFT PIN: This allows a 455 KHz IF offset for dual-conversion AM (or FM) receivers; SSB models don't use this function even if present. This pin is connected to the Transmit keyline and senses the logic voltage change from Receive to Transmit. In addition the PLL chip uses 5 KHz rather than 10 KHz Phase Detector input frequencies. (It divides the 10.240 MHz reference by 2,048 rather than 1,024.) During the Receive-to-Transmit switch, the internal counter in the Programmable Divider shifts up by exactly 91 counts. By using a 5 KHz input, this results in a 91 x 5 KHz = 455 KHz up-shift of the VCO for the transmit carrier frequency.

One U.S. and U.K. variation on the T/R offset method shifts the ROM count and the VCO down about 3 KHz to the 13 MHz range on Transmit, where it's doubled to 27 MHz. This eliminates the need for separate Transmit and Receive VCOs. The method is used in synthesizers with the TC9109/MB8733, LC7136/37, and LC7132 chips. A direct 27 MHz Transmit VCO would be difficult to shield from RF power amp feedback, causing spurious FM of the VCO. Originally only a few early American CBs had them; the SM5124A PLL rigs are using them again. They require complex inductive switching, because the VCO must now shift down in the Receive mode by 10.695 MHz.

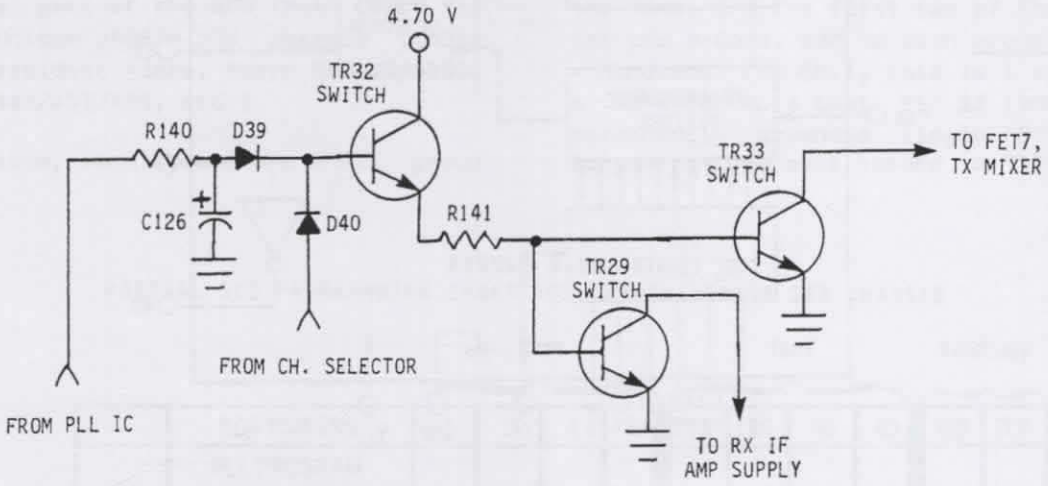
LOCK DETECTOR and MISPROGRAM CODE PINS: When the MC pin is present and connected, incorrect program codes on the IC pins will be sensed. This might be caused by modification attempts or by a faulty Channel Selector. The MC pin will switch logic states, triggering a kill circuit that turns off the transmitter.

The LD pin can be activated by any fault that causes the loop to unlock, which includes both internal chip problems and faults external to the chip itself. For example if the Downmixer transistor were bad, the loop would unlock and switch the LD pin; the MC wouldn't necessarily be activated, because the programming itself is correct. This is a subtle difference. It's possible in either circuit for an associated switching transistor or diode to short, causing the "No Transmit" symptom.

Figure 3-30 shows a normally-LOW LD circuit. If the loop is unlocked, PLL Pin 1 goes HIGH, turning on D39. This makes the base of TR32 HIGH and it conducts, making the bases of TR29 and TR33 HIGH. When TR33 turns on, it pulls down the supply voltage to the transmitter

Mixer. TR29 "ON" shunts a different supply to ground and kills one IF amplifier. D40 "ON" does the same thing; this is connected to the Channel Selector switch. The switch is designed so any in-between channel positions will also output a voltage that triggers the Transmit Inhibit circuit. The majority of 40-channel switches work this way.

FIGURE 3-30
EARLY LOCK DETECTOR CIRCUIT
(Cobra 138/139XLR, etc.)



The preceeding LD is typical of older circuits, where designers spared no expense in the number of components used. Figure 3-31 shows a more current and cheaper T/R inhibit circuit, this one normally-HIGH. When LD Pin 4 goes LOW, it turns on D13 and grounds out the bias of IF amp TR3 in the receiver. It also removes the base bias on TR12, turning it off and pulling its collector HIGH via R95. This raises the emitter of transmitter preamp TR13, turning it off too. Most LD circuits kill both Transmit and Receive. (The MB8719/MB8734 LD circuit is also described later in this chapter.)

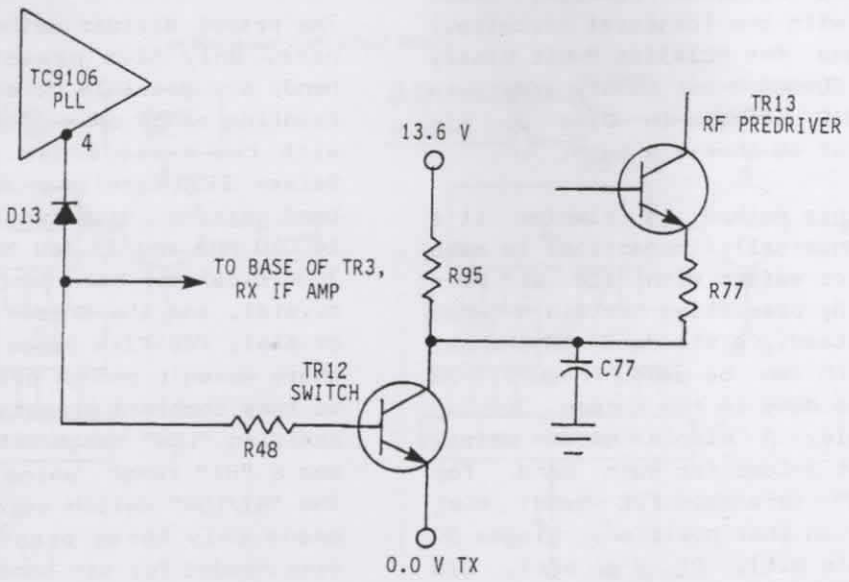
FREQUENCY SELECT: Many PLL chips are designed with great flexibility beyond just CB use. The IC sometimes has an "FS" or "Frequency Select" pin which changes all the Programmable Divider division ratios by the same amount. The most common option is 5 KHz/10 KHz increments. The logic state of this pin must be correct for the circuit design or the radio won't work! For example, a standard 10 KHz CB synthesizer can't be changed to a 5 KHz channel synthesizer, because the Channel Selector that programs it must <u>also</u> be capable of dividing into 5 KHz segments. And that could only happen by <u>doubling</u> the existing N-Codes.

You may get some repairs where this was tried; check the voltage on the FS pin to verify. Examples of chips having this option are the SM5104/MC145104, PLL02A, and MC145106. (The whole Motorola PLL family in general.) These chips have many other non-CB synthesizer uses, such as in aircraft and marine VHF radios, RF and audio signal generators, scanners, etc.

PRESETTABLE DIVIDER: IC pins may also preset a fixed N-Code, which is added to the sum of the other program pins. In the earlier example using the PLL02A, the Ch.1 N-Code was 330. However a look at that full Truth Chart would show that Pins 7 and 8 <u>never</u> change for the full 40 channels. With Pin 7 (256's bit) permanently HIGH and Pin 8 (128's bit) permanently grounded (LOW) for all 40 channels, the N-Code was <u>preset</u> for 256 + the binary sum of whatever is HIGH on Pins 9-15. The preset was therefore 256 + (64 + 8 + 2), which gave the binary total of 330.

This preset divider arrangement is very common in the older chips. Sometimes the preset pin has just two possible options. The best example is the MB8719. Pin 10 is a preset pin, either 64 + N when HIGH, or 128 + N when LOW. "N" is the binary sum of Pins 11-16.

FIGURE 3-31
SIMPLIFIED LOCK DETECTOR
(Cobra 19LTD, President Veep, etc.)



UP/DOWN CHANNEL CONTROL: Some radios have a remote control for UP/DOWN channel selection from the mike or front panel. The mike may also have remote VOLUME and SQUELCH controls. (Eg., Cobra 31+, 33+, Fuzzbuster Z-50, Z-80, HyGain 2679A, 2710X, 2716, Midland 77-149, President AX-11, Realistic TRC419, TRC423, TRC462, Uniden PRO-330E. You can step up or down from the current channel, either one at a time or continuously by holding in the step button.

In the older circuits this consisted of a Scan IC and clock generator, and some logic gating tied directly to the PLL programming lines. The scan was programmed by external PROM ICs or completely in ROM within the scan IC. Pushing the "UP" or "DOWN" button outputs the correct binary or BCD codes in a continuous sequence. This results in channel frequencies that step consecutively. A second Decoder/Driver IC will be paralled across the scanning IC output to generate the correct LED channel display.

The SM5123A PLL chip (Cobra 18+, 21+, 25+, 29+) and the C5121 PLL chip (Midland 77-155, Regency Info-CB1, Info-CB2, etc.) each contain internal UP/DOWN scan generators as well as all the other IC functions we've seen. Individual ROM program lines are no longer even needed, since one or two IC pins can control the scan; the expensive Channel Selector switch can now be completely eliminated if so desired.

Problems in this circuit include:

1. No scan.
2. Scans but LED channel display is wrong or missing.
3. No scan and no LED display.

With symptom #3, the Scan IC (or the SM5123A or C5121 PLL) is the obvious suspect. When it won't scan but the display is otherwise correct, check the PLL program lines against the Truth Chart for the correct logic changes, working backwards towards the Scan IC output lines until they're lost; the IC is the most obvious suspect. When the scan's OK but the display is dead or wrong, suspect the LED Decoder/Driver IC in radios that use them.

EXPANDED COVERAGE SYNTHESIZERS

The current popularity of expanded coverage export models requires that you understand their synthesizers too. Such knowledge also suggests how to expand other radios by using the same methods. Following are examples of the most common expansion techniques and some broadbanding hints for the standard models.

Method #1: The Preset Divider

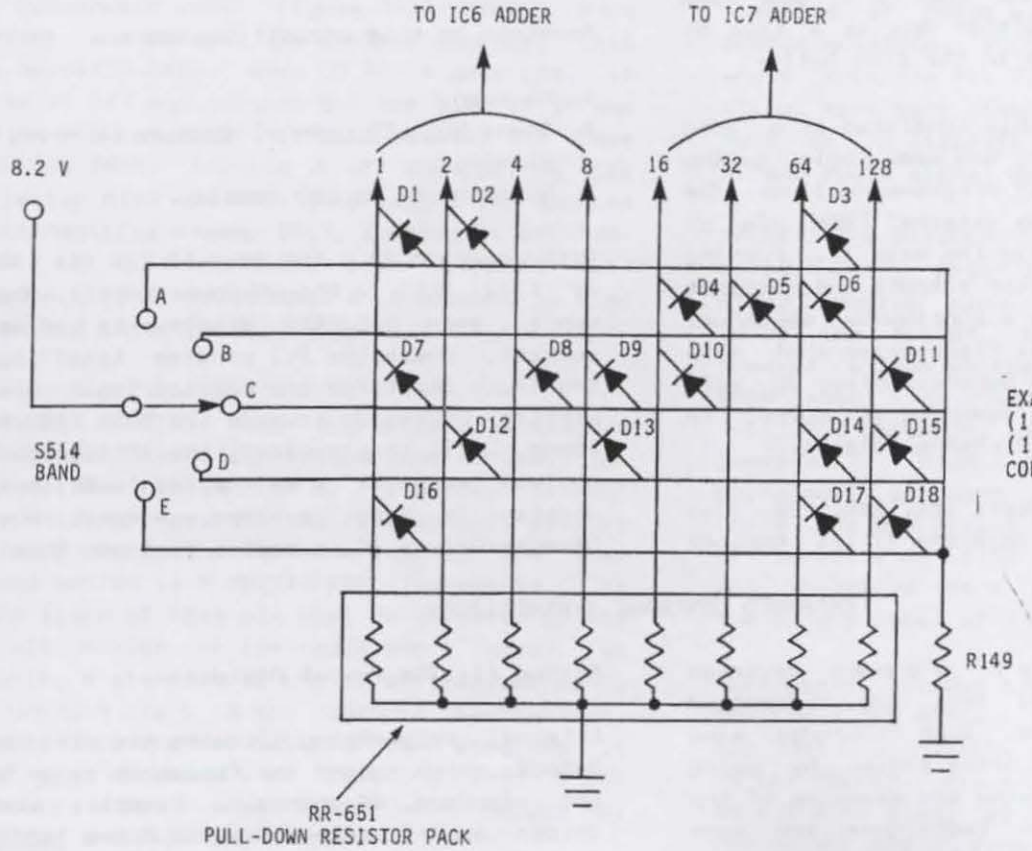
External programming circuits may also preset N-Codes which expand the frequency range beyond the standard 40 channels. Examples are the Uniden export radios like the Cobra 148GTL-DX, Superstar 360FM, Stalker 9-FDX, President Grant

or Jackson. (Also the Superstar 3600, 3900, Galaxy 2100, Super Galaxy, Excalibur Samurai, Excalibur base, and President Franklin; these are Uniden clones with the identical circuits.) The PLL circuit uses the MC145106 9-bit binary PLL and a pair of CD4008 4-bit binary adders to produce up to 240 channels in five or six consecutive bands of 40 channels each.

The reason for this method is simple: it's physically and economically impractical to make a Channel Selector switch with 120 or more positions on it. By presetting certain N-Codes for each band instead, a standard 40-channel binary wafer switch can be used. Figure 3-32 shows how this is done in the Uniden Jackson and similar models. A simple diode matrix controls the preset N-Code for each band. For example, Band "C" (standard FCC band) must preset "157" + N; in that position, diodes D7 (1's bit), D8 (4's bit), D9 (8's bit), D10 (16's bit), and D11 (128's bit) will conduct to result in (1 + 4 + 8 + 16 + 128) = 157.

The preset divider method does have its limits here. Only five presets and therefore five bands are possible before exceeding the binary counting range of a standard 40-channel switch with two 4-bit adder chips. That's why the Galaxy 2100/Excalibur Samurai chassis, a six-band version, uses <u>two</u> loop mixing crystals of 14.010 MHz and 15.360 MHz, where the Superstar 3900/Excalibur base just needed the 14.460 MHz crystal, and the Uniden Jackson the 14.550 MHz crystal, for five bands. Beyond the fifth band there weren't enough preset possibilities left, so they combined presets and crystals: a three-position "LOW" range with a 14.010 MHz crystal, and a "HI" range using a 15.360 MHz crystal. The "HI/LOW" switch selects the crystal, which means only three presets (LOW, MID, HI) are ever needed for six bands. See Figure 3-33A.

FIGURE 3-32
DIODE MATRIX FOR PRESETTING N-CODES
(Uniden Jackson)



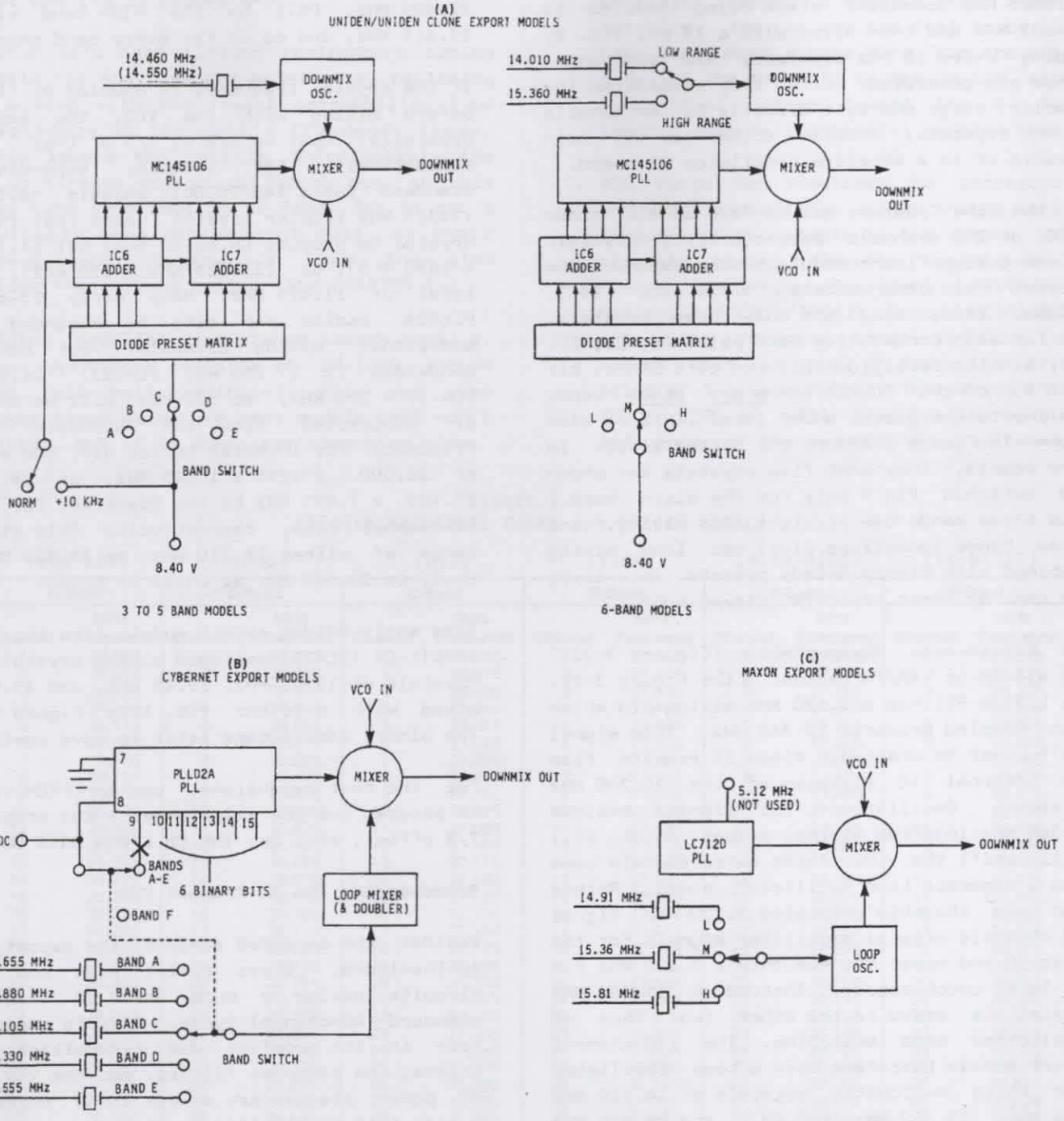
BAND PRESETS:

BAND "A" = 67 + N
BAND "B" = 112 + N
BAND "C" = 157 + N
BAND "D" = 202 + N
BAND "E" = 247 + N

EXAMPLE: FOR BAND "C", DIODES D7 (1's), D8 (4's), D9 (8's), D10 (16's), AND D11 (128's) ARE CONDUCTING. THE RESULT IS:

1 + 4 + 8 + 16 +128 = 157

FIGURE 3-33
EXPANDED COVERAGE METHODS



Method #2: The Switchable Downmixer

The other export expansion method changes the Downmixer injection signal. By replacing the fixed Downmixer signal with one that's higher or lower, extra 40-channel bands are produced. Since this signal is derived from a crystal oscillator it's a simple matter of switching crystals. When this signal is changed it drives the VCO up or down, generating new mixing frequencies for the transmitter Mixer and 1st receiver Mixer stages. This method is commonly found in all the Cybernet export models, many of the Korean Maxon chassis, and a few very early Uniden export models. Each manufacturer uses minor variations on this principle to get the same result.

The Cybernet export models (Figure 3-33B) are basically American chassis with extra loop mixing crystals added. The U.S. version has a 10.0525 MHz Downmixer stage being doubled to 20.105 MHz and then mixed with a 17 MHz VCO. By adding extra 10 MHz crystals, new 40-channel bands are generated. Later they eliminated the doubler stage and went directly to switchable 20 MHz crystals, located either on the main chassis or on a separate oscillator PC board.

By the time Cybernet got to five or six bands (200 or 240 channels respectively), crystals became a significant manufacturing expense. The current six-band models (Lafayette 2400, Palomar 2400, etc.) use only three crystals, one for each consecutive band pair: AB, CD, EF. They simultaneously control the 64's binary bit (Pin 9) of the PLL02A on <u>every other</u> band, similar to the preset adder idea. (This is also shown in Figure 3-33B by the dotted lines. In some models, they kept five crystals as shown and switched Pin 9 only for the sixth band.) Thus three bands use straight loop mixing, and three bands (sometimes five) use loop mixing combined with binary N-Code presets. This saves the cost of three crystals. Clever huh?

The Korean-made Maxon chassis (Figure 3-33C) are all AM or AM/FM radios. Like Figure 3-22, the LC7120 PLL has a 5.120 MHz mixing pin which when tripled produces 15.360 MHz. This signal can't ever be changed, since it results from the internal IC division of the 10.240 MHz Reference Oscillator. But signals besides 15.360 MHz injected at the proper point will still shift the VCO. These extra signals come from a separate Loop Oscillator board. Rather than use the chip's tripled 5.120 MHz signal <u>and</u> separate crystal oscillator signals for the lower 40 and upper 40, the chip's 5.120 MHz pin is left unconnected. Instead a 15.360 MHz crystal is added to the other two. Thus no complicated band switching. The 120-channel export models therefore have a Loop Oscillator with three switchable crystals of 14.910 MHz (LOW 40), 15.360 MHz (FCC 40), and 15.810 MHz (HIGH 40). Many American PLL circuits use the 15.360 MHz loop mixer, meaning this expansion principle can be applied to any of them too.

Notice successive loop crystals are 450 KHz higher or lower than the standard FCC band when mixed directly with the VCO. That's because a standard 40-channel CB band is 440 KHz wide. (27.405 MHz - 26.965 MHz = 440 KHz.) Except for the five skips, the channels are 10 KHz apart. By adding 10 KHz to the 440 KHz bandwidth, the frequencies will be continuous when changing bands. For example, if Ch.40 on the MID band is 27.405 MHz, Ch.1 on the HIGH band will be 27.415 MHz, and so on for every band change.

If the crystal frequency is doubled or tripled before mixing with the VCO, the expansion crystal(s) must be 1/2 or 1/3 of that 450 KHz respectively. For example, expanding the standard Cobra 148/2000GTL chassis having an 11.325 MHz tripler crystal means that the next crystal to produce Ch.41-80 must be: 11.325 MHz + (450 ÷ 3), or (11.325 MHz + 150 KHz), for a total of 11.475 MHz. Many early 23-channel PLL02A radios can also be expanded with additional mixing crystals, but now the bandwidth is 27.255 MHz (Ch.23) - 26.965 MHz (Ch.1) = 290 KHz, so 300 KHz will be added to or subtracted from the standard mixing frequency. For 10-Meter Novice use, add a <u>total</u> of 28.500 - 27.255 = 1.245 MHz, or 28.500 - 27.405 = 1.095 MHz to the Downmixer for 23- or 40-channel rigs, respectively. This gives a range of either 28.210 MHz or 28.060 MHz at Ch.1, to 28.500 MHz at Ch.23 or Ch.40.

Some early Uniden export models like the Cobra 148GTL-DX (PC879) switched mixing crystals too. Crystals of 15.00 MHz, 15.45 MHz, and 15.90 MHz mixed with a 16 MHz VCO, like Figure 3-33C. The binary adders came later to save costs.

For the best expansions, use an EPROM circuit to program out the skips, get 5 KHz steps or a T/R offset, etc. See **THE CB EPROM DATA BOOK.**

Broadbanding The 40-Channel CBs

Besides the expanded range of the export model synthesizers, these radios also use tuned circuits having a much lower Q than the standard 40-channel types. This is especially true in the receiver and transmitter mixer stages, the bandpass filters, and the VCO. (The RF power stages are always low-Q anyway to avoid self-oscillation.) Since people will always attempt endless modifications to expand the standard CBs, the following techniques may prove helpful in broadbanding such equipment.

1. One of the simplest ways to broadband tuned circuits is to increase the coupling between them. Most bandpass and mixer circuits are interconnected by a very small (2-5 pF) series coupling capacitor. Try increasing this capacitor from perhaps 10-100 pF. Don't

get carried away with excess coupling or the gain may drop too much. Examples: C47 and C48 in Figure 4-14, C163 in Figure 6-33, and C62 and C63 in Figure 6-31.

2. Since it's hard finding replacement tuning coils for the export models, try replacing the slug with the lowest permeability type available in the coil's frequency range. This lowers the coil Q. Unfortunately the slug threads may be different too, so this may take some hunting to find. Try to get a suitable Toko replacement coil, or their low-Q slugs. Or try S.J. Tonks; they also stock these low-Q coils. (See CHAPTER 1.)

3. Adding parallel resistance lowers coil Q. Try shunting a resistor of 1K-10KΩ across the full coil winding(s). This may also lower stage gain. In many models that won't matter, but if it does, try something else.

4. Many modern CBs have an unused coil connection at one end of the primary and/or secondary winding. Instead the winding is partially tapped to control the impedance matching. You can cut the foil trace to the tap and jumper a bare wire from the circuit side of the tap foil to the unused winding connection, which lowers the Q. Again, lowered gain is a potential problem here.

5. VCO range may sometimes be increased by changing capacitance values in the varactor circuit. For example in the newer Uniden circuits having discrete transistor VCOs (Cobra 146GTL, President AR144/AX144, Realistic TRC451/TRC453, Uniden PC244/PC122, etc.) the varactor anode is usually in series with about 47 pF from the driving point of the loop filter. Increasing this to about .001 µF will greatly increase the influence of the varactor's capacitance and

FIGURE 3-34
FREQUENCY/CHANNEL CHART FOR EXPORT MODELS

(LOW-LOW)		(LOW)		(MID)		(HIGH)		(HIGH-HIGH)		(10 METER)	
A-Band		B-Band		C-Band		D-Band		E-Band		F-Band	
Channel	MHz Frequency	Channel	MHz Frequency	Channel	MHz Frequency	Channel	MHz Frequency	Channel	MHz Frequency	Channel	MHz Frequency
1	26,065	1	26,515	1	26,965	1	27,415	1	27,865	1	28,315
2	26,075	2	26,525	2	26,975	2	27,425	2	27,875	2	28,325
3	26,085	3	26,535	3	26,985	3	27,435	3	27,885	3	28,335
4	26,105	4	26,555	4	27,005	4	27,455	4	27,905	4	28,355
5	26,115	5	26,565	5	27,015	5	27,465	5	27,915	5	28,365
6	26,125	6	26,575	6	27,025	6	27,475	6	27,925	6	28,375
7	26,135	7	26,585	7	27,035	7	27,485	7	27,935	7	28,385
8	26,155	8	26,605	8	27,055	8	27,505	8	27,955	8	28,405
9	26,165	9	26,615	9	27,065	9	27,515	9	27,965	9	28,415
10	26,175	10	26,625	10	27,075	10	27,525	10	27,975	10	28,425
11	26,185	11	26,635	11	27,085	11	27,535	11	27,985	11	28,435
12	26,205	12	26,655	12	27,105	12	27,555	12	28,005	12	28,455
13	26,215	13	26,665	13	27,115	13	27,565	13	28,015	13	28,465
14	26,225	14	26,675	14	27,125	14	27,585	14	28,025	14	28,475
15	26,235	15	26,685	15	27,135	15	27,585	15	28,035	15	28,485
16	26,255	16	26,705	16	27,155	16	27,605	16	28,055	16	28,505
17	26,265	17	26,715	17	27,165	17	27,615	17	28,065	17	28,515
18	26,275	18	26,725	18	27,175	18	27,625	18	28,075	18	28,525
19	26,285	19	26,735	19	27,185	19	27,635	19	28,085	19	28,535
20	26,305	20	26,755	20	27,205	20	27,655	20	28,105	20	28,555
21	26,315	21	26,765	21	27,215	21	27,665	21	28,115	21	28,565
22	26,325	22	26,775	22	27,225	22	27,675	22	28,125	22	28,575
23	26,355	23	26,805	23	27,255	23	27,705	23	28,155	23	28,605
24	26,335	24	26,785	24	27,235	24	27,685	24	28,135	24	28,585
25	26,345	25	26,795	25	27,245	25	27,695	25	28,145	25	28,595
26	26,365	26	26,815	26	27,265	26	27,715	26	28,165	26	28,615
27	26,375	27	26,825	27	27,275	27	27,725	27	28,175	27	28,625
28	26,385	28	26,835	28	27,285	28	27,835	28	28,185	28	28,635
29	26,395	29	26,845	29	27,295	29	27,845	29	28,195	29	28,645
30	26,405	30	26,855	30	27,305	30	27,755	30	28,205	30	28,655
31	26,415	31	26,865	31	27,315	31	27,865	31	28,215	31	28,665
32	26,425	32	26,875	32	27,325	32	27,775	32	28,225	32	28,675
33	26,435	33	26,885	33	27,335	33	27,785	33	28,235	33	28,685
34	26,445	34	26,895	34	27,345	34	27,795	34	28,245	34	28,695
35	26,455	35	26,905	35	27,355	35	27,805	35	28,255	35	28,705
36	26,465	36	26,915	36	27,365	36	27,815	36	28,265	36	28,715
37	26,475	37	26,925	37	27,375	37	27,825	37	28,275	37	28,725
38	26,485	38	26,935	38	27,385	38	27,835	38	28,285	38	28,735
39	26,495	39	26,945	39	27,395	39	27,845	39	28,295	39	28,745
40	26,505	40	26,955	40	27,405	40	27,855	40	28,305	40	28,755

NOTE: BAND "C" IS FCC BAND.

therefore the tuning range. This same principle applies to circuits where a capacitor is shunted across the VCO varactor; try increasing its value.

In these same chassis, you can also change the emitter and collector resistors of the VCO transistor to increase its gain. In the PC833/PC965/PB015 it's R98 (1KΩ) and R99 (56Ω) at TR22, and in the PB062 it's R102 (330Ω) and R103 (56Ω) at TR21. Replace both with about 180-220Ω. Combining the capacitor change above with the resistor changes makes these chassis go about 160 channels.

6. For IC VCOs like the UHIC005 or UHIC007, cut the trace connecting the hot side of the VCO coil winding to the IC. Connect a Maxitune or Superdiode in series, with its cathode end toward the IC input pin. These diodes are available from Selman Enterprises or C.C. Distributors; see CHAPTER 1.

Figure 3-34 shows a six-band Frequency/Channel expansion chart for your reference.

PLL SYNTHESIZER EVOLUTION

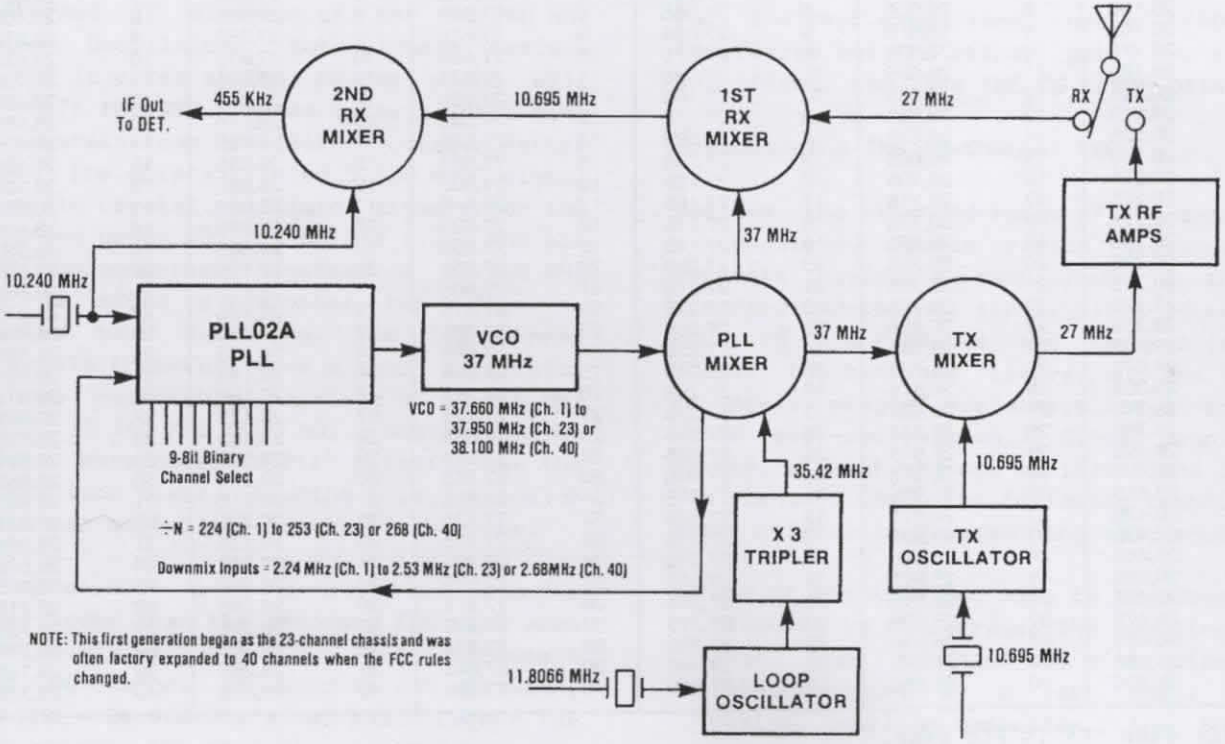
The following common AM-type PLL synthesizer examples are presented in chronological order of evolution, so you can see the changes and simplifications that occurred over the years.

EXAMPLE #1: THE CYBERNET PLL02A EARLY & LATE GENERATION PLL

The PLL02A AM circuit takes one of two forms. The first-generation chassis used three crystals, and the late-generation chassis was reduced to two crystals. The PLL chip uses straight 9-bit binary programming (pins 7-15) with internal pull-down resistors on them. The pins are normally LOW (0.0 V) unless forced HIGH (about 8 VDC) by external switching.

EARLY CIRCUIT: See Figure 3-35. The VCO runs at 37 MHz and is mixed with a 35.420 MHz signal derived from tripling an 11.8066 MHz crystal oscillator. The difference frequency is selected and becomes the downmix input. For example, the Ch.1 VCO is 37.660 MHz; when mixed with 35.420 MHz, the result is 37.660 - 35.420

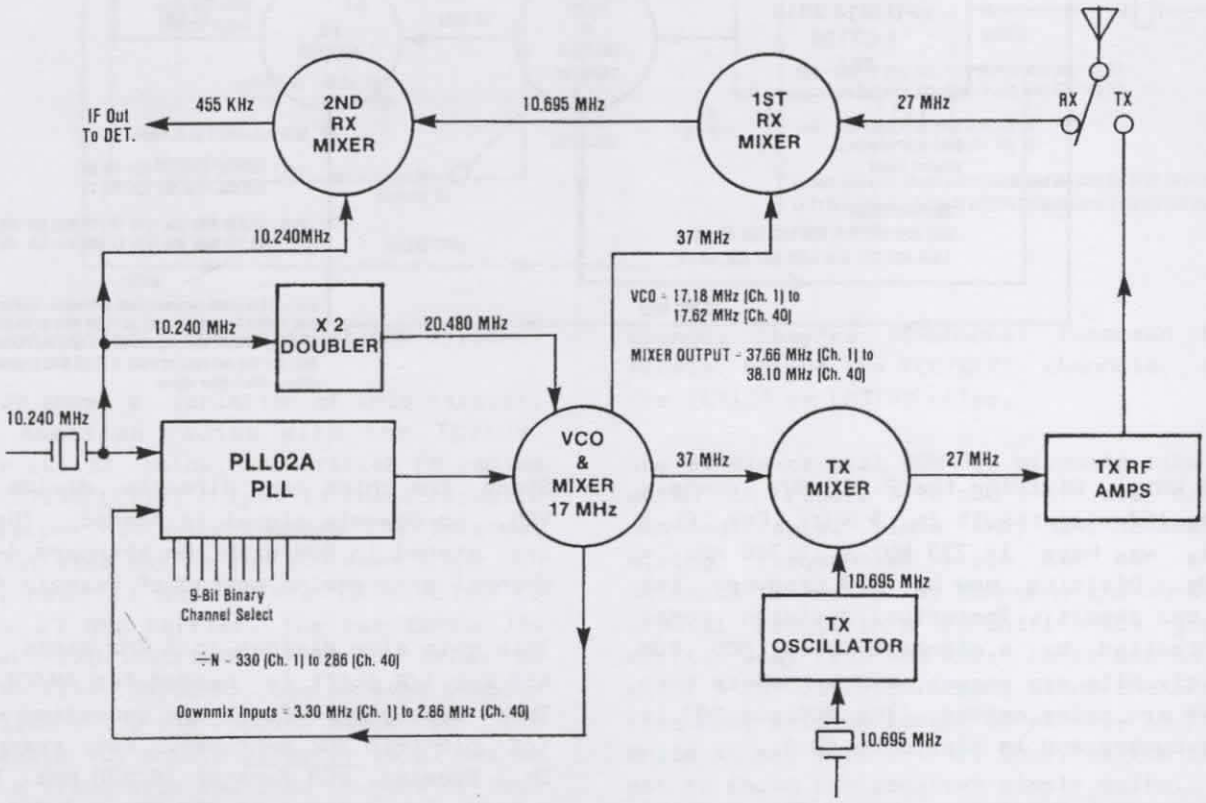
FIGURE 3-35
PLL02A EARLY AM CIRCUIT



= 2.24 MHz. The program pins are set for the binary number "224," which when divided into 2.24 MHz gives the required 10 KHz used by the chip. Pin 8 (128's bit) + Pin 9 (64's bit) + Pin 10 (32's bit) are always HIGH and preset the N-Code to (128 + 64 + 32) = 224; pins 11-15 vary with each channel and the N-Code extends to "253" for 23-channel models or to "268" for 40-channel models. (This was one of those chassis where some models were factory-expanded during the 23-to-40 transition era.)

LATE CIRCUIT: See Figure 3-36. Note this is the same circuit we've been discussing in this chapter. In this version the 11 MHz oscillator and its tripler stage have been eliminated. Instead a sample of the 10.240 MHz Reference Oscillator is doubled to 20.480 MHz and mixed with a 17 MHz VCO. For example, the Ch.1 VCO is 17.180 MHz. Mixing this with 20.480 MHz gives a downmix of 20.480 - 17.180 = 3.30 MHz. Now a binary "330" is programmed to produce the required 10 KHz rather than the "224" needed in the early circuit. Pin 7 (256's bit) presets a binary "256" and is added to the binary sum of pins 9-15. Pin 8 (128's bit) is grounded, since its value is never needed here.

FIGURE 3-36
PLL02A LATE AM CIRCUIT



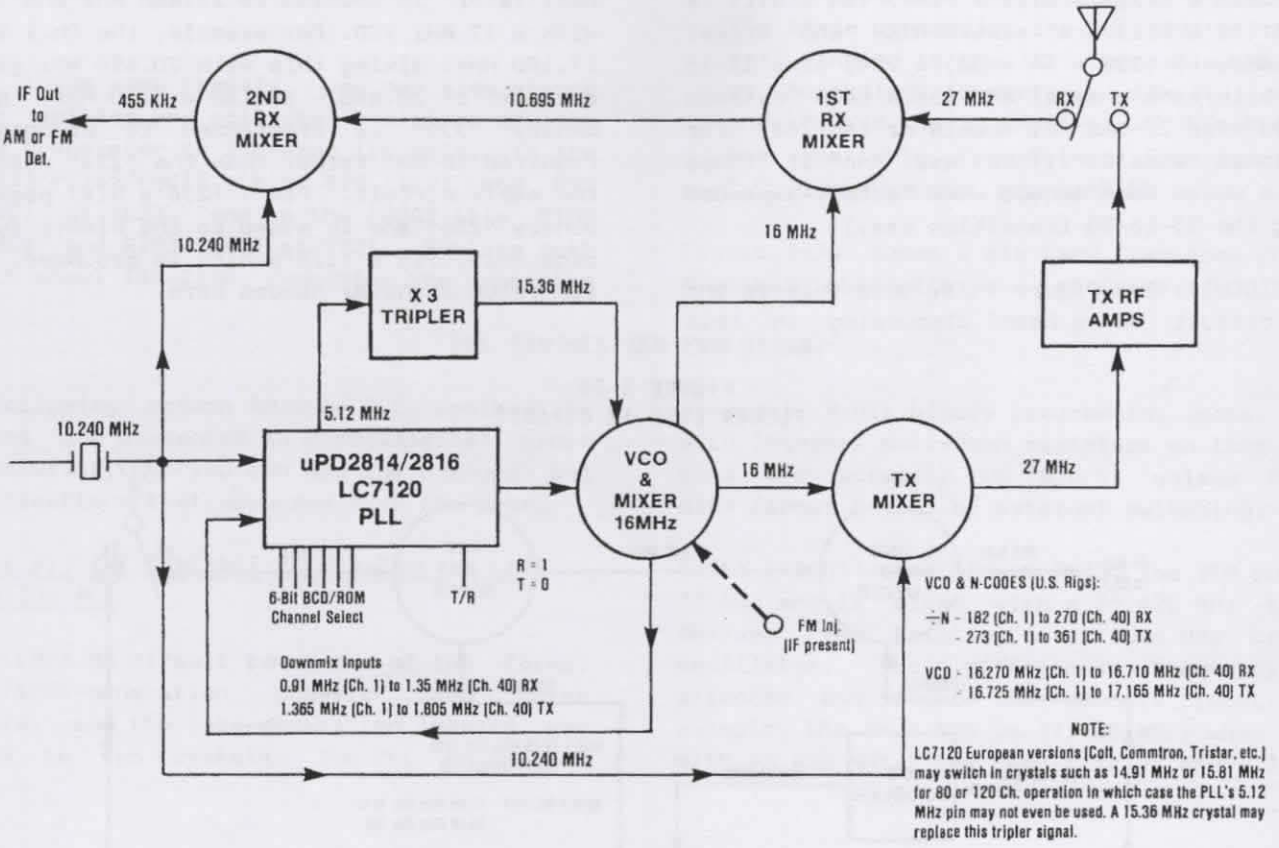
EXAMPLE #2: THE µPD2814/µPD2816 PLL

Refer to Figure 3-37. The µPD2814/2816 chips are pin-for-pin identical. (The µPD2824 is also identical except the Pin 9 T/R shift function is missing. To my knowledge it's never been used in any non-SSB radios.) The chips are the first generation use of ROM programming. There are several possible N-Code sets which can be used, depending upon the particular circuit and the state of Pin 9 (T/R) and Pin 20 (FS). All AM (and FM) chassis use the same method.

Since AM/FM radios require a double-conversion receiver with the low IF at 455 KHz, the T/R shift (Pin 9) is always used. This pin changes between Transmit and Receive to shift the VCO by 455 KHz. The result is an N-Code of 91-135 on Receive, and 136-180 on Transmit.

Pin 10 outputs 5.120 MHz. This is tripled by a coil to 15.360 MHz and mixes with the VCO; the difference frequency is selected to produce the downmix into the PLL chip. Example: The Ch.1 Receive VCO is 16.270 MHz; subtracting the 15.360 MHz downmixer gives 16.270 - 15.360 = 0.910 MHz. Since a T/R shift is involved, the chip uses 5 KHz Phase Detector inputs rather

FIGURE 3-37
μPD2814/2816 AM CIRCUIT
(Sometimes LC7120)



than 10 KHz. Dividing the 0.910 MHz downmix signal by 182 will result in 5 KHz. For Ch.1 Transmit, we have 16.725 MHz - 15.360 MHz = 1.365 MHz. Dividing now by 273 produces the same 5 KHz result. The actual division codes are controlled by a standard 6-bit BCD ROM input; six bits are enough, since numbers more than "39" are never needed. (The BCD sum "0" is the 40th number and is always Ch.40.)

For the export versions, a separate crystal oscillator PCB generates the 15.360 MHz PLL signal directly, along with 14.910 MHz and 15.810 MHz. This allows 120-channel operation. This chassis is most commonly found in the Korean-made Maxon radios (Colt 210, Colt 510, Commtron, Midland 100M, 150M, etc.), where the LC7120 PLL chip is used with the same results.

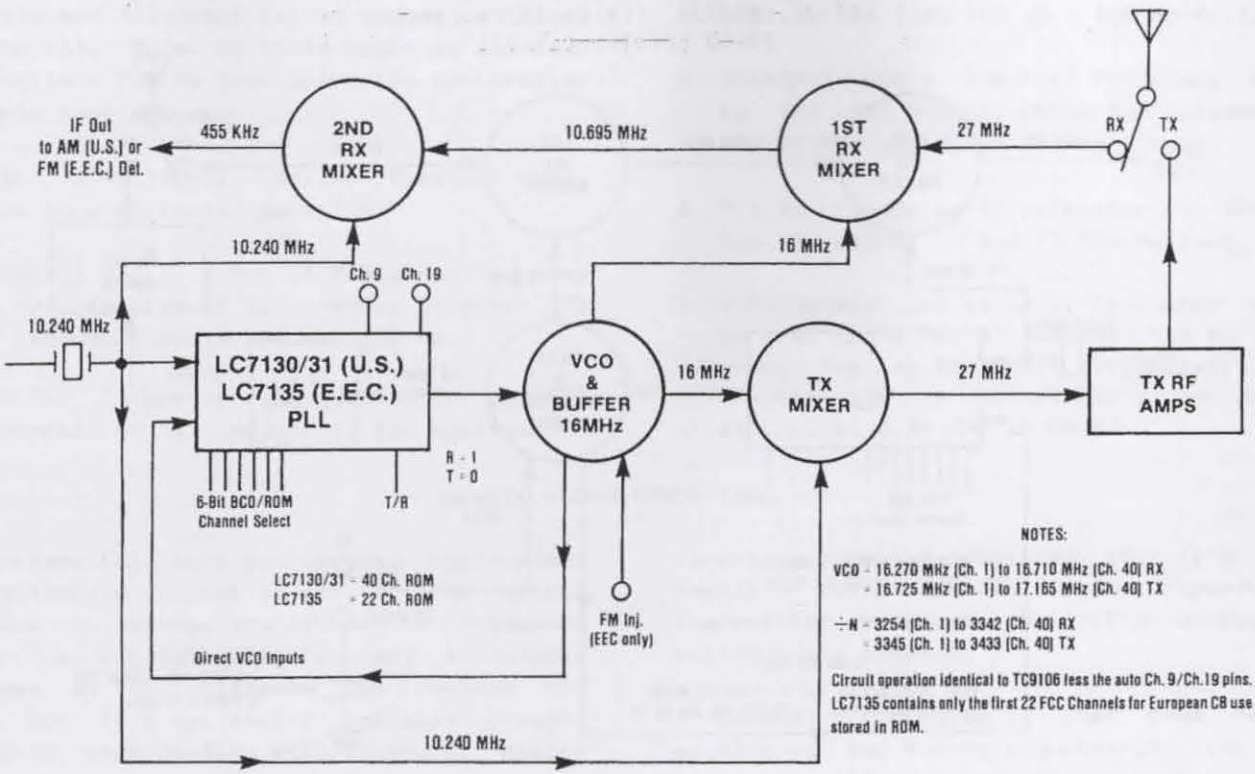
EXAMPLE #3: THE LC7130/LC7131 PLL

See Figure 3-38. The LC7130/31 are examples of the newest PLLs designed to make illegal channel modifications virtually impossible. Since the chips can directly divide a 16 MHz VCO, no downmix signal is needed. The N-Codes are stored in ROM with the standard 6-bit BCD channel programming method of Example #2.

This chip also divides in 5 KHz steps, since a 455 KHz T/R shift is needed for AM/FM radios. Thus separate N-Codes are generated when the T/R pin (Pin 20) switches. For example, the Ch.1 Receive VCO runs at 16.270 MHz. The ROM's N-Code is 3,254; 16.270 MHz ÷ 3,254 = 5 KHz. For Ch.1 Transmit, the N-Code is 3,345 and the VCO frequency is 455 KHz higher, or 16.270 MHz + .455 = 16.725 MHz. The result again is 5 KHz.

A sample of the 10.240 MHz Reference Oscillator goes to both the 2nd receive mixer stage and the transmit Mixer stage. The difference or sum respectively is chosen for the 455 KHz 2nd IF or the 27 MHz transmitter signal. An identical PLL circuit uses the TC9106 (U.S.) or TC9119 (U.K.); the only difference is that these chips don't have the automatic Ch.9/Ch.19 recall feature as additional pins, and a random 8-bit

FIGURE 3-38
LC7130/LC7131 AM CIRCUIT
(ALSO TC9106, TC9119, SM5123A)



program code controls the internal ROM divider.

Figure 3-39 shows a variation of this circuit, found in American radios with the TC9109, MB8733, or LC7132 chips, and British FM radios with the LC7136/LC7137 chips. In these circuits the T/R switch not only changes the internal N-Codes, but also shifts the VCO down 3 MHz on Transmit, near 13 MHz. This is doubled to become the 27 MHz carrier. The new Cobra 33+ and Uniden PRO-510E/520E, 710E and other AM chassis (SM5124A, SM5125B) use an even simpler method, eliminating the doubler stage too: the 16 MHz Receive VCO shifts directly to 27 MHz on Transmit; a transistor switches in more or less inductance across the VCO tank circuit.

The non-standard British CB channels will have changed to the standard FCC/CEPT frequencies by late 1987. Since the only channel difference between the TC9106/TC9119 and LC7132/LC7136 radios is the specific ROM division, it's a simple matter to convert British radios to the standard channels by changing just the PLL chip. (Unfortunately such changes probably won't be legal, and UK operators may have to buy brand new radios complying with stricter technical specs.) The Uniden PC404 and Cybernet Atron 2000FM radios are two examples of this change; they're 40-channel European FM-only models having the FCC/CEPT channels, and use the TC9109 or LC7132 chips.

The single-crystal ROM PLL circuits like those shown in Figure 3-38 and 3-39 are basically non-modifiable, since they have no additional mixing frequencies which can be changed. Attempts to modify by changing the 10.240 MHz crystal result in a T/R shift which gradually drifts away from 455 KHz; there are no longer exact 5 KHz division steps, since the reference frequency will no longer be exactly 10.240 MHz. While it may work on say, Ch.1, by the time you get to Ch.40 the receiver simply quits.

I know one very good English company offering a complete outboard synthesizer that replaces the LC7120, LC7132, LC7137, TC9106, TC9119, and µPD2810 PLL synthesizer circuits: S.J. Tonks (CB Components), 53/55 Darlaston Road, Pleck, Walsall, West Midlands, WS2 9QT, ENGLAND. The telephone is (0922) 646710. Their PLL unit is a compact, pretuned conversion board designed for easy installation, and with no special test equipment. It gives a switchable choice of 40 FCC or 40 upper channels. The price is about US $40; write for current prices and include a schematic and the exact radio model.

FIGURE 3-39
LC7132, MB8733, TC9109 AM/FM CIRCUIT
(ALSO LC7136, LC7137)

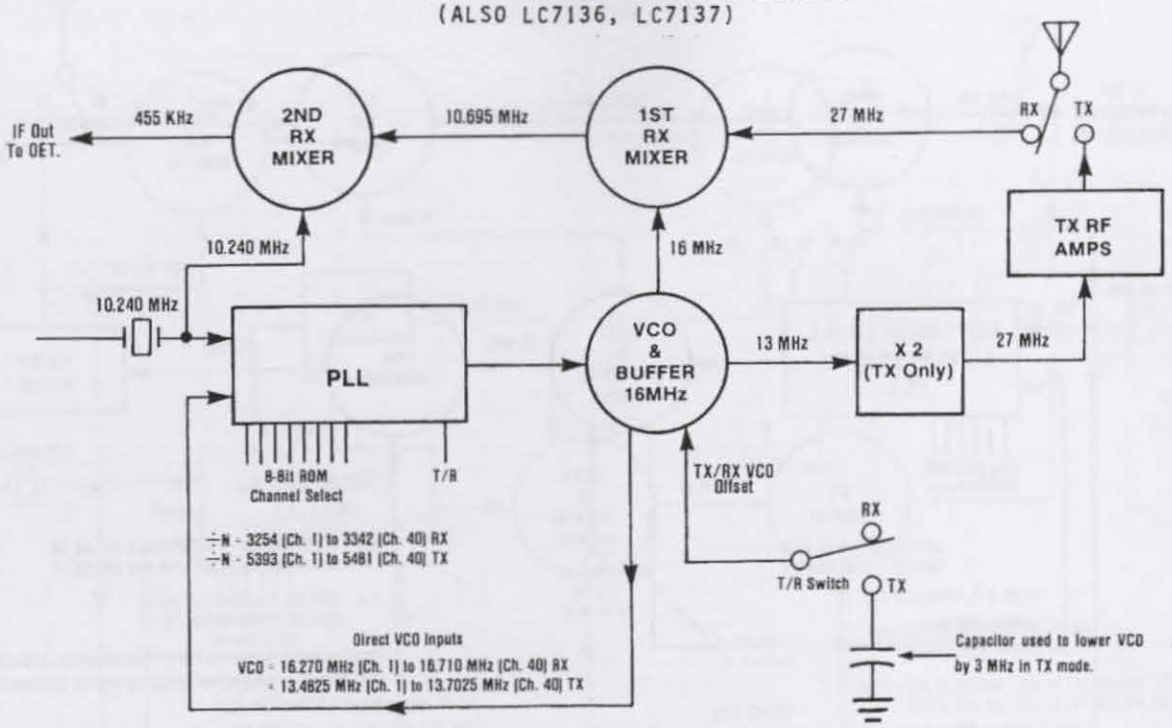
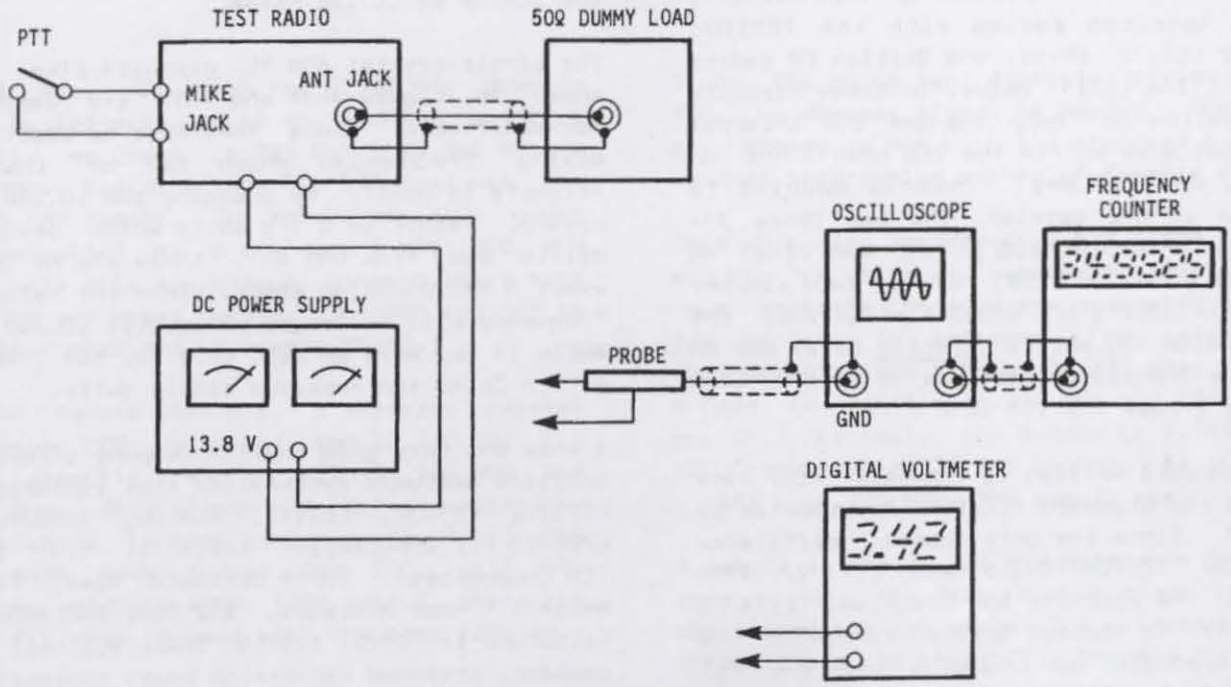


FIGURE 3-40
EQUIPMENT SET-UP FOR PLL ALIGNMENT



PLL SYNTHESIZER ALIGNMENT

Ajustment of PLL synthesizers involves setting all crystal oscillator frequencies, setting the VCO/Phase Detector for correct DC drive voltage on a given channel, and tuning any mixer circuits. SSB radios require some extra steps, as discussed in CHAPTER 6. Here we'll describe

the PLL alignment for a popular AM chassis (Cybernet PTBM049A0X, under many names) whose Schematic and Alignment Layout appear on Pages 144 and 145. Refer to those pages as you read this section. Figure 3-40 shows the synthesizer equipment test set-up.

1. PRESET CONDITIONS: Ch.19, Receive mode, Delta Tune at center position.

2. REFERENCE OSC.: Input of frequency counter to TP1 (Emitter of Q1). Adjust trimmer CT1 for frequency of 10.240 MHz ±50 Hz.

3. DOUBLER: 'Scope or RF Voltmeter to TP2 (secondary of T1). Adjust T1 for maximum.

4. VCO: Input of digital DC voltmeter to TP8 (opposite side of R1 from IC1 Pin 5). Adjust coil L1 for 3.60 VDC ±0.1 VDC on Ch.1.

5. TRANSMIT OSC.: Input of frequency counter to TP3 (IC3 Pin 2). Check for presence of 10.695 MHz ±50 Hz in Transmit mode.

6. MIXER: 'Scope or RF voltmeter to TP4 (IC3 Pin 4). Adjust L2 and T2 for maximum, Ch.19.

7. VCO/DOWNMIX: Set to Ch.1, frequency counter to TP4. Check for 37.660 MHz. Set to Ch.40; check for 38.100 MHz. Alternately, check downmix signals at IC1 Pin 2 for 3.30 MHz at Ch.1 to 2.86 MHz at Ch.40.

PLL TROUBLESHOOTING

PLL problems fall into two general categories: no synthesizer output at all, or the output frequency is wrong. You'll need a frequency counter, a digital voltmeter, and a 'scope. Sometimes an RF voltmeter can replace the 'scope but it's not really reliable enough, especially when dealing with timing or mixing problems. A good test set-up if your 'scope has a "Z" axis input is to connect that to your frequency counter; this allows you to use the 'scope probe for simultaneous waveform and frequency readings without having to switch instruments. Of course you do have the service manual or SAMS, which tells you the various voltages and signals to look for, right?

Symptoms associated with PLL synthesizers are:

1. No Transmit.
2. No Receive.
3. No Transmit or Receive.
4. A few channels dead.
5. A few channels duplicated.
6. Low transmitter power and/or poor receiver sensitivity.
7. No channel control; out of lock with the VCO free-running at its natural frequency.
8. No Transmit or Receive, one band end only.
9. Off frequency on all channels.

Following are some general guidelines to isolate PLL problems, and a specific example. With the symptoms of "No Receive or Transmit, Any Channel" and correct voltages to the PLL circuit already verified, you can be pretty sure the synthesizer's the problem. A quick check is to measure the Lock Detector pin; if the voltage level there shows an out-of-lock condition, you've verified it. It's always possible there are two distinct receiver and transmitter problems, but it's unlikely if voltages are correct.

A common PLL problem is that some "expert" misaligned the tuning adjustments, and proper alignment will cure it. Always look for signs of previous "repair" work, and get in the habit of questioning the customer first to determine the exact problem and repair history.

SPECIAL CAUTION! The plastic VCO block used in all the Cybernet PLL02A radios has a tuning slug which is very fragile and will crack if you don't use the correct tuning tool. Once it cracks, you'd have to unsolder the entire block from the main PC board to get to it from the bottom for removal. Worse, if it's the export type chassis you'll never be able to get a replacement. Don't touch this adjustment at all if the synthesizer works through its normal frequency range! If you must adjust it, the GC Electronics #9440 plastic alignment tool is the correct one that fits this slug.

On a related subject, you'll often find the standard tuning slugs cracked or frozen in the coil from a previous "adjustment." These can still be saved if you're very careful. The slugs have the same screwdriver slot at both ends; remove the transformer completely from the PC board and you'll be able to use the bottom slot to unscrew the jammed slug. Then screw it back in from the top side and reinstall the transformer. If some ferrite breaks off in the process, it usually won't be enough to prevent correct tuning anyway.

Here are a few general PLL troubleshooting suggestions:

1. Is there any receiver noise? Usually with a dead PLL you'll hear some hiss noise, but at a lower-than-normal volume. If there's no noise at all, the problem may be in the voltage supply rather than the synthesizer.

   Assuming there's noise, check the synthesizer area with a 'scope or RF voltmeter, looking for the presence of all oscillator and mixing signals. Also 'scope the downmix input pin of the PLL IC to see if it's there. With a dual-trace 'scope, you can view the Reference Oscillator on one channel and the downmix on the other, which should be at a much lower frequency.

   Remember that an RF probe can't tell the difference between a single frequency and mixed frequencies, but a 'scope can. Don't be misled. If one mixer input is missing there will still be RF at the output, but of the wrong frequency. A missing mixer input signal will also cause the stage to have a lower-than-normal RF output voltage.

2. The synthesizer typically has from one to three oscillators and one or two mixer stages. If any one stage is defective, the wrong output is generated. Check each stage with your 'scope until you lose the signal, then make DC and resistance measurements to isolate the bad part. A problem with inexperience is to immediately suspect a bad PLL chip if IC voltages, especially the one driving the VCO, are wrong. The real problem is usually in the VCO or mixer, not the PLL IC. If there's evidence that somebody replaced the PLL chip but the radio still doesn't work, suspect problems in the mixer or oscillator stages.

3. A variation of Step 2 is to inject the missing frequency with your RF signal generator. If operation is restored you know that particular signal was missing. Now work backwards, injecting from the output to the input, one stage at a time. You may have to use more than one generator frequency as you proceed. Once the injection point is moved past the defective area, it no longer restores normal operation so you've got it isolated. Inject using a high-impedance probe or you might load down or mistune something, making your tests meaningless.

4. You can test the VCO and associated circuitry by applying a DC clamping voltage. Disconnect the series component that normally drives the VCO from the PLL/filter circuit, usually a resistor. Apply a filtered DC voltage to this control point instead. The voltage should be in the range normally supplied from the PLL chip; the alignment instructions will say something like "Adjust VCO coil for 3.60 VDC at Ch.1." A DC supply variable from about 1-5 VDC is perfect. Changing this voltage should also make the VCO frequency change.

MISCELLANEOUS SERVICING TIPS: Due to all the amateurish PLL modifications around, it's a good idea when replacing a PLL IC to include a socket for it. PLLs are CMOS, and besides potential static damage, you can't keep soldering and unsoldering those delicate foil traces forever! Keep a small supply of 16, 18, 20, 22, and 24 pin low-profile DIP sockets handy and you'll save yourself many future headaches and call-backs.

On the subject of CMOS, be sure you're doing everything possible to prevent static from destroying the chips. Measures include the use of grounded soldering irons, grounded wrist straps, and leaving the chip in its conductive foam or package until needed. I happen to have a carpeted work area and the Arizona climate is very dry, encouraging static.

Here's a simple way to eliminate static in a carpeted room: get a plastic spray bottle with a trigger squeeze on it, like those used for all-purpose cleaners or Windex. Fill it with a mixture of 50% water and 50% Downey laundry fabric softener. Every month or two, spray a fine mist on the carpeted work areas. This prevents static electricity buildup. Computer owners take note too! (My computer is in the same room as my electronic servicing bench.)

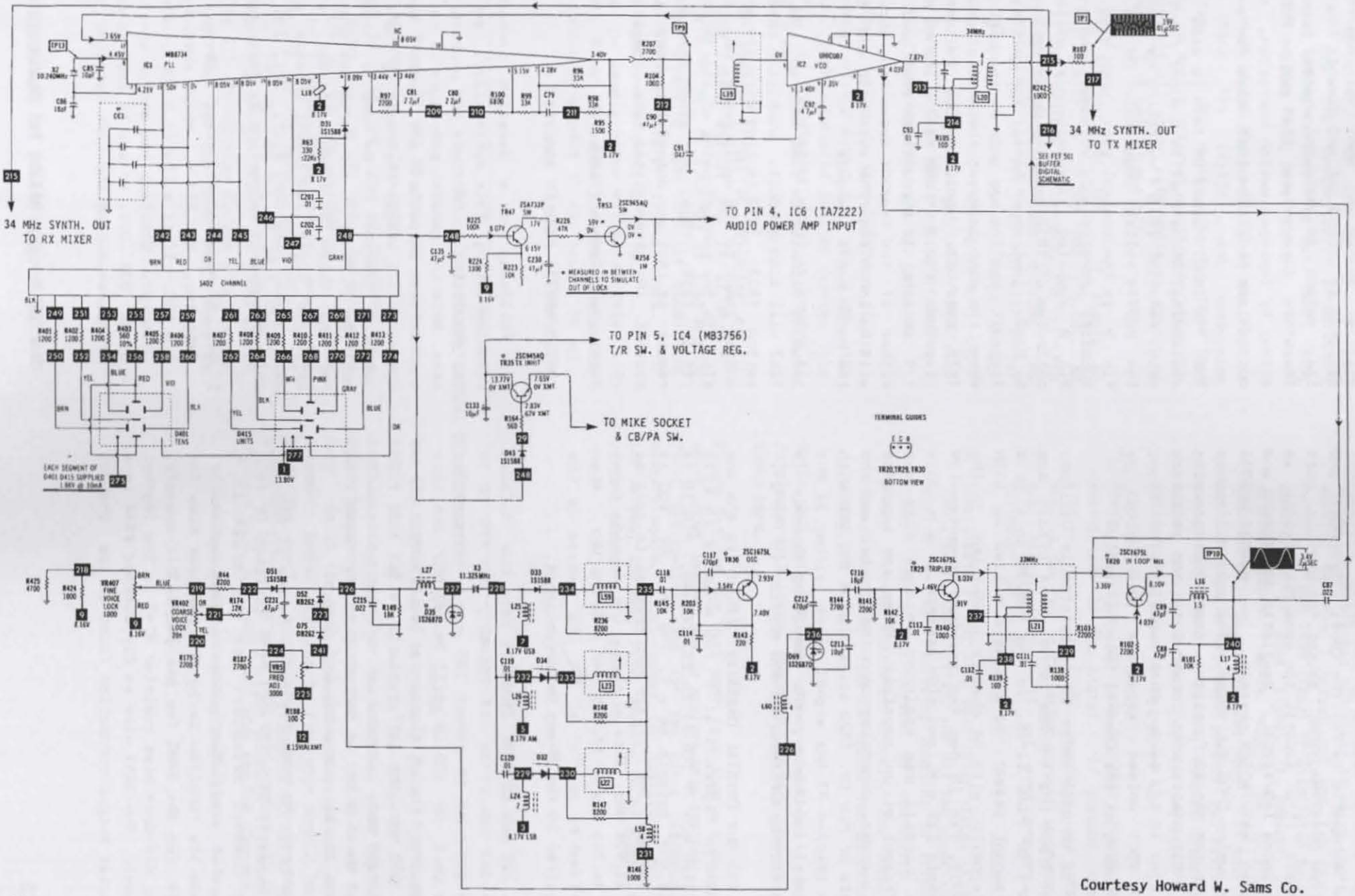
A Practical PLL Example

Now we'll analyze a real circuit. You'll discover that being logical and methodical is all it takes to fix what first appears to be a tough problem! Figure 3-41 is reprinted by permission of the Howard W. Sams Co.

MB8719/MB8734 Frequency Synthesizer Circuit Description

Refer to Figure 3-41. I've purposely chosen

FIGURE 3-41
THE MB8719/MB8734 PLL SYNTHESIZER



Courtesy Howard W. Sams Co.

this circuit because of its great popularity. The schematic is for the Cobra 148/2000GTL and Uniden GRANT/MADISON; except for certain part numbers it's exactly the same PLL circuit as the Cobra 140/142GTL, Realistic TRC450/490 and Uniden WASHINGTON chassis. The MB8719/MB8734 are custom CMOS PLL chips. The only difference is in the Pin 10 functions. Channel programming is 6-bit binary with internal pull-up resistors on pins 10-16, making them normally HIGH (about 8.0 VDC) unless forced LOW (0.0 volts) by grounding at the Channel Selector switch.

Pin 10 on both chips is a Presettable Divider. When HIGH the N-Code is 64 + the binary sum ("N") of Pins 11-16. In the MB8734 this is a permanent preset; it's always pulled up HIGH internally, with no chassis connection. In the MB8719, Pin 10 has two possible presets: LOW presets 128 + N, and HIGH presets 64 + N. This PLL circuit was designed to work with two different mixing crystals. There are two sets of N-Codes, depending upon the crystal and the state of Pin 10. TR20 mixes the 34 MHz VCO with the tripled 33 MHz signal from either 11 MHz crystal oscillator; the resulting downmix is filtered by C89/L16/C88 and applied to Pin 17.

11.325 MHz CRYSTAL CHASSIS: (This is the one shown in Figure 3-41.) The N-Codes in this version are 79 (Ch.1) to 123 (Ch.40). Pin 10 is HIGH and presets 64 + N. The Ch.1 AM VCO is 34.765 MHz. The 11.325 MHz crystal is tripled to 33.975 MHz. This produces the downimx input of 34.765 MHz - 33.975 MHz = 0.790 MHz. When divided by an "N" of 79, the result is the required 10 KHz Phase Detector input.

11.1125 MHz CRYSTAL CHASSIS: Here the N-Codes are 143 (Ch.1) to 187 (Ch.40), and Pin 10 is now grounded to preset 128 + N. For example, the Ch.1 AM VCO is still 34.765 MHz, but this time the tripler signal is 11.1125 MHz x 3 = 33.3375 MHz. The difference is 34.765 - 33.3375 = 1.4275 MHz, which is trimmed to exactly 1.43 MHz. With an "N" of 143, the result is still 10 KHz to the Phase Detector.

LOCK DETECTOR CIRCUIT: Pin 6 is the LD pin and is normally HIGH (8 VDC). D31 isolates it from the Channel Selector. R63 was drawn in a somewhat misleading place on this schematic, since its function is to provide base bias for TR35. (On the SAMS for the 140/142GTL chassis, they did draw bias resistor R147 in the logical place!) The GRAY wire to Circuitrace #248 is a special output connection found on the Channel Selector switch of most PLL radios; it's designed to ground out and disable the radio if the switch is between channel positions. Therefore Circuitrace #248 can be forced LOW either by improper switch operation, or by an out-of-lock condition that makes Pin 6 go LOW.

The "TX INHIT" label on TR35 is also somewhat misleading, since that is a minor function. Its main function is T/R switching by control of the MB3756 voltage regulator. On the MB3756, Pin 5 is the control pin: when HIGH, Pin 6 supplies Receive-only voltage, and when LOW, Pin 8 supplies Transmit-only voltage. The collector of TR35 normally pulls up to 13.8 VDC by R162. (Not shown here.) The emitter is the Transmit keyline and goes to the MIKE socket. When the mike is keyed the emitter grounds and TR35 conducts, pulling its collector and therefore Pin 5 of the MB3756 LOW to make the T/R switch. If Circuitrace #248 goes LOW for either of the reasons described above, TR35 will be inhibited from switching and therefore the radio can't transmit.

Assuming Circuitrace #248 does go LOW, switch TR47 will also conduct, supplying base bias to switch TR53. TR53 is tied directly across the audio input to the audio power amp IC4, and also to the control point of the AMC/ALC amps. (TR34, TR25, TR24, not shown here.) The net result is that any out-of-lock condition will prevent the transmitter from operating, and will also kill the audio signal in both the Receive and Transmit modes.

MB8719/MB8734 PROBLEM ANALYSIS

The following is a detailed procedure for troubleshooting this synthesizer, and assumes you've logically narrowed the problem to this area. Note the general procedure is to start at the mixer output(s) and work backwards, checking all stages that make up the composite output. This idea can be used to troubleshoot any type of PLL circuit. Parts designations are for the Cobra 148/2000GTL chassis, with the alternate Cobra 140/142GTL chassis parts in parentheses. See SAMS #219, 221, 230, 249, or 251 for complete schematics by model numbers.

1. Use AM mode for all steps. Check the Lock Detector, PLL Pin 6, which should be about 8.0 VDC. If it's LOW (0.0 VDC), the loop is unlocked. Unsolder one end of the switching diode D31 (D25) to see if lock is restored. If disconnecting the Lock Detector restores

normal operation, the problem is in this circuit, not the synthesizer; troubleshoot associated active devices like D31, TR47, TR53, D43, TR35. (D25, TR45, D44, TR37.)

2. Do you read 10.240 MHz at Pin 8 of the PLL? If not, check the crystal and associated capacitors. If OK, replace the PLL IC. This PLL has an active internal oscillator which can fail even if all other chip voltages appear to be normal. I've seen it happen!

3. Check the frequency at TP1. It should be 34.765 MHz (Ch.1) to 35.205 MHz (Ch.40), AM mode. If the readings are correct, the PLL chip is working properly and the problem lies elsewhere. If not correct, the VCO will either be free-running in the 35 MHz range or not working at all. If not running at all, check VCO/Mixer IC2 (IC1) voltages and associated passive devices. Also check tuning of VCO coil L19 (L13). If OK and free-running, go to #4.

4. Check signal continuity from VCO/Mixer IC Pin 1 to secondary of VCO output coil L20 (L14) which is TP1. Check associated passive devices like C93 (C75). If free-running signal is present at TP1, go to #5.

5. Check for downmix signal at collector of PLL Mixer TR20 (TR19) and at Pin 17 of PLL IC. Should be 0.790 MHz to 1.23 MHz or 1.43 MHz to 1.87 MHz, depending upon chassis model and specific 11 MHz tripler crystal used. If downmix signal not present, go to #6.

6. Check PLL Mixer TR20 (TR19). The 34 MHz VCO signal should be present at the base. If not, suspect possible bad VCO/Mixer IC which could be working for Pin 1 output but not for Pin 10 output, or bad TR20 (TR19) or associated passive devices. If base signal is present check emitter signal, which should be 33.975 MHz (33.3350 MHz) depending upon model. If base and emitter signals are both present but collector signal (the downmix) is not, suspect transistor and/or the associated passive devices. If emitter signal is missing, go to #7.

7. Check collector of tripler TR29 (TR23) for appropriate 33 MHz signal. If present, check tripler coil L21 (L18) secondary and other passive devices in collector circuit to pinpoint open signal path. If not even present at collector, go to #8.

8. Investigate 11 MHz loop oscillator stage. Check TR30 (TR24), the crystal, and all the associated passive devices, including coupling to tripler stage. Check for crystal RF continuity to ground through Clarifier circuit, and forward bias on switching diode D34 (D33) for AM offset tuning.

NOTE: D32 and D34 were drawn backwards in SAMS Fotofacts #251 (Cobra 2000GTL), but are correct as shown here.

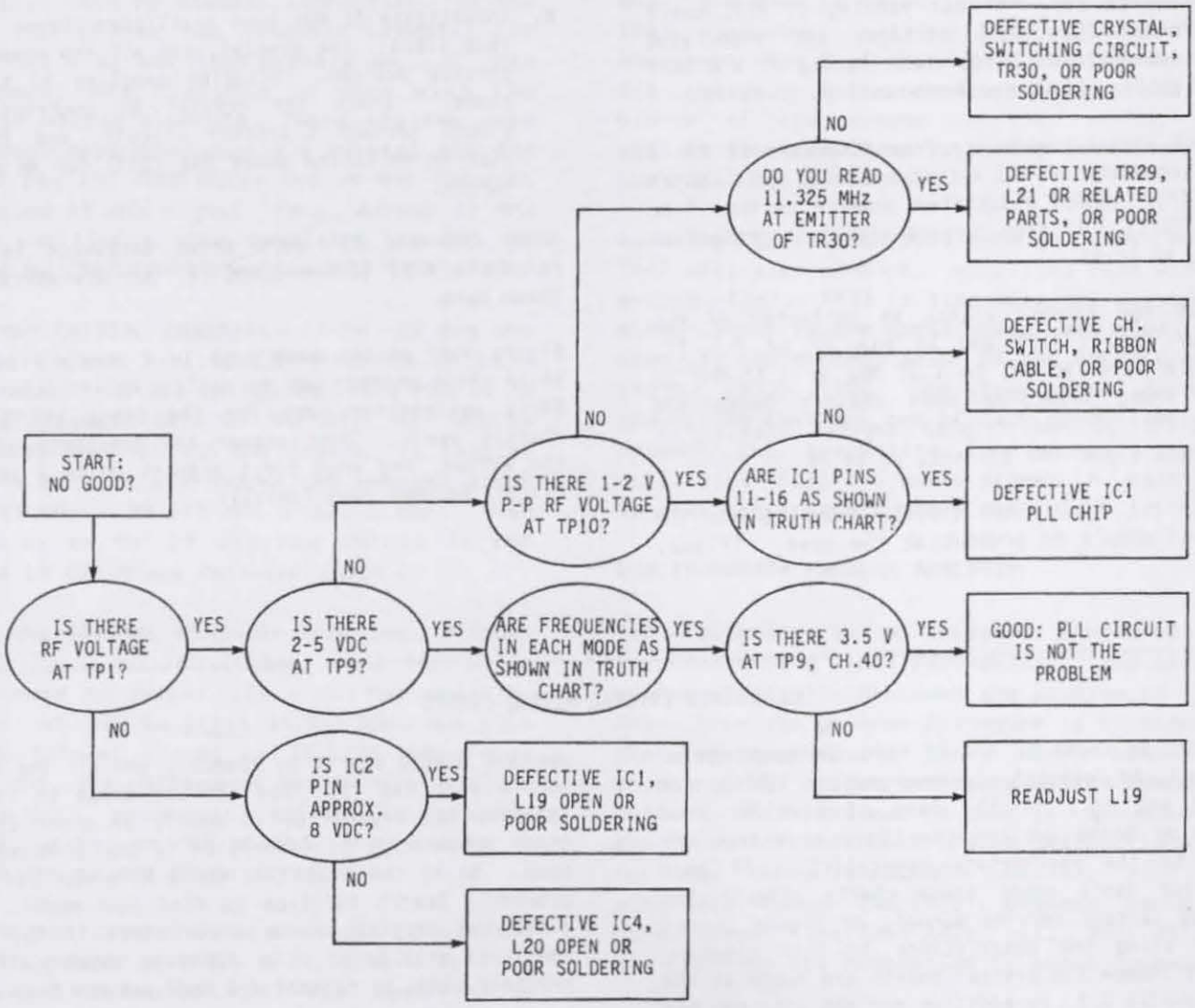
Figure 3-42 on the next page is a simple Flowchart which shows another way to analyze this synthesizer. Parts designations are for the Cobra 148/2000GTL chassis again. Just answer the questions, follow the arrows, and what first appears to be a complex circuit becomes very logical!

23-CHANNEL CRYSTAL MIXING CHARTS

The charts on Pages 87 and 88 show the most common 23-channel AM crystal synthesizers. (Also see Pages 52 and 54.) In the case of specific dead channels or modes you can use these to narrow the problem to the appropriate crystal(s). If your synthesizer isn't among these charts consult the SAMS, the factory service manual, or figure it out yourself using the descriptions in this chapter. (The most common SSB crystal charts are found at the end of CHAPTER 6.) In addition our Web site now has .PDF files that show all the other most common AM and SSB mixing charts by channel, and all the known models that had it. You can use these to find a specific bad crystal or to modify an older CB for other frequencies or conversion to the 10-Meter Ham band. Go to the page link shown here and use your browser's Search function to find your model. Then click the crystal scheme shown above it for that model; it will bring up a .PDF page showing all the crystals used, by channel and mode and how they mix.

www.cbcintl.com/docs/xtals.htm

FIGURE 3-42
MB8719/MB8734 TROUBLESHOOTING FLOWCHART
(Cobra 148/2000GTL, Uniden Grant/Madison)



	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	16.200	4.765	Ch.13 (27.115)	16.350	4.765
Ch. 2 (26.975)	"	4.775	Ch.14 (27.125)	"	4.775
Ch. 3 (26.985)	"	4.785	Ch.15 (27.135)	"	4.785
Ch. 4 (27.005)	"	4.805	Ch.16 (27.155)	"	4.805
Ch. 5 (27.015)	16.250	4.765	Ch.17 (27.165)	16.400	4.765
Ch. 6 (27.025)	"	4.775	Ch.18 (27.175)	"	4.775
Ch. 7 (27.035)	"	4.785	Ch.19 (27.185)	"	4.785
Ch. 8 (27.055)	"	4.805	Ch.20 (27.205)	"	4.805
Ch. 9 (27.065)	16.300	4.765	Ch.21 (27.215)	16.450	4.765
Ch.10 (27.075)	"	4.775	Ch.22 (27.225)	"	4.775
Ch.11 (27.085)	"	4.785	Ch.23 (27.255)	"	4.805
Ch.12 (27.105)	"	4.805			

Additional Crystals Used: 5.545 MHz RX all 23 channels;
6.000 MHz TX all 23 channels

Synthesis: "A" + "B" + 6.000 = direct on-channel TX frequency;
"A" + "B" + 5.545 = RX frequency (offset by 455 KHz)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	32.845	10.180	Ch.13 (27.115)	32.995	10.180
Ch. 2 (26.975)	"	10.170	Ch.14 (27.125)	"	10.170
Ch. 3 (26.985)	"	10.160	Ch.15 (27.135)	"	10.160
Ch. 4 (27.005)	"	10.140	Ch.16 (27.155)	"	10.140
Ch. 5 (27.015)	32.895	10.180	Ch.17 (27.165)	33.045	10.180
Ch. 6 (27.025)	"	10.170	Ch.18 (27.175)	"	10.170
Ch. 7 (27.035)	"	10.160	Ch.19 (27.185)	"	10.160
Ch. 8 (27.055)	"	10.140	Ch.20 (27.205)	"	10.140
Ch. 9 (27.065)	32.945	10.180	Ch.21 (27.215)	33.095	10.180
Ch.10 (27.075)	"	10.170	Ch.22 (27.225)	"	10.170
Ch.11 (27.085)	"	10.160	Ch.23 (27.255)	"	10.140
Ch.12 (27.105)	"	10.140			

Additional Crystals Used: 4.300 MHz TX all 23 channels;
4.755 MHz RX all 23 channels

Synthesis: "A" - "B" + 4.300 = direct on-channel TX frequency;
"A" - "B" + 4.755 = RX frequency (offset by 455 KHz

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	16.965	9.5450	10.000	Ch.13 (27.115)	17.115	9.5450	10.000
Ch. 2 (26.975)	"	9.5550	10.010	Ch.14 (27.125)	"	9.5550	10.010
Ch. 3 (26.985)	"	9.5650	10.020	Ch.15 (27.135)	"	9.5650	10.020
Ch. 4 (27.005)	"	9.5850	10.040	Ch.16 (27.155)	"	9.5850	10.040
Ch. 5 (27.015)	17.015	9.5450	10.000	Ch.17 (27.165)	17.165	9.5450	10.000
Ch. 6 (27.025)	"	9.5550	10.010	Ch.18 (27.175)	"	9.5550	10.010
Ch. 7 (27.035)	"	9.5650	10.020	Ch.19 (27.185)	"	9.5650	10.020
Ch. 8 (27.055)	"	9.5850	10.040	Ch.20 (27.205)	"	9.5850	10.040
Ch. 9 (27.065)	17.065	9.5450	10.000	Ch.21 (27.215)	17.215	9.5450	10.000
Ch.10 (27.075)	"	9.5550	10.010	Ch.22 (27.225)	"	9.5550	10.010
Ch.11 (27.085)	"	9.5650	10.020	Ch.23 (27.255)	"	9.5850	10.040
Ch.12 (27.105)	"	9.5850	10.040				

Synthesis: "A" + "C" = direct on-channel TX frequency;
"A" + "B" = RX frequency (offset by 455 KHz)

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	33.300	6.490	6.035	Ch.13 (27.115)	33.150	6.490	6.035
Ch. 2 (26.975)	"	6.480	6.025	Ch.14 (27.125)	"	6.480	6.025
Ch. 3 (26.985)	"	6.470	6.015	Ch.15 (27.135)	"	6.470	6.015
Ch. 4 (27.005)	"	6.450	5.995	Ch.16 (27.155)	"	6.450	5.995
Ch. 5 (27.015)	33.050	6.490	6.035	Ch.17 (27.165)	33.200	6.490	6.035
Ch. 6 (27.025)	"	6.480	6.025	Ch.18 (27.175)	"	6.480	6.025
Ch. 7 (27.035)	"	6.470	6.015	Ch.19 (27.185)	"	6.470	6.015
Ch. 8 (27.055)	"	6.450	5.995	Ch.20 (27.205)	"	6.450	5.995
Ch. 9 (27.065)	33.100	6.490	6.035	Ch.21 (27.215)	33.250	6.490	6.035
Ch.10 (27.075)	"	6.480	6.025	Ch.22 (27.225)	"	6.480	6.025
Ch.11 (27.085)	"	6.470	6.015	Ch.23 (27.255)	"	6.450	5.995
Ch.12 (27.105)	"	6.450	5.995				

Synthesis: "A" - "C" = direct on-channel TX frequency;
"A" - "B" = RX frequency (offset by 455 KHz)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	11.705	7.4600	Ch.13 (27.115)	11.855	7.4600
Ch. 2 (26.975)	"	7.4700	Ch.14 (27.125)	"	7.4700
Ch. 3 (26.985)	"	7.4800	Ch.15 (27.135)	"	7.4800
Ch. 4 (27.005)	"	7.5000	Ch.16 (27.155)	"	7.5000
Ch. 5 (27.015)	11.755	7.4600	Ch.17 (27.165)	11.905	7.4600
Ch. 6 (27.025)	"	7.4700	Ch.18 (27.175)	"	7.4700
Ch. 7 (27.035)	"	7.4800	Ch.19 (27.185)	"	7.4800
Ch. 8 (27.055)	"	7.5000	Ch.20 (27.205)	"	7.5000
Ch. 9 (27.065)	11.805	7.4600	Ch.21 (27.215)	11.955	7.4600
Ch.10 (27.075)	"	7.4700	Ch.22 (27.225)	"	7.4700
Ch.11 (27.085)	"	7.4800	Ch.23 (27.255)	"	7.5000
Ch.12 (27.105)	"	7.5000			

Additional Crystals Used: 7.800 MHz TX all 23 channels;
7.345 MHz RX all 23 channels

Synthesis: "A" + "B" + 7.800 = direct on-channel TX frequency;
"A" + "B" + 7.345 = RX frequency (offset by 455 KHz)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	10.850	8.6150	Ch.13 (27.115)	11.000	8.6150
Ch. 2 (26.975)	"	8.6250	Ch.14 (27.125)	"	8.6250
Ch. 3 (26.985)	"	8.6350	Ch.15 (27.135)	"	8.6350
Ch. 4 (27.005)	"	8.6550	Ch.16 (27.155)	"	8.6550
Ch. 5 (27.015)	10.900	8.6150	Ch.17 (27.165)	11.050	8.6150
Ch. 6 (27.025)	"	8.6250	Ch.18 (27.175)	"	8.6250
Ch. 7 (27.035)	"	8.6350	Ch.19 (27.185)	"	8.6350
Ch. 8 (27.055)	"	8.6550	Ch.20 (27.205)	"	8.6550
Ch. 9 (27.065)	10.950	8.6150	Ch.21 (27.215)	11.100	8.6150
Ch.10 (27.075)	"	8.6250	Ch.22 (27.225)	"	8.6250
Ch.11 (27.085)	"	8.6350	Ch.23 (27.255)	"	8.6550
Ch.12 (27.105)	"	8.6550			

Additional Crystals Used: 7.500 MHz TX all 23 channels;
7.975 MHz RX all 23 channels

Synthesis: "A" + "B" + 7.500 = direct on-channel TX frequency;
"A" + "B" + 7.975 = RX frequency (offset by 455 KHz)

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	38.275	11.765	11.310	Ch.13 (27.115)	38.375	11.715	11.260
Ch. 2 (26.975)	38.285	"	"	Ch.14 (27.125)	38.385	"	"
Ch. 3 (26.985)	38.295	"	"	Ch.15 (27.135)	38.395	"	"
Ch. 4 (27.005)	38.315	"	"	Ch.16 (27.155)	38.415	"	"
Ch. 5 (27.015)	38.275	11.715	11.260	Ch.17 (27.165)	38.475	11.765	11.310
Ch. 6 (27.025)	38.285	"	"	Ch.18 (27.175)	38.485	"	"
Ch. 7 (27.035)	38.295	"	"	Ch.19 (27.185)	38.495	"	"
Ch. 8 (27.055)	38.315	"	"	Ch.20 (27.205)	38.515	"	"
Ch. 9 (27.065)	38.375	11.765	11.310	Ch.21 (27.215)	38.475	11.715	11.260
Ch.10 (27.075)	38.385	"	"	Ch.22 (27.225)	38.485	"	"
Ch.11 (27.085)	38.395	"	"	Ch.23 (27.255)	38.515	"	"
Ch.12 (27.105)	38.415	"	"				

Synthesis: "A" - "C" = direct on-channel TX frequency;
"A" - "B" = RX frequency (offset by 455 KHz)

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	34.971	8.006	8.461	Ch.13 (27.115)	35.121	8.006	8.461
Ch. 2 (26.975)	"	7.996	8.451	Ch.14 (27.125)	"	7.996	8.451
Ch. 3 (26.985)	"	7.986	8.441	Ch.15 (27.135)	"	7.986	8.441
Ch. 4 (27.005)	"	7.966	8.421	Ch.16 (27.155)	"	7.966	8.421
Ch. 5 (27.015)	35.021	8.006	8.461	Ch.17 (27.165)	35.171	8.006	8.461
Ch. 6 (27.025)	"	7.996	8.451	Ch.18 (27.175)	"	7.996	8.451
Ch. 7 (27.035)	"	7.986	8.441	Ch.19 (27.185)	"	7.986	8.441
zh. 8 (27.055)	"	7.966	8.421	Ch.20 (27.205)	"	7.966	8.421
Ch. 9 (27.065)	35.071	8.006	8.461	Ch.21 (27.215)	35.221	8.006	8.461
Ch.10 (27.075)	"	7.996	8.451	Ch.22 (27.225)	"	7.996	8.451
Ch.11 (27.085)	"	7.986	8.441	Ch.23 (27.255)	"	7.966	8.421
Ch.12 (27.105)	"	7.966	8.421				

Synthesis: "A" - "B" = direct on-channel TX frequency;
"A" - "C" = RX frequency (offset by 455 KHz)

	BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"		BOTH RX&TX "A"	RX ONLY "B"	TX ONLY "C"
Ch. 1 (26.965)	32.700	6.190	5.735	Ch.13 (27.115)	32.850	6.190	5.735
Ch. 2 (26.975)	"	6.180	5.725	Ch.14 (27.125)	"	6.180	5.725
Ch. 3 (26.985)	"	6.170	5.715	Ch.15 (27.135)	"	6.170	5.715
Ch. 4 (27.005)	"	6.150	5.695	Ch.16 (27.155)	"	6.150	5.695
Ch. 5 (27.015)	32.750	6.190	5.735	Ch.17 (27.165)	32.900	6.190	5.735
Ch. 6 (27.025)	"	6.180	5.725	Ch.18 (27.175)	"	6.180	5.725
Ch. 7 (27.035)	"	6.170	5.715	Ch.19 (27.185)	"	6.170	5.715
Ch. 8 (27.055)	"	6.150	5.695	Ch.20 (27.205)	"	6.150	5.695
Ch. 9 (27.065)	32.800	6.190	5.735	Ch.21 (27.215)	32.950	6.190	5.735
Ch.10 (27.075)	"	6.180	5.725	Ch.22 (27.225)	"	6.180	5.725
Ch.11 (27.085)	"	6.170	5.715	Ch.23 (27.255)	"	6.150	5.695
Ch.12 (27.105)	"	6.150	5.695				

Synthesis: "A" - "C" = direct on-channel TX frequency;
"A" - "B" = RX frequency (offset by 455 KHz)

4 RECEIVER CIRCUITS

Now that you understand how the various mixing frequencies are generated, we'll analyze the most complicated part of a CB, the receiver. There's a lot more happening in the receiver than in the transmitter, and troubleshooting can be more difficult. Several circuits are shared by Receive and Transmit and will indicate problems different than Receive-only circuits. Logic is the key to repair, once you know what every circuit does and how they interact. In this chapter we'll examine those circuits unique to the receiver. After some basic theory, we'll start at the "front end" and work down to the speaker, catching other special circuits along the way.

THE TRANSISTOR AMPLIFIER

Although tube radios are still around, you'll do the most repair work on solid-state radios. ICs are widely used in modern transceivers but the plain old bipolar transistor is still the workhorse of a CB radio. Let's review a little about their operation.

Figure 4-1 shows the basic classes of bipolar transistor amplifiers again. NPN devices are shown but can just as easily be PNP types by reversing supply voltage polarities. The Common Emitter and Common Base are what you'll find most. Note again the input/output phase relationships of each. FETs are also used, both junction and dual-gate MOS types, most commonly in RF amplifiers, receiver mixers, and synthesizer mixers. You can identify a transistor's basic frequency range by the type of associated components; in this example they're low-frequency (audio or DC) circuits. The distinguishing feature of all RF/IF amplifiers is the use of tuned circuits rather than the RC circuits shown in the figure.

SINGLE-CONVERSION VS. DUAL-CONVERSION

Figure 4-2 shows block diagrams of the two basic CB receiver types: the single-conversion and double- or dual-conversion superheterodyne. ("Heterodyne" is another term for mixing.) The "superhet" has been around virtually unchanged since the early 1930s, which tells you something about its usefulness. Its most important advantage is that the bulk of the gain and selectivity takes place in a single narrow-bandwidth IF (or two, in the case of dual-conversion) regardless of the actual input frequency band. This allows simpler and cheaper circuits, since gain blocks are most effective when designed for a single frequency.

Techs have argued for years about the relative merits of each, but in my opinion there's only one real determining factor: cost. The dual-conversion circuit is more complicated, requires more parts, and is therefore more expensive. The main advantage of single-conversion is that fewer stages are needed to produce a given signal-to-noise ratio, since each stage adds more noise along the way. The reason AM/SSB single-conversion types are found at all in today's crowded bands is because improved manufacturing techniques allow more selective crystal IF filters to be used. But you get what you pay for and to prove it, compare the receiver performance of chassis like the Cobra 140/142GTL or 146GTL/PC244 (single-conversion) to the Cobra 148/2000GTL (dual-conversion) chassis on AM.

As shown, the dual-conversion circuit requires a second Local Oscillator (L.O.) and a second mixer stage. The IF frequencies are usually 10.695 MHz and 455 KHz, universal standards for which parts are readily available. Some popular chassis use a 7.8 MHz or 11.275 MHz IF in a single-conversion circuit, or as the high IF of a dual-conversion circuit with 455 KHz as the 2nd AM IF. There are a few unusual CB IFs, like the 4.3 MHz used in some Johnsons. The dual-conversion type has superior image rejection.

Incidentally, the reason for using the same IF path on AM and SSB in most single-conversion receivers is because only one of the two AM sidebands will be detected. Each sideband has exactly the same voice intelligence. Since SSB uses a very narrow IF filter, one AM sideband of up to 2.5 KHz width can pass through it, but not both. Another "economy" move...

FIGURE 4-1
BASIC TRANSISTOR AMPLIFIERS

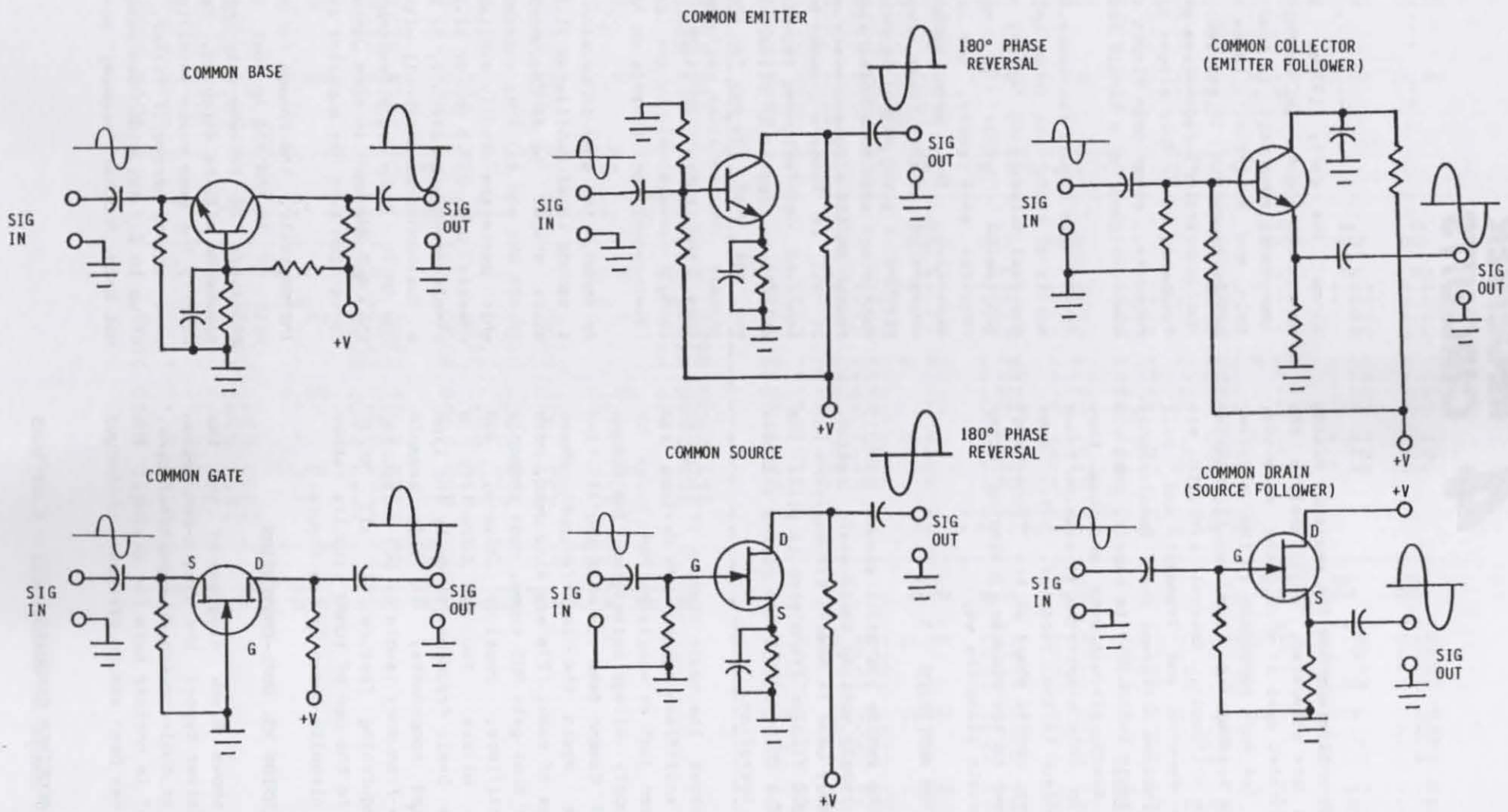
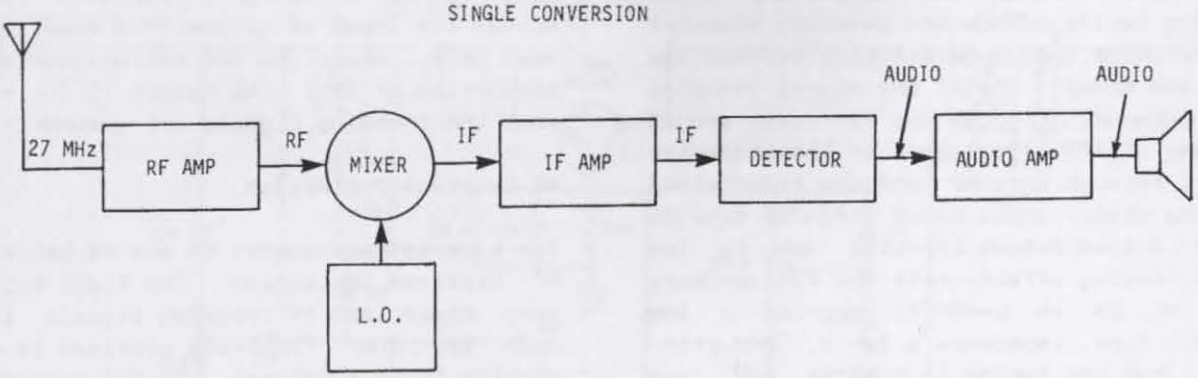
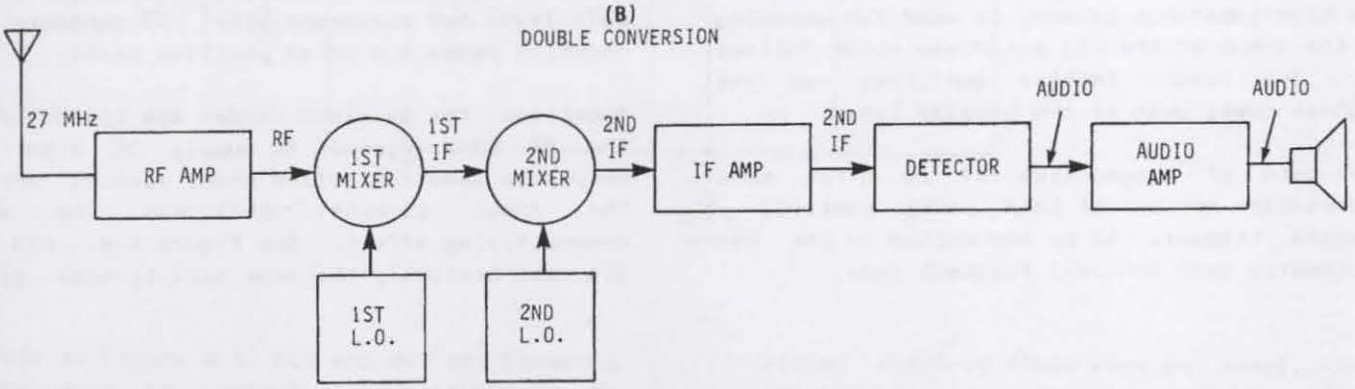


FIGURE 4-2
BASIC RECEIVER BLOCK DIAGRAMS

(A)
SINGLE CONVERSION



(B)
DOUBLE CONVERSION



THE RF AMPLIFIER

This stage is called the receiver "front end," since it's closest to the antenna. Depending upon its design relative to the mixer and IF stages, it may or may not affect performance greatly. The main purpose is to provide some selectivity ahead of the mixer and overcome the internal noise generated by the other stages. (Actually though at 27 MHz, external man-made noise has a greater effect on weak-signal reception.) Thus the RF Amplifier improves the Signal-to-Noise or S/N ratio.

A poorly-designed front end degrades the receiver's dynamic range by overloading the mixer, causing spurious signals. The RF stage is broadly tuned, since it must pass a band of frequencies rather than just one channel. For CB receivers a single active RF stage is all that's needed. Gain is typically 10-20 dB.

Symptoms of a bad RF amplifier stage include:

1. No Receive.
2. Signals very weak; can only hear extremely strong nearby stations.
3. Signal strenth fluctuates because AGC is missing.

There are basically four transistor RF amp circuits: the Common Emitter, Common Base, JFET, and dual-gate MOSFET. For CB use about 90% are split between the Common Emitter and Common Base; FETs are rare because they cost more than bipolar devices. You'll find FETs used mostly in radios from the old premium independent manufacturers like CPI, Johnson, Motorola, or SBE, all of whom priced themselves right out of the CB business!

Common Emitter RF Amp

Figure 4-3 shows a Common Emitter RF amp. Base bias is supplied from the resistive divider R12/R13. Tuned transformers before and after the active device narrow the passband somewhat and also provide impedance matching between the antenna and mixer. The 27 MHz signal couples from the antenna, through the pi-filter and L2 to the base of TR7. The output at the collector is coupled through another bandpass transformer (L3) to the mixer. Input tuned circuits tend to be lower Q than output circuits due to the antenna's loading effect; note the full primary winding of L2 is used to provide a low impedance. (Low impedance = low Q, and vice-versa.) Thus its tuning is broader and less critical than the output circuit, L3. Rather than using the secondary of L3, a sample from its high-impedance primary is used for matching to the input of the FET 1st Mixer which follows it. The Common Emitter amplifier has the highest power gain of the bipolar types.

The gain of stages like TR7 is often made adjustable by an RF GAIN panel control, a chassis trimpot, or by connection to the AGC (Automatic Gain Control) feedback loop.

The RF GAIN control is sometimes replaced by a simple "DX/LOC" switch using fixed resistor values. Regardless of the method, the effect is to control the gain by adjusting the bias on TR7, or by shunting a variable resistance across its input to ground. The shunt method is used here, where the AGC voltage controls the conduction of TR6; the harder it turns on, the more the incoming signals are grounded.

RF Overload Protection

The back-to-back diodes D1 and D2 below are for RF overload protection. The front end has a very heavy load of incoming signals impressed upon it, and front-end overload is a major problem in CB receivers. In the presence of a very strong signal or noise spike, the diodes turn on to clamp excess signal voltage at a safe level for the transistor. D1 conducts on negative peaks and D2 on positive peaks.

Sometimes the overload diodes are connected to the RF GAIN circuit to supply DC bias and therefore some controlled shunt loading across the input circuit; this has the same desensitizing effect. See Figure 4-4. D13 and D14 are basically the same back-to-back diode

FIGURE 4-3
COMMON EMITTER RF AMPLIFIER
(Cobra 29GTL, 29LTD, etc.)

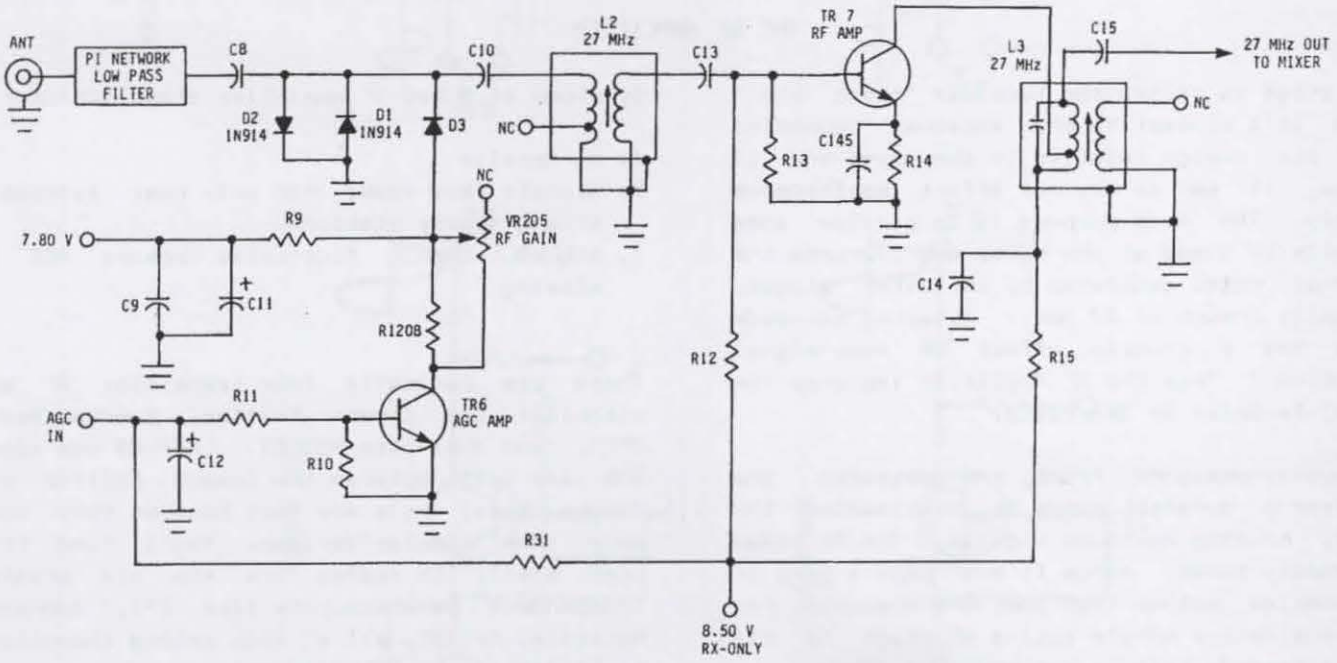
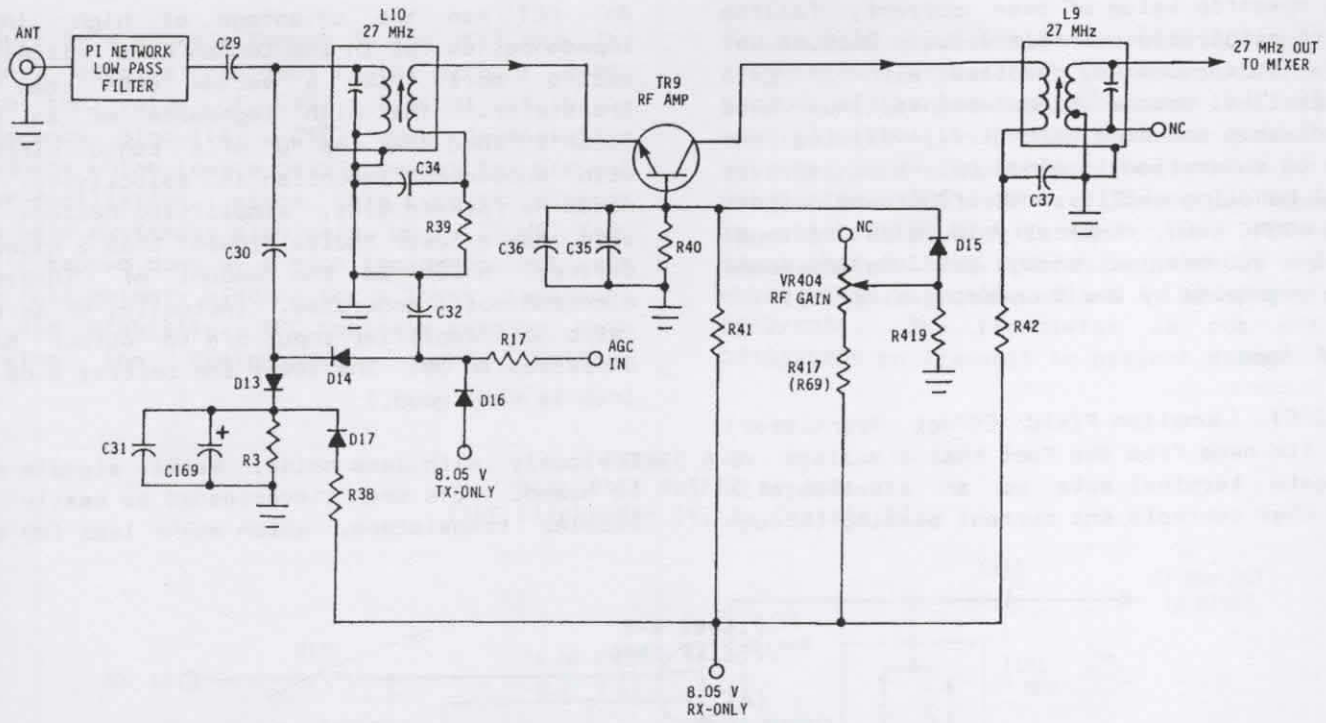


FIGURE 4-4
COMMON BASE RF AMP USING CONTROLLED LOADING FOR RF GAIN
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



circuit as Figure 4-3. D16 and D17 are steering diodes used to control T/R switching. On Receive D17 is turned on, reverse-biasing D13 somewhat. But on strong enough positive peaks, D13 conducts through C30 and C31. D14 clamps on negative RF peaks through C30 and C32. R17 applies AGC voltage proportional to the strength of the incoming signals, controlling the conduction of D14 and D13 to lower gain.

In the Transmit mode, D13 and D14 are heavily forward-biased by D16 and the Transmit-only voltage. This shunts any transmitted RF and prevents it from overloading and possibly destroying TR9. The use of such steering diodes for electronic T/R control is a common technique discussed further in CHAPTER 7.

The overload diodes are silicon types, which conduct at about 0.6 VDC. Sometimes replacing silicon types with germanium or hot-carrier diodes will improve a specific overload situation (like a close neighbor or truck stop) by lowering the turn-on voltage. But this could also generate IMD and other distortion if the diodes turn on too easily with normal signals. Silicon diodes were meant for this function.

If either overload diode were to short, the sensitivity would drop like a rock and produce the "No Receive" symptom, since there'd be a direct short across the signal input path. When troubleshooting this particular problem, check these diodes as well as the RF amp and its alignment. The RF overload circuit is especially important with electronic T/R switching, since the full transmitter output can be coupled directly into the front end if a shunt switching circuit fails to work right.

Common Base RF Amp

Figure 4-4 is a Common Base RF amp. The signal is coupled to the emitter of TR9 instead of the base. Otherwise the main difference is the input/output impedance ratios. The Common Base has a lower input impedance; note the use of the full L10 primary winding. In fact it's already close to 50 ohms, making it a better match for the 50Ω antenna input. The collector circuit has a high impedance, so the secondary of L9 is tapped down. This high impedance accounts for the high voltage and power amplification of the Common Base type circuit. The figure shows one possible method of RF GAIN

control; i.e., controlling gain by controlling the base bias on TR9.

The maximum gain for a bipolar RF stage occurs at a specific value of base current, falling off on either side of this value. Because of this, it's common practice with RF GAIN circuits to use a higher-than-optimum base current when reducing gain (i.e., driving the stage to saturation), since this also improves signal handling ability. The front end doesn't need much gain, typically 10-20 dB maximum. Ideally it has just enough gain to overcome noise generated by the succeeding mixer(s).

FET RF Amps

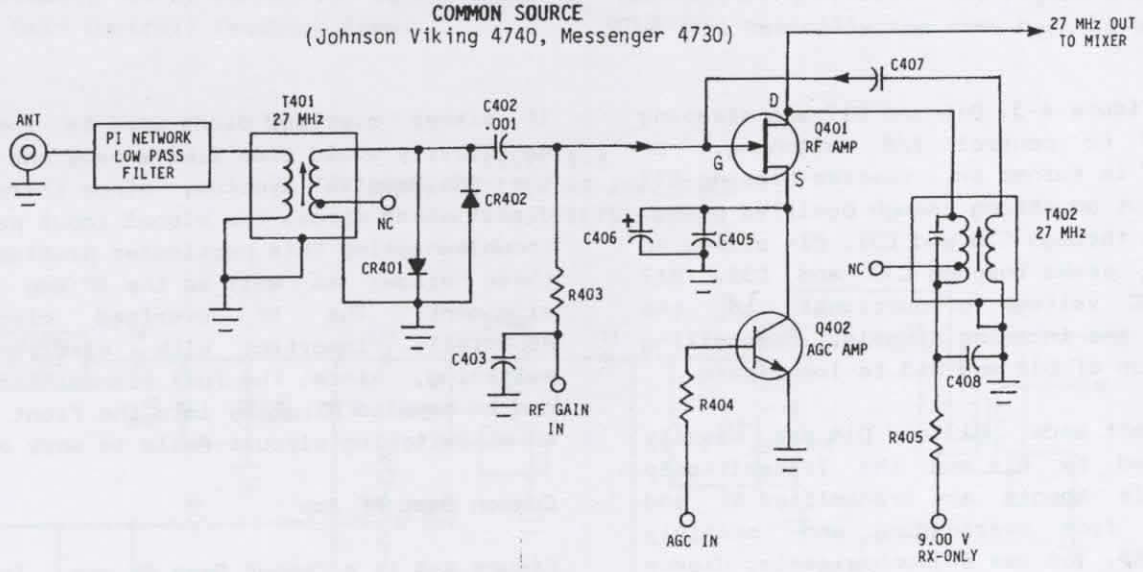
The JFET (Junction Field Effect Transistor) gets its name from the fact that a voltage on its gate terminal sets up an electrostatic field that controls the current passing through it, almost exactly like a triode vacuum tube. The more negative the gate voltage, the less current between source and drain.

An FET has the advantage of high input impedance (except in the Common Gate circuit), acting more like a vacuum tube than a transistor. The high impedance of an FET doesn't load down the "Q" of a tuned circuit with subsequent reduction in selectivity. It needs no forward bias, simplifying design. It also has a lower "Noise Figure" than a bipolar device, which is the amount of internal electron noise generated. (Actually, NF is the ratio of amplifier input S/N to output S/N, expressed in dB. The lower the better; 6 dB or less is very good.)

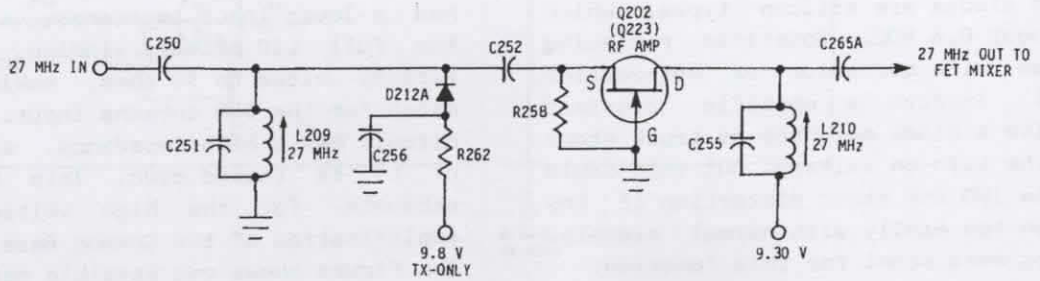
Obviously with less noise, weaker signals can be heard. FETs aren't overloaded as easily as bipolar transistors, which means less IMD and

FIGURE 4-5
JFET RF AMPS

(A)
COMMON SOURCE
(Johnson Viking 4740, Messenger 4730)



(B)
COMMON GATE
(CPI 300/400/2000)

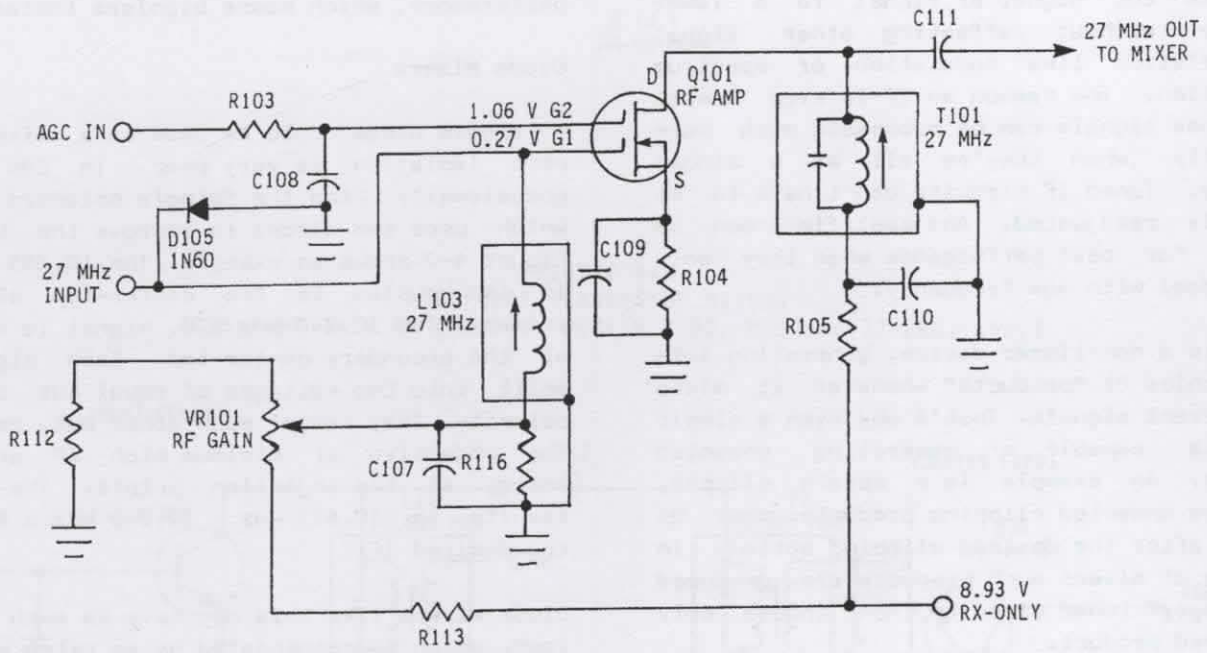


cross-modulation. Thus it offers the highest possible front end sensitivity and selectivity and greater signal handling ability (dynamic range) than a bipolar transistor.

Figure 4-5A shows a Common Source JFET amp. The signal couples from T401 to the gate of Q401. Note the value of C402, typical of high-impedance circuits. C407 adds degenerative feedback which lowers gain somewhat to prevent self-oscillation, since this type of circuit can have extremely high gain, up to 25 dB. T402 isn't tapped down at a high impedance, but uses the full primary winding for a lower impedance to aid stability. AGC controls gain by both varying the drain-source supply voltage directly (Q402), and by a negative-going feedback voltage on the gate (R403). C405 keeps the source at RF ground, while C406 adds the required AGC delay.

Figure 4-5B shows the Common Gate RF amp. This is much more stable than the Common Source type because of its lower gain, about 12-15 dB. No special stability precautions are needed. The extremely low input impedance makes a good match for a 50Ω antenna. The output impedance is relatively high to match the JFET mixer input that follows, which is no doubt why they chose this circuit. Class A biasing is by C252/R258. The transistor is cut off by D212A/L209 on Transmit to prevent damage.

FIGURE 4-6
DUAL-GATE MOSFET RF AMP
(SBE Sidebander IV, V, Console V)



In Figure 4-6 a dual-gate MOSFET is used. It has the same advantages as the JFET with even better dynamic range. The MOS construction is a special process in which the doped silicon acts like a variable resistor. The resistance is controlled by the gate bias, which in turn controls the drain-source current. The MOSFET requires a positive gate voltage to amplify, as shown. The signal is applied to gate 1 and the AGC bias to gate 2. RF gain is controlled by manually varying the bias on gate 1 through VR101 and the associated divider resistors.

Unlike JFETs, MOSFET gates are electrically insulated from the rest of the silicon wafer. (MOS means "Metal Oxide Silicon," the physical process of depositing the insulation on the wafer.) MOS devices are easily damaged by static electricity, which can punch right through the insulation; use proper handling techniques when replacing them. A germanium diode, D105, is included externally to help clamp large voltage spikes. Many MOSFET devices have internal diode protection (i.e., "gate-protected") which is also supposed to clamp

such spikes to a safe level. But don't count on it; use proper grounding procedures!

The MOSFET is far superior to bipolar transistors, but their higher cost makes them very rare in CB use. I was pleasantly surprised to find them used in the new Midland 77-250 for both the front end and the 1st mixer stages!

RF MIXERS

There are as many varieties of CB RF mixers as RF amplifiers. Again you'll find bipolar and FET devices as well as ICs and simple diode mixers. All of these except diode mixers are also used for synthesizer mixers, so knowing how they work will help you fix those too.

The purpose of the (1st) mixer stage is to convert the 27 MHz signal to a lower frequency, the Intermediate Frequency or IF, for further processing. (In tube radios it's often called the "converter" stage.) In dual-conversion receivers the IF is converted a second time to an even lower frequency. A mixer simply translates the higher RF signal to a lower frequency without affecting other signal characteristics like modulation or spectrum distribution. The reason an IF is even needed is because signals can be processed much more efficiently when they're all at a single frequency. Tuned IF circuits don't have to be constantly readjusted. And amplifiers can be designed for best performance when they only have to deal with one frequency.

A mixer is a non-linear device, generating lots of harmonics or "products" whenever it mixes two different signals. That's why even a simple diode is capable of generating unwanted harmonics. An example is a speech clipper, where the unwanted clipping products must be removed after the desired clipping action. In the case of mixers such products are produced on purpose; tuned circuits then choose only the desired product.

Mixers can be divided into the general classes of active and passive. The passive kind uses diodes and ideally has no loss or gain, but in practice does have several dB loss. At 27 MHz diodes also generate a lot of noise. Since they have no gain, they need much higher L.O. injection voltages. Their advantages include circuit simplicity and strong signal-handling ability. Since diodes are naturally broadbanded they have a wide dynamic signal range. Active mixers may have up to several dB gain, reducing the L.O. injection requirements. A careful mixer design adds very little noise. About 90% of CB mixer circuits use active devices, mostly bipolar transistors but occasionally FETs in some better models.

Mixer design considerations include: level of available L.O. injection, isolation between the two signal injection ports, IMD, and noise. The mixer should receive only enough incoming signal to overcome its own noise. Extremely strong input signals result in desensitization, cross-modulation, and IMD. Thus the mixer must handle strong signals well, which normally means an FET for the active device. Unfortunately for CB use the tradeoffs are usually low cost and simplicity vs. high performance, which means bipolars instead.

Diode Mixers

A single diode could be used as a mixer, but port isolation is very poor. In CBs you'll occasionally find the "single balanced mixer" which uses two diodes to improve the balance. Figure 4-7 shows an example. The 10.695 MHz 1st IF is coupled to the center-tap of T13's primary. The 10.240 MHz L.O. signal is injected at the secondary center-tap. Each signal is split into two voltages of equal but opposite polarity. They cancel each other out, realizing the objective of minimum high IF and L.O. energy at the injection points. The mixing results in 10.695 MHz - 10.240 MHz = 455 KHz, the desired IF.

Diode mixers like this may have as much as 8 dB loss, which is compensated by an extra stage of IF amplification following the mixer. Note the diodes are germanium; the 10.695 MHz IF is very weak at this point, and the lower turn-on voltage of germanium is desirable. If a mixer diode ever needs replacement you should replace the pair, matching both for equal forward resistance with your ohmmeter.

The new Midland 77-250 uses a similar active balanced mixer, with FETs instead of diodes for even better performance. (Incidentally, this rig is one of the hottest new receiver designs in a long time, with great sensitivity and selectivity!) FET replacement in such radios should also include both devices of a pair.

FIGURE 4-7
SINGLE-BALANCED DIODE MIXER
(Cybernet PTBM048 chassis: J.C. Penney 981-6247,
Lafayette Telsat SSB140, Midland 79-892, etc.)

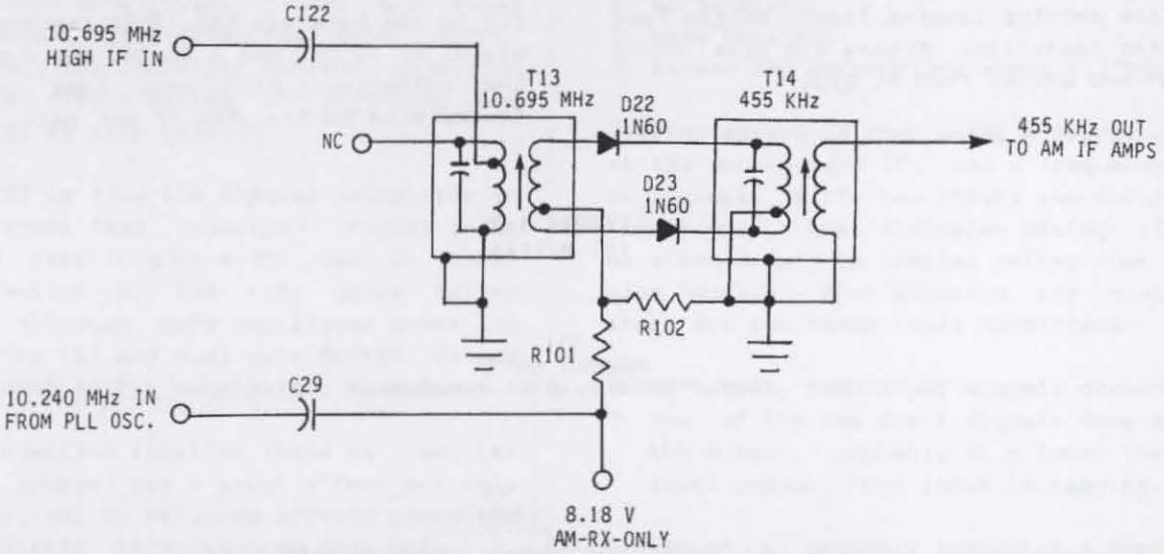
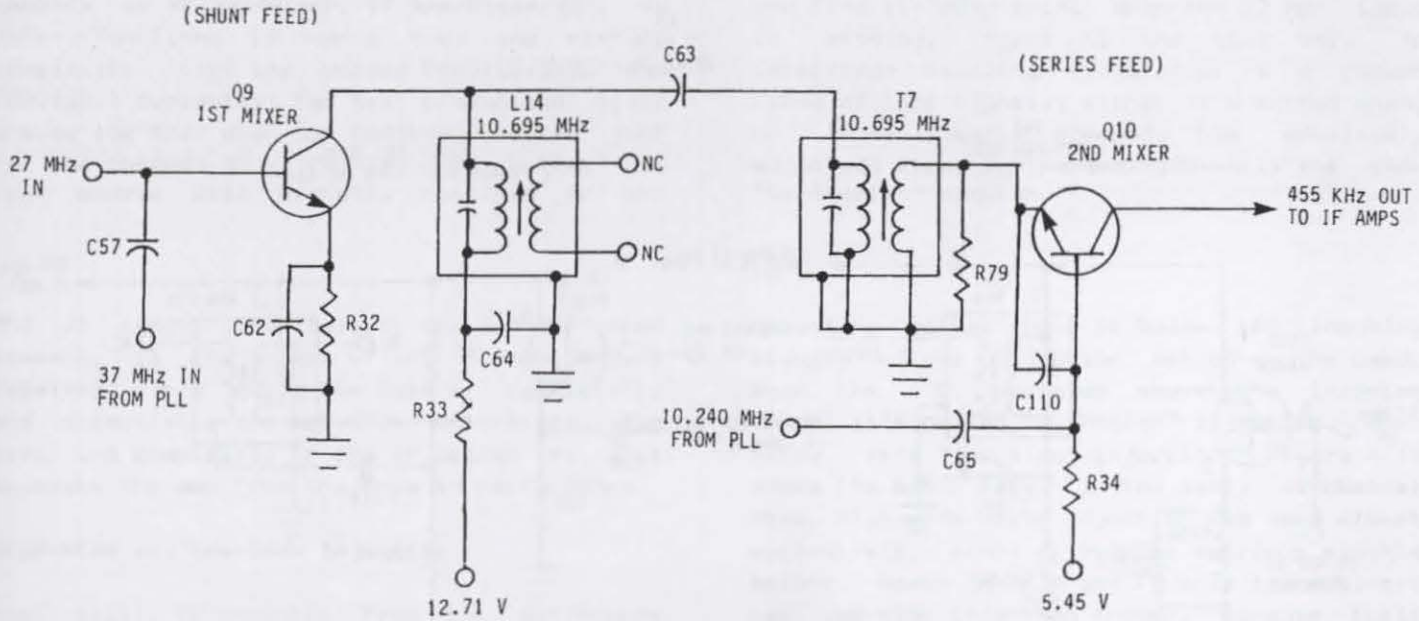


FIGURE 4-8
BIPOLAR TRANSISTOR MIXERS
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)



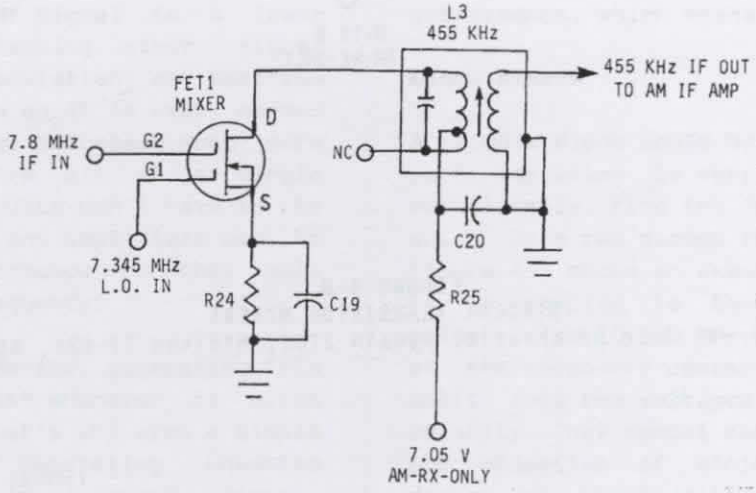
Bipolar Transistor Mixers

This is the most common active mixer device. Usually both mixing signals are applied to the base (shunt feed), although you'll also see the RF and L.O. signals applied to both the base and the emitter (series feed). Series feed gives better isolation. Figure 4-8 uses shunt feed at Q9 and series feed at Q10.

Q9 combines the 27 MHz input and the 37 MHz PLL input at the base. The Ch.1 synthesizer input is 37.660 MHz, giving the IF of 37.660 MHz - 26.965 MHz = 10.695 MHz at Q9's collector. The 2nd mixer, Q10, couples the 10.695 MHz input to its emitter via T7 and the 10.240 MHz from the PLL to its base via C65. This results in the IF signal of 10.695 MHz - 10.240 MHz = 455 KHz at the collector. C110 adds some degenerative feedback to control the IF amp gain.

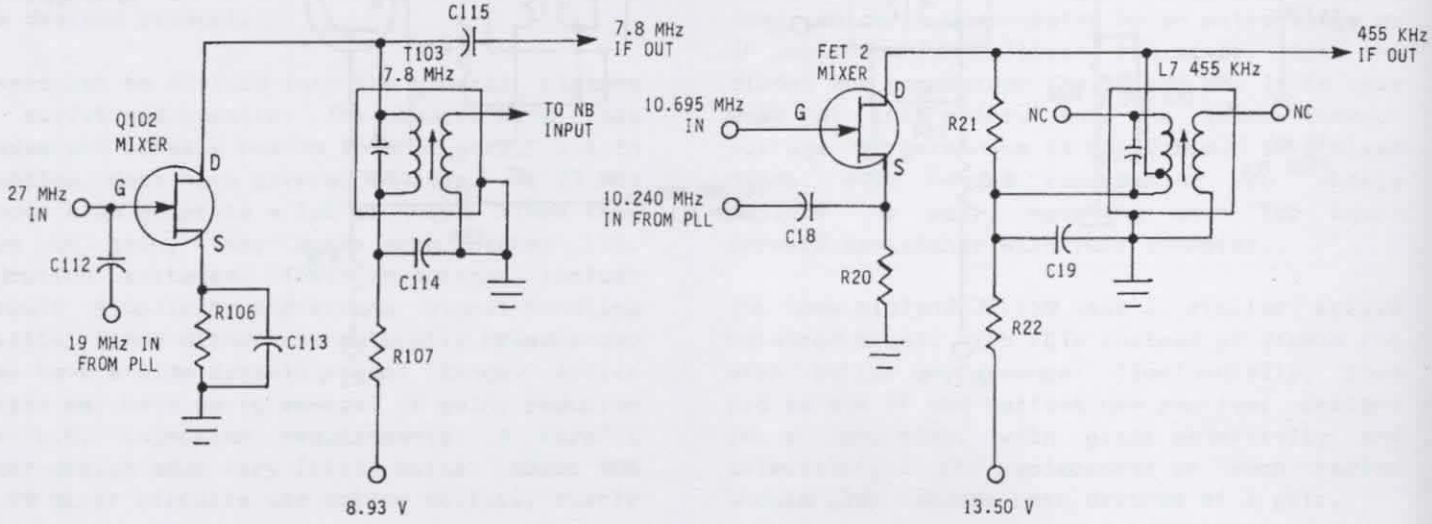
FIGURE 4-9
FET MIXERS

(A)
DUAL-GATE MOSFET
(Cobra 148/2000GTL, Uniden Grant/Madison)



(B)
SHUNT-FED JFET
(SBE Sidebander IV, V, Console V)

(C)
SERIES-FED JFET
(Cobra 29GTL, 29LTD, etc.)



FET Mixers

The JFET or dual-gate MOSFET has superior mixer performance. The greater signal handling ability makes them more resistant to overloading and IMD. The lower Noise Figure also improves sensitivity. Figure 4-9 shows three examples. With the dual-gate MOSFET (Figure 4-9A), the isolation between injection ports is a simple matter of injecting one mixing signal at each gate.

Note the JFET is like the bipolar transistor in that both shunt feed injection (Figure 4-9B) and series feed (Figure 4-9C) can be used. Source injection of the L.O. gives better isolation, although more oscillator power is required. The FET and dual-gate MOSFET mixers are also common in PLL synthesizer circuits.

The L.O. injection location (base vs. emitter or gate vs. source) has a great effect not only on isolation, but on required driving power and loading. Emitter injection requires more L.O. drive voltage but has the advantage of lighter loading on the synthesizer oscillator that drives it. On the other hand the lower drive requirement for base injection, which has a lower impedance, means more driving power is taken from the driving stage. That's why a VCO Buffer stage is often added between the synthesizer and mixer to minimize such loading.

There's now a small trend towards ICs which combine an RF Amp/Mixer, IF Amp/Mixer/AGC, or other functions to reduce cost and circuit complexity. (Like the Uniden PRO510E/520E and PRO710E.) Currently, Far East production costs are so low that such use has been limited just to the cheaper AM or FM rigs. The better SSB type models will probably continue to use discrete components for a long time yet.

MIXER TROUBLESHOOTING

The symptoms of a faulty receiver mixer are:

1. No Receive.
2. Weak Receive.
3. Excess IMD or spurious signals ("birdies").

Testing mixers is done using a signal generator at the appropriate IF, and a frequency counter or 'scope. With two inputs you should see a 'scope output that indicates mixing. (I.e., the waveform should be complex rather than a single sine wave.) When checking the mixer stage there are two basic fault conditions:

1. No output, both input signals present.
2. One of the two input signals does appear in the output, probably at a lower-than-normal level though. (One input is missing.)

Condition #1 probably indicates a dead active mixer device. Check its DC voltages and interpret them. If the device is good you'll have to check associated parts like resistors, capacitors, coils, etc.

For #2, one input is missing and you'll have to trace back to its source to find the open signal path. If the IF is missing, inject one from your signal generator into the base/gate to confirm it. Or backtrack to the L.O. until you find its open point. When the 27 MHz input is missing, inject it the same way. An interstage coupling transformer is a common cause of lost signals; either it's burned open, or (more likely) somebody has previously adjusted it wrong, producing exactly the same "No Receive" symptom.

IF AMPLIFIERS

The IF stage, particularly the 2nd IF when present, is the heart of any communications receiver. It's where the bulk of sensitivity and selectivity are actually determined. The care and complexity of the IF design are what separate the men from the boys in performance.

High-Side vs. Low-Side Injection

The (1st) IF results from the difference between the incoming 27 MHz frequency and the L.O. frequency at the (1st) mixer. Since these difference frequencies can result from the L.O. operating either above or below the incoming signal, either injection method can be used. When the L.O. operates above the incoming signal it's called "high-side" injection. When below, it's "low-side" injection. Figure 4-10 shows the basic idea. In the early 40-channel days, high-side mixer injection was used almost exclusively, since it reduces spurious signals better. Newer AM-only and FM-only transceivers use low-side injection though, because their synthesizers can now use a 16 MHz VCO signal directly, eliminating the downmixer. Again, an economic tradeoff of parts vs. performance.

FIGURE 4-10
MIXER INJECTION METHODS

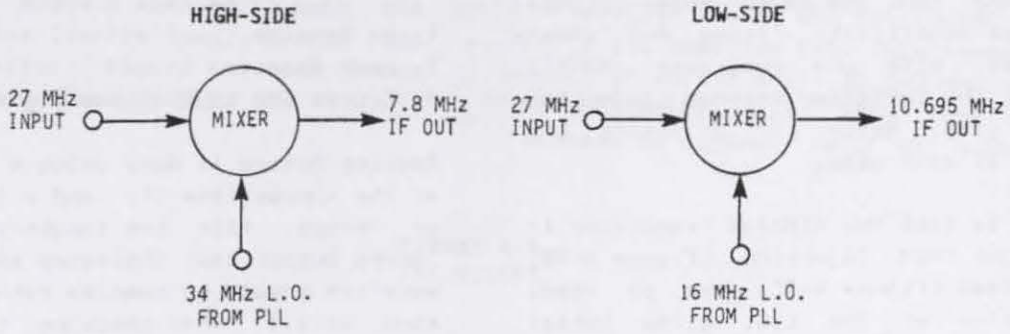


Image Rejection

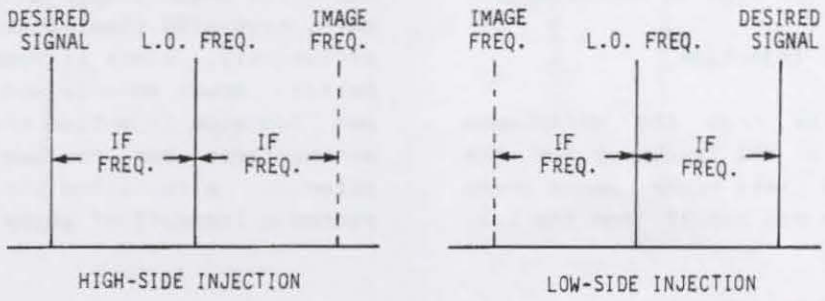
A basic mixing problem is the generation of "image" frequencies. It's most noticeable in single-conversion receivers. See Figure 4-11. Mixing causes not only the desired sum or difference frequency to be generated, but also an image frequency which is the same as the IF but on the opposite side of the L.O. from the desired IF. Since its mixing results in the same IF frequency, it can easily pass through the IF amplifier and degrade performance.

An example might be a single-conversion receiver with a 1 MHz IF, tuned to a station at 20 MHz. Using high-side injection, this means the L.O. would be at 21 MHz. (21 MHz - 20 MHz = 1 MHz, the IF). Now suppose there was a strong undesired station at 22 MHz. This station would produce the same 1 MHz IF, but on the opposite side of the L.O.: 22 MHz - 21 MHz = 1 MHz. Even though the front end is tuned to 20 MHz, it's not selective enough to eliminate the 22 MHz signal completely. So what happens? Both the 20 MHz and the 22 MHz signals look "right" to the IF, and are amplified and passed along. If the undesired station is strong enough it can totally wipe out the desired station!

From this example you can see it's the ratio of the desired frequency to the IF frequency that's important. By using a much higher IF like 7.8 MHz or 10.695 MHz, image rejection is greatly improved because the images are so far removed from the desired frequency (in this case 7.8 MHz or 10.695 MHz away) that they're out of the passband. The tuned circuit might pass something 1 MHz away, but not 8 MHz away. This is why a high IF is always chosen when designing single-conversion receivers.

The tradeoff in doing this means reduced gain and selectivity. The choice of IFs is therefore a compromise between several important factors. That's why the dual-conversion receiver, which has more tuned circuits, generally offers better performance; not only is image rejection improved with a high first IF, but a second IF conversion offers cheap selectivity and gain too. It's the best of both worlds...

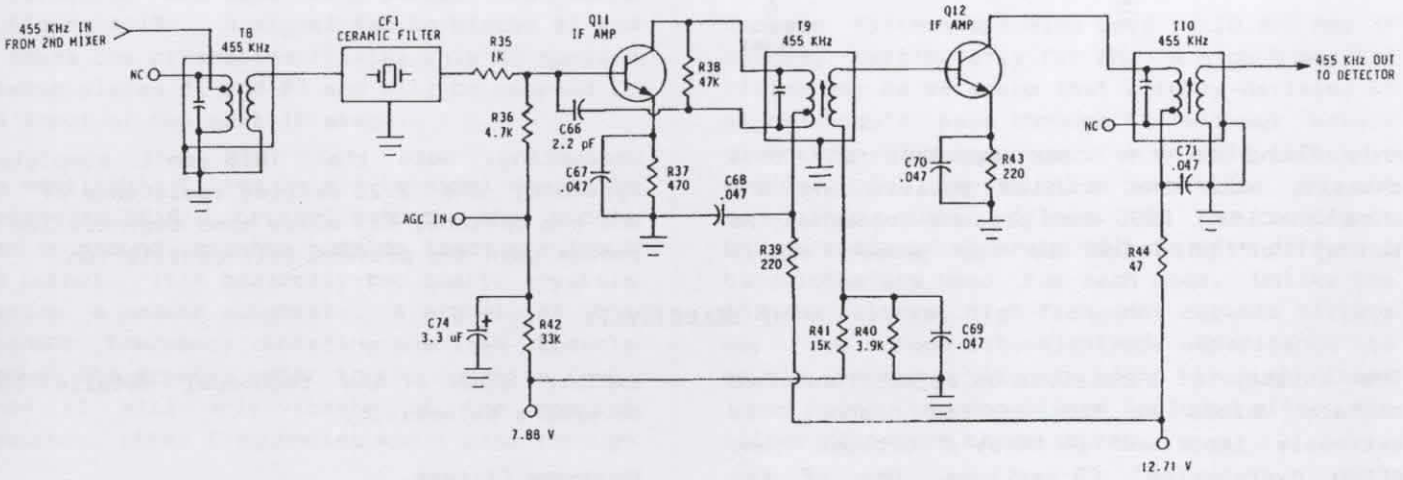
FIGURE 4-11
MIXER IMAGE FREQUENCIES



Images can't be removed after the fact; the only way to eliminate them is by good selectivity before the mixer stage. This selectivity is achieved by the use of crystal and ceramic filters in the high and low IF stages respectively. Dual-conversion receivers rarely use amplifiers at the high IF, because it's cheaper to get the gain and selectivity at the lower IF frequency. (Ceramic filters are cheaper than crystal filters.) The purpose of the high IF is to improve image rejection by the addition of its tuned circuits.

For FM, images aren't a problem because of its inherent "capture effect." If more than one station is present only the strongest signal will even be detected; it captures the channel. On AM or SSB, all signals passing through the IF can be heard by a listener.

FIGURE 4-12
TYPICAL 455 KHz IF STRIP
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)



Typical IF Amplifier Strips

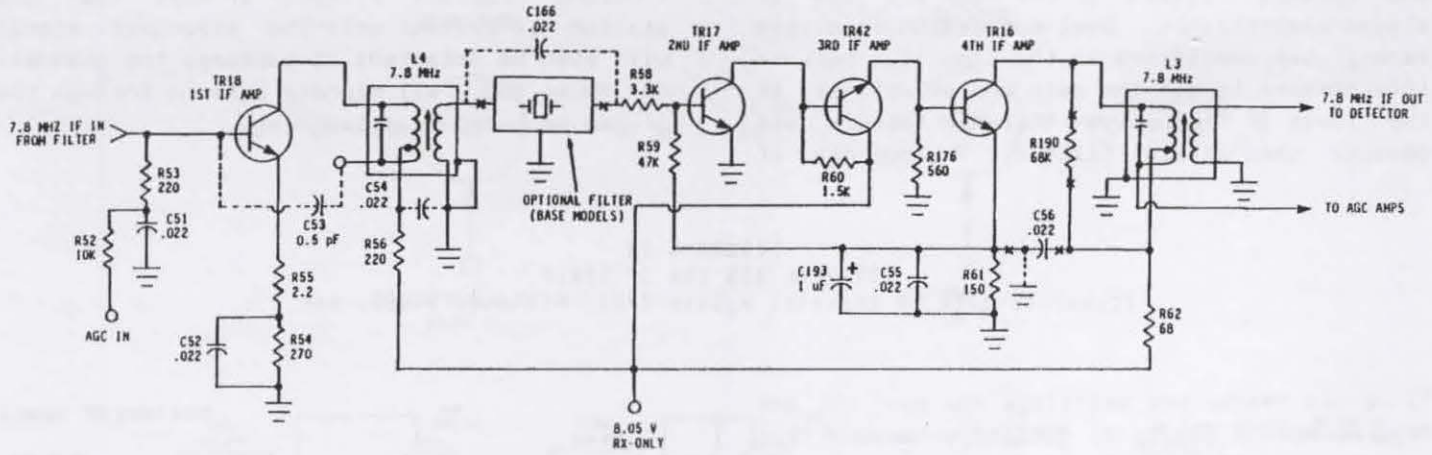
Figure 4-12 shows the IF stages of a very common dual-conversion AM/FM receiver. Bipolar transistors in the Common Emitter configuration are almost always used. Inputs are at the base, outputs at the collector. There are several tuned transformers and one or more ceramic filters to shape the passband response and improve selectivity and adjacent-channel rejection. Voltage gains in transistor IF amps are about 10 dB, depending upon the number of filters and tuned circuits. This particular circuit will be described in more detail later.

DC coupling between transistor IF amps is also commonly used, like the improved IF strip of Figure 4-13. This is popular in all the Uniden SSB (American and export) models. TR42 is actually not an amplifier; it's an Emitter Follower (i.e., Common Collector) circuit that couples TR17 to TR16. This is like the Cathode Follower in tube circuits, where a high-to-low impedance change is needed. Think of it as a buffer stage. The name comes from the fact that the emitter voltage "follows" the base voltage, always being 0.6 V lower. TR42 saves the cost of another interstage transformer but more importantly, it preserves the high gain of TR17 by virtue of its high input impedance. You can always couple from a low impedance into a higher impedance, but never the other way around without losing a lot of signal.

The net result is greater signal handling ability and dynamic range without the kind of desensitizing and blocking suffered by less sophisticated designs. The AGC spec for this popular chassis is typically 80-90 dB, which is excellent. If you've ever listened to one of these, you know it's practically impossible to shut it down with a strong signal.

The "Xs" and dotted lines in the drawing indicate optional parts which may only be used if needed. The 7.8 MHz monolithic filter is

FIGURE 4-13
TYPICAL DC-COUPLED IF STRIP
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



only found in the base versions of this chassis, with the mobiles substituting the cheaper C166. R190 when present broadens the tuning of L3. C56 is for power supply decoupling. Note that TR18 isn't completely bypassed; the 2.2Ω emitter resistance of R55 and the optional C53 allow some degeneration to reduce gain and prevent self-oscillation.

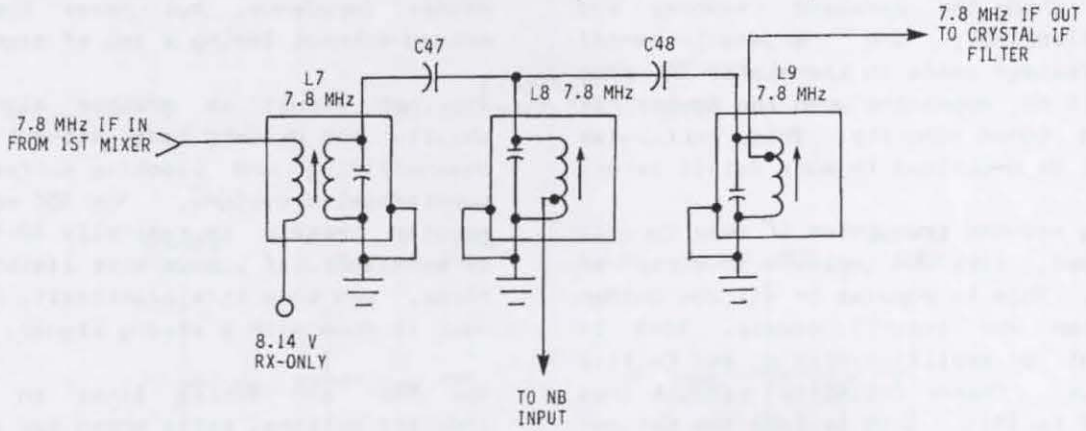
IF SELECTIVITY

The ability of a receiver to reject unwanted signals close to the desired channel is extremely important in today's crowded (and often overpowered) CB services. One of the most common complaints of CB operators is "bleedover" interference from strong local stations that may be many channels away from the actual channel being received. Let's explore some of the technical details that determine selectivity.

Bandpass Filters

The high IF stages may or may not have additional selectivity besides the transformers themselves. One of the best ways to establish

FIGURE 4-14
BASIC IF SELECTIVITY USING BANDPASS FILTER
(Cobra 148/2000GTL, Uniden Grant/Madison)



some basic selectivity after the 1st mixer is with a bandpass filter. Figure 4-14 shows an example. It consists of two or three capacitively-coupled IF transformers. This gives a good response characteristic and better bleedover rejection than the more conventional inductively-coupled IF stages found in tube radios. Its relatively broad response isn't that important anymore, because now there are inexpensive crystal and ceramic IF filters to increase selectivity further downstream.

Monolithic IF Filters

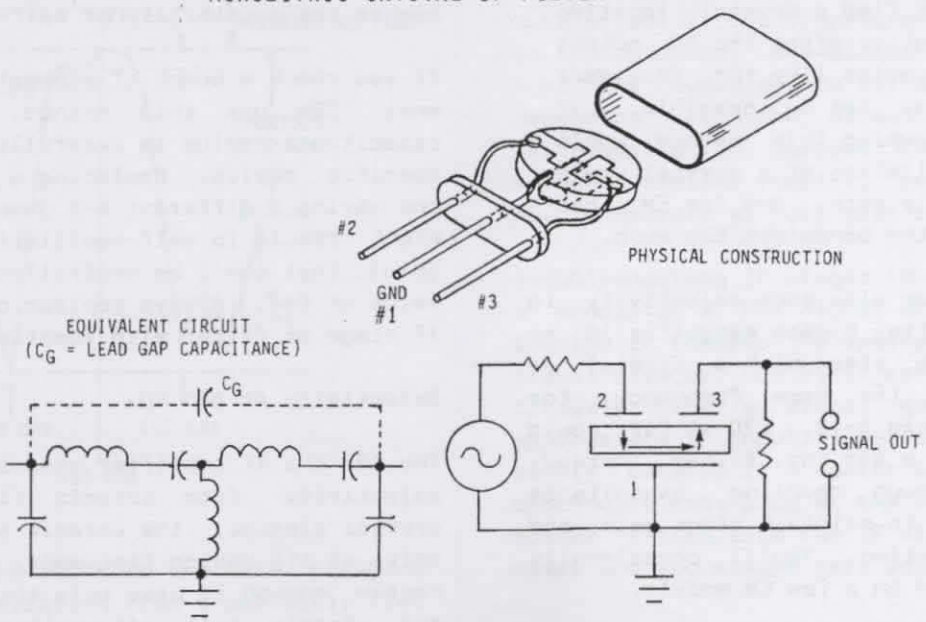
Besides a bandpass filter, the better models will include a 10.695 MHz "monolithic" crystal filter between the 1st and 2nd mixers. Its construction and equivalent circuit are shown in Figure 4-15. A signal fed to plates #1 and #2 makes the crystal oscillate; this AC appears between plates #1 and #3 and will be coupled to the input of the next IF stage.

The monolithic filter is a 3-terminal device in a standard HC18/U crystal holder; the middle lead is ground, and the outside leads are input and output. It's basically two quartz crystals sharing a common substrate. A signal at the resonant frequency entering one lead travels through the crystal wafer to the opposite lead. Since it will only vibrate at the correct frequency, other frequencies won't pass through and are sharply attenuated. The thickness of the wafer at the two points determines its bandpass characteristic. In CB IFs they've been used quite effectively for interstage coupling at 10.695 MHz and 7.8 MHz.

For base and mobile CBs having the same main chassis, you'll often find a monolithic crystal filter only in the base versions; the mobiles will substitute a capacitor in the two input/output holes to couple the IF signal across. Examples include the Cobra 138/139XLR chassis, and the Cobra 140/142GTL chassis. Selectivity in the mobile versions can be greatly improved by replacing this capacitor with the missing monolithic IF crystal filter. These can be ordered from Cobra, Uniden, or us.

Ceramic filters are also used in 10.695 MHz IF stages, particularly for FM. A high-Q crystal filter may be so sharp that a fully-deviated FM signal can't pass through it without severe distortion. The response of a ceramic filter is broader. Its construction is similar to the monolithic quartz filter. In the multimode Uniden radios, separate filters with different bandwidths are used for each mode. Unlike the 455 KHz filters, high-frequency ceramic filters may have enough interelectrode capacitance to couple spurious signals right through them. Tuned circuits are always included after the filter to remove these spurs.

FIGURE 4-15
MONOLITHIC CRYSTAL IF FILTER



Tips On Improving Selectivity

Selectivity can often be vastly improved by the simple addition of an ordinary series coupling crystal in the high IF stage. This applies to both tube and solid-state transceivers. Most of these stages are capacitively coupled, like C47 in Figure 4-14. Remove the capacitor and install the crystal instead. Solder a wire to the crystal case and ground it to the chassis common foil. The most eligible radios are those with a first IF of 7.8 MHz, 10.695 MHz, 11.275 MHz or 9.785 MHz. (This is the idea behind our **CHANNEL GUARD** IF filters, except they're even sharper than a single crystal.) When ordering crystals, specify the series mode type, 10 pF load capacitance, solder leads.

You can do the same for tube radios, which often had no IF filtering at all. Add a 455 KHz ceramic filter in the low IF. In those circuits there wasn't always a coupling capacitor, so you might need to cut a hard PC trace between the 2nd mixer and the 1st 455 KHz IF amp to do it. And if money's no object, replace a coupling capacitor in a 455 KHz stage with a 455 KHz crystal (cost about $20) instead of a ceramic filter. In vintage radios like the Trams and Brownings the cost is justified, since this can add tremendous IF selectivity.

> CAUTION: If the radio has a Noise Blanker, don't use this technique when the crystal location falls inside the NB loop, since the increased selectivity will lengthen the noise pulses and make them harder to remove. You must find a crystal location before the NB input or after the NB output point. In some radios like the President Jackson, this may not be possible. If stages are DC-coupled this method won't work, since installation of a crystal would block the DC supply path. And for FM, this trick may narrow the bandwidth too much.

Another method which also adds selectivity is to replace the emitter bypass capacitor in an appropriate IF amp stage with a crystal or ceramic filter of the same frequency. For example back in Figure 4-12, C70 at Q12 could be replaced with a 455 KHz filter instead; there's still enough coupling capacitance through the filter to maintain stage gain and prevent AC degeneration. You'll occasionally see this method used in a few CB models.

Finally, in circuits where the IF transformer windings aren't needed to supply DC to the transistors or tubes, you could simply replace the transformer itself with a filter soldered across the appropriate input and output signal connections. This trick is especially useful in older radios that used double-tuned IF coupling transformers between the active stages.

Controlling Filter Response

The passband response of an IF filter is critically dependent upon proper impedance matching of its input and output terminals. Any change in input or output impedance will effect the response characteristic. Too high an impedance will increase its "Q" and sharpen the bandwidth, with possible self-oscillation; too low an impedance and the bandwidth becomes too broad. In many circuits the impedances are controlled by tuned circuits on both sides. In others the input has a tuned circuit but the output couples to the base of the following stage through some series resistance of about 2KΩ or less. Since IF amplifiers are always Common Emitter types, the typical 2KΩ input impedance can be easily matched this way.

To keep the input impedance of the succeeding stage as constant as possible, it's carefully biased and usually includes some degenerative feedback to control gain. Returning again to Figure 4-12, the small capacitor C66 supplies a bit of collector-to-base feedback on Q11. Since Q11 is a Common Emitter amp, this feedback is 180° out of phase with the base and will lower its gain. (Remember, the higher the gain, the higher the possibility of self-oscillation.)

If you check a bunch of schematics, you'll find most CBs use this method. The feedback capacitance value is carefully chosen for the specific device. Replacing a transistor with one having a different b-c junction capacitance might result in self-oscillation (or reduced gain) that can't be controlled by the existing value of C66. Always replace components in the IF stage or filter with identical types.

Selectivity At 455 KHz

The 455 KHz IF amplifier stages get their basic selectivity from ceramic filters. Like a crystal element, the ceramic element resonates only at its design frequency. This makes it narrow enough to pass only the desired signal and sharply roll off anything outside this passband. Most AM and FM CBs use a single

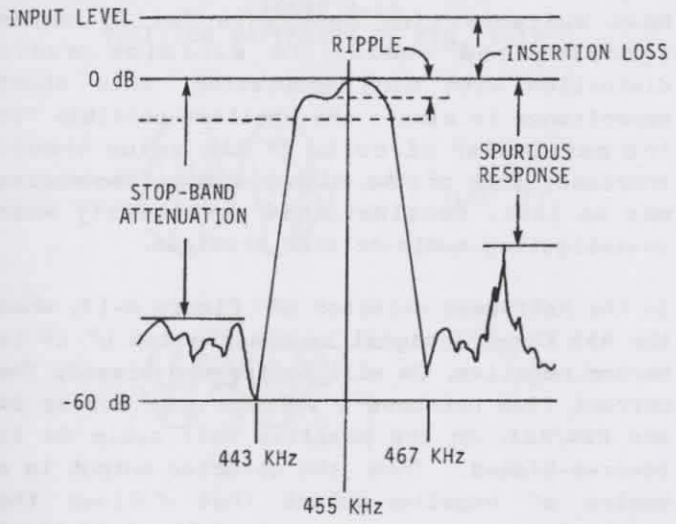
Murata CFU455H or CFW455H filter, a small plastic block having three or five leads respectively. Radios like the Tram D201/D201A and Midland 77-250 may cascade two or three of these to sharpen the selectivity even more. Many older tube-type radios had no filtering at all; they were made in the uncrowded (!) days of CB radio, when selectivity and bleedover weren't problems. Following are the specifications for the Murata filters; note the "CFW" series with its greater number of resonators has slightly better rejection.

MODEL	CENTER FREQ.	-6 dB WIDTH	-50 dB WIDTH	STOP BAND ATTEN.	INSERTION LOSS	IN/OUT IMPEDANCE
CFU455H	455 KHz	±3 KHz	±10 KHz	25 dB	6 dB	2KΩ
CFW455H	455 KHz	±3 KHz	±9 KHz	35 dB	6 dB	2KΩ

IF Skirt Selectivity

The IF "skirt selectivity" is a graphic representation of a particular receiver filter characteristic. When the preceeding specs are plotted on a graph of attenuation vs. center frequency like Figure 4-16, the result is a curve shaped like a bell or a woman's skirt. The steeper the sides, the better the selectivity. But a tradeoff with extremely narrow passbands is that frequency stability is much more critical; as a practical matter the real bandwidth is often made wider than the minimum possible to compensate for drift.

FIGURE 4-16
IF "SKIRT" SELECTIVITY



The flat top of the skirt is the main passband response. Any deviation from a perfectly flat response is called "ripple" and means that all IF frequencies aren't being passed equally. A good filter shouldn't exceed 1-2 dB of ripple.

IF TROUBLESHOOTING

Problems related to the IF section include:

1. No Receive.
2. Weak Receive.
3. Audio distortion.
4. Squeal (self-oscillation).
5. Improper (or no) AGC action.
6. Poor selectivity.

The most common failures are the transistors, coupling transformers, capacitors, or filter element, in that order. Opens and shorts in any of these will kill the normal signal level. Misalignment of transformers causes similar symptoms and is extremely common, since there are "screwdriver wizards" everywhere these days! Improper alignment of the IF can be more subtle too: if the transformers aren't centered in the passband, the sidebands may be cut such that the audio sounds either tinny or bassy, depending upon the direction of mistuning. Self-oscillation narrows the IF response to produce similar results, and also causes the AGC to operate at full gain reduction.

Troubleshooting IF stages is done by injecting a modulated 27 MHz signal at the front end and tracing it towards the speaker with a 'scope or signal tracer, or by injecting the IF signal directly from a signal generator into the appropriate IF input. I prefer the first method simply because it's easier to attach a quick-disconnect coax plug at the coax socket than to solder a lead into the IF stage. It's not as messy and you always have both hands free.

Remember that receiver signal levels at this point are extremely low, making them very

difficult to view directly on a 'scope even with inputs of several thousand microvolts. The signal tracer method is easier, since you just listen for the modulated signal as you probe, without having to take your eyes off the PC board. There's nothing more aggravating than accidentally blowing a good circuit with a test probe that slips and shorts something!

Probe your way from inputs to outputs until the signal is lost. It may be something obvious, like an open transformer or ceramic filter. More likely it's the active device. Measure the transistor voltages and interpret them. If you don't find an obvious short or open and voltages appear normal, suspect a capacitor like the emitter bypass. (Like C67 or C70 in Figure 4-12.) An open bypass will drastically reduce stage gain.

DIODE DETECTOR CIRCUITS

Diode detector circuits in CB radios are very straightforward. But there are several detectors besides the one for audio, like those for AGC and S-Meter voltages, and sometimes squelch. The Automatic Noise Limiter (ANL) is also found in this general circuit area. With all these extra diodes, it's hard to tell which recover audio and which perform the other functions. If unmarked on the schematic, you can usually tell the audio detector by backtracking from the VOLUME control wiper.

There's little to go wrong with detector circuits. Either the diode's working or it's open, leaky, or shorted. This can be checked very quickly with some front-to-back ohmmeter measurements like any other diode. (NOTE: most Detector diodes are germanium and normally show higher reverse leakages than silicon.) With all the other diodes around the audio diode, it's possible to detect audio even if the actual audio diode is bad. You have to logically match the symptom with the appropriate stage being affected, such as:

DETECTOR DIODE

1. No receiver audio, S-Meter working.
2. Weak receiver audio.
3. Distorted audio.

S-METER/AGC DIODE

1. No S-Meter function, receiver audio normal.
2. Weak receiver audio due to excess gain reduction from faulty AGC detector.
3. Extremely garbled or distorted audio on strong signals due to total lack of AGC action; RF/IF amps running at full gain.

ANL DIODE

1. No receiver audio with ANL switch turned on.
2. No ANL noise supression.

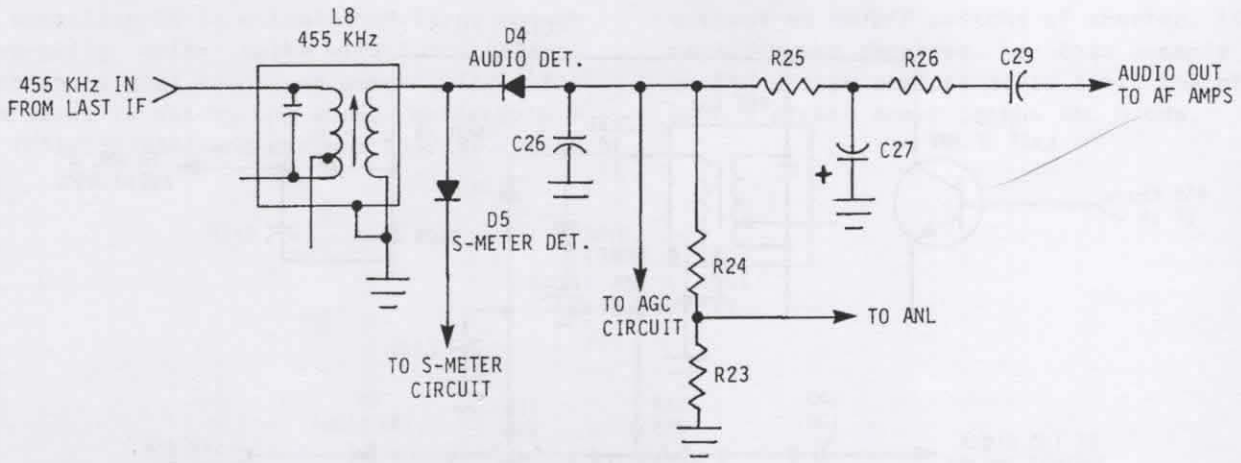
The AM Audio Detector

Most AM CBs use one of two detector types: the half-wave, and the voltage doubler. These are identical to those used in DC power supplies. The simplest and cheapest is the half-wave using a single diode in series with the IF signal path. Detector diodes are always germanium (1N34, 1N60, 1N270, ECG109, etc.) for their lower turn-on voltage. Since diodes are low-impedance devices when conducting, they do load down the last IF stage and reduce its selectivity somewhat. But the lost selectivity isn't a problem as long as the detector is working properly and the last IF transformer wasn't previously replaced with the wrong impedance type. Hopefully the real selectivity occurred long before the last IF stage!

The detector is always followed by RF decoupling and a low-pass filter. Bypass values range from about 470 pF to .0068 µF, which have suitable time constants for RF while ignoring the audio. To minimize audio distortion with high modulation, this shunt capacitance is always the smallest possible for the particular circuit. If the value should increase, some of the higher audio frequencies may be lost. Consider this possibility when investigating audio-related problems.

In the half-wave detector of Figure 4-17, when the 455 KHz RF signal causes the top of L8 to become negative, D4 will be forward-biased. The current flow produces a voltage drop across D4 and R24/R23. On the positive half cycle D4 is reverse-biased. Thus the detector output is a series of negative pulses that follows the modulation envelope rather than the individual signal components. But all frequency components must be passed unchanged in amplitude or the detected audio will be distorted. Filtering is by C26 and the T network R25/C27/R26. When a single diode is placed in series with the IF

FIGURE 4-17
HALF-WAVE AM DETECTOR
(Cobra 29XLR, 89XLR, etc.)



path like this, it's called a "voltage detector"; a "current detector" would be one that's placed in shunt across the IF path. CBs generally use voltage type audio detectors.

Figure 4-18 shows the waveforms present in Figure 4-17. The detector output voltage at C26 is the average of the resulting RF input pulses, and varies at the same rate as the original modulating signal. With a single detector diode (D4) only half the RF waveform appears, as shown. The DC component is still present in the waveform but is later removed by C29. This DC is useful for AGC and S-Metering, which is why those are sampled before C29. When the varying DC component is coupled across C29 only the voltage variations appear on the other side, resulting in the pure audio signal shown. This detected signal has a very low level and is coupled to the audio chain for power amplification to speaker levels.

FIGURE 4-18
DETECTOR WAVEFORMS OF FIG. 4-17

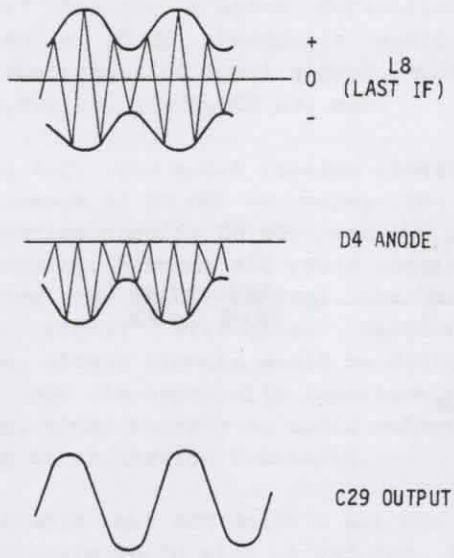
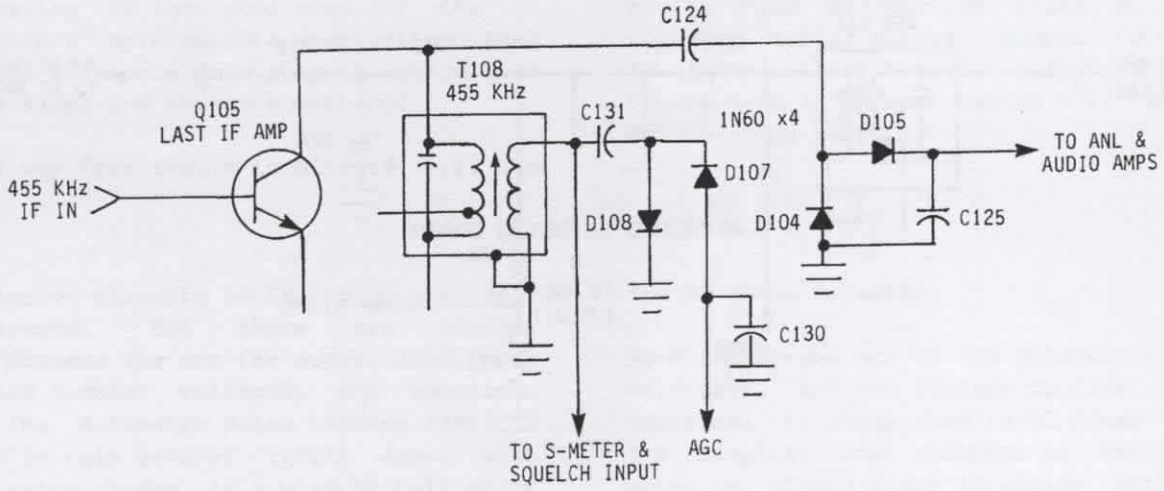


Figure 4-19 is a voltage doubler detector. The doubler circuit has several advantages. Both halves of the RF cycle are rectified, producing twice as much audio voltage output. In this circuit D105 conducts on the positive half cycle, and D104 on the negative half. (It doesn't matter which diode is which, as long as the other is wired oppositely. You'll find such detectors either way.) In addition to higher output there's less loading on the last IF amplifier stage. The doubler also reduces audio distortion, because simpler RF filtering can be used with less attenuation of the higher audio frequencies. Note the AGC detector is also a doubler (D107/D108) for higher control voltage.

A common symptom of a bad detector is what appears to be poor sensitivity. When the diode is leaky and has low front-to-back resistance with one lead disconnected, don't hesitate to replace it. Remember, germanium normally shows higher ohmmeter leakages than silicon, so don't be fooled. They're also more heat-sensitive when soldering, so be quick about it or use a small clip-lead for a heatsink.

FIGURE 4-19
VOLTAGE DOUBLER AM DETECTOR
(Kraco KCB4004)



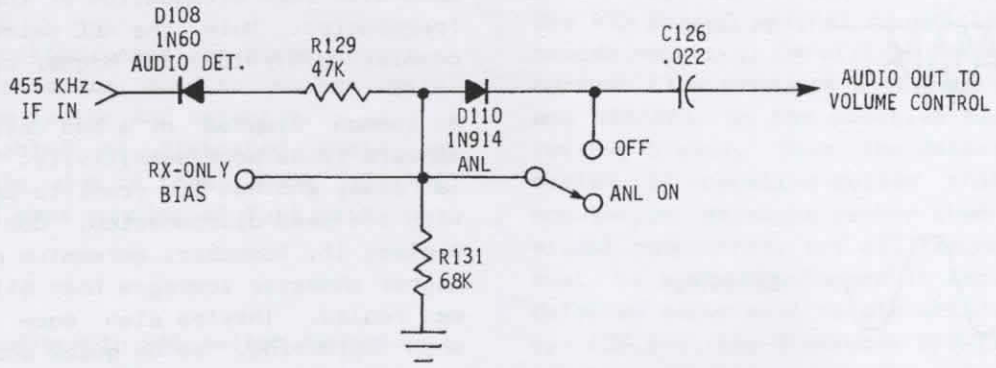
Most tube-type radios used a 6AL5 or similar diode detector. If you suspect a detector problem, confirm by tube substitution.

AUTOMATIC NOISE LIMITER (ANL)

Noise limiters are rather simple circuits used to reduce noise spikes that get through the detector. Any short duration, high-intensity noise exceeding the average audio level is cut off. The diode acts like a clipper for this function. Silicon fast-switching diodes of the 1N914 type are used. The disadvantages of diode noise limiters are reduction of the higher audio frequencies and distortion on strong signals, since modulation peaks may also be clipped unintentionally.

There are two basic ANL circuits: the series gate, and the shunt. Both appear about equally. Figure 4-20 shows the simplified series gate circuit. D110 conducts in the "ON" position and audio can pass through it. R129/R131 and the Receive-only voltage source set the proper bias level. When a noise burst occurs, a large negative voltage develops across R129/R131. The diode is momentarily reverse-biased or cut off, preventing noise from reaching the audio chain. In the "OFF" position audio passes around D110. When this type of ANL follows a half-wave detector (like this example) it doesn't act on the positive-going noise pulses, since the

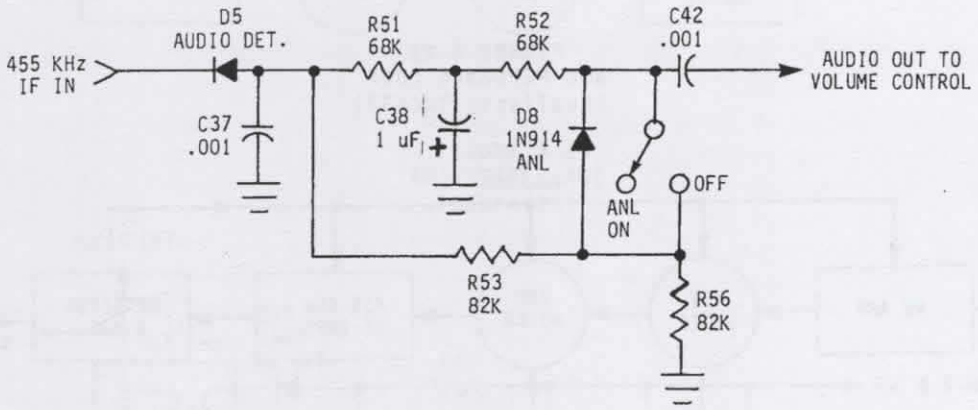
FIGURE 4-20
SERIES-GATE ANL CIRCUIT
(Cobra 90LTD, Midland 76-300)



detector itself passes only the negative-going part of the signal.

Figure 4-21 shows the shunt ANL circuit. In normal operation D8 is cut off. A large enough negative-going noise spike will turn it on, shunting the signal to ground momentarily. The turn-on level is set by the audio detector's T filter (R51/C38/R52) and divider R53/R56. With the switch in the "OFF" position signals pass around D8. If D8 were open it would simply have no limiting action. Many older radios had this diode permanently connected in the circuit without an ON/OFF switch; if shorted, little or no audio was received. In this example there's enough series resistance to limit the effect of such a direct short in the ANL diode.

FIGURE 4-21
SHUNT ANL CIRCUIT
(Uniden PC77)



AUTOMATIC GAIN CONTROL (AGC)

The purpose of AGC (sometimes called Automatic Volume Control or AVC) is to keep the audio output level constant with widely varying input levels. Otherwise you'd be blasted out of your seat if a stronger station came on the channel. "Constant" for the CB specs definition means less than a 10 dB change in audio output between the specified input signal levels, such as 1-100,000 µV, 10-50,000 µV, etc.

With good AGC, the audio remains linear over a dynamic range of 60 dB or more; the better AM/SSB radios specify 80 dB, and 100 dB would be outstanding. Without AGC you'd constantly be readjusting the VOLUME control for different incoming signal strengths. Besides this annoyance, strong signals would be distorted or garbled. AGC is especially important for SSB reception, since there's no audio output anyway until the other station transmits.

It's desirable that AGC doesn't act too quickly or weak signals would also be reduced. To avoid this, AGC begins only after the incoming signal reaches a predetermined level. This is known as "delayed AGC" and is used in most CBs. Delayed AGC is the preferred method and usually works only in the IF; excess reverse bias on an RF amp can sometimes degrade the dynamic range and Noise Figure. Many CBs get around this problem by using controlled loading on the front end coupling transformer instead of directly controlling the RF amp transistor bias.

The stronger the incoming signal, the more AGC voltage developed. Since AGC is usually a negative-going voltage, it will reverse-bias an amplifier and lower its gain. Weak signals won't develop AGC, letting the amps run at full gain. The AGC "threshold" is the point where AGC action first begins, and depends on the detector diode characteristics and the total amount of gain preceeding it. In HF receivers like CBs, this threshold will be about -100 dBm to -110 dBm (about 1.0 µV), which means it doesn't take much signal to start AGC action!

Finally, the AGC circuit must have a "fast attack and slow decay" characteristic; the fast attack ensures that the gain reduction will

occur almost instantaneously, with a slow decay time long enough to maintain the level between syllables of SSB speech or a rapidly fading AM carrier. The time constants are set with RC networks. For CB these times range from about 50-200 mS attack and 0.5-3.0 seconds decay. Figure 4-22 shows the basic AGC feedback loop.

The control voltage is developed by sampling some of the IF signal at the detector, rectifying it to DC, filtering it, and using this average DC voltage to control the bias on several receiver stages. For good AGC a minimum of two stages must be controlled, which in CBs usually means the 27 MHz front end and one of the IF amplifiers. In this example, both mixers are also controlled for superior AGC action.

There are two main sampling locations for AGC. In "audio-derived AGC" the voltage comes from the same place as the audio; i.e., on the audio side of the detector diode(s). A superior method used for SSB is "RF-derived AGC," with the sample coming from the last IF amplifier stage. Audio-derived AGC is generally poor in SSB/CW communications receivers because it causes the annoying problem of "clicking" or "pumping" due to its long attack time. But it is acceptable, and is used for AM-only CBs.

FIGURE 4-22
AGC FEEDBACK LOOP
(Realistic TRC433)

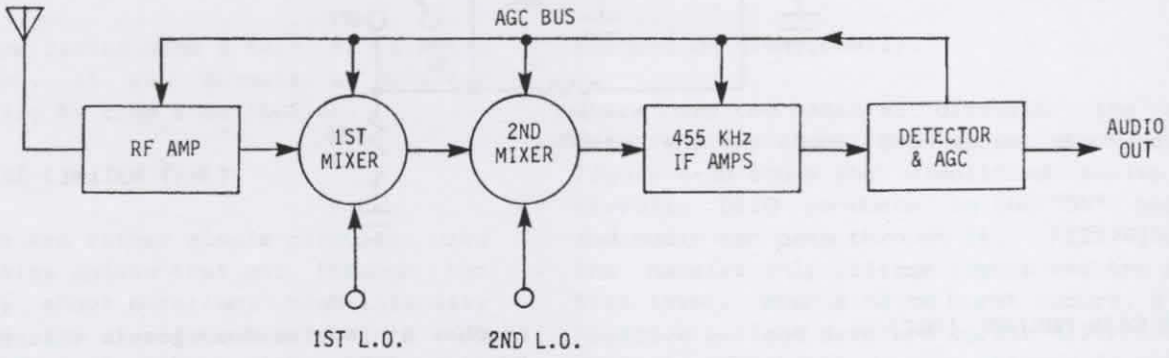


Figure 4-23 shows the simplest kind of audio-derived AGC, similar to that of the Cobra 29XLR in Figure 4-17. The AGC sample is tapped off the audio detector diode. Like the detected audio, the AGC thus derived is a negative-going voltage which when connected to the base or gate of a transistor will lower its gain. In this case it controls the base bias of the RF amp and both mixers. C123 removes RF, and with R124 lengthens the time constant so the AGC voltage is mainly DC.

Figure 4-24 shows adjustable AGC. R42/VR6 set the conduction bias for AGC diode D10. C44 and C13 filter RF. C46/R41 establish a suitable time constant. Note the AGC/S-Meter and AM detectors come from separate IF points. In most AM radios a single germanium diode of the 1N34/1N60 type is used for AGC. The improved detector circuit back in Figure 4-19 also used a diode voltage doubler for AGC. In either case the use of separate AGC and audio diodes is preferred, since it reduces loading and therefore distortion on the audio detector.

Diodes also help produce the delayed AGC. The action of D10 will be delayed somewhat because it doesn't conduct until a signal strong enough to overcome the preset bias appears. Until that happens, C46 sees a pure AC signal and no AGC voltage develops. When a signal appears D10 conducts on negative signal peaks, effectively shorting out the negative IF output from T12. C46 therefore sees a more positive than negative signal and filters it to a smooth positive AGC voltage. As the received signal gets stronger, D10 conducts harder and harder, dropping more voltage from the AGC line. In this particular chassis the no-signal AGC bus is about 1.48 VDC, dropping to about 0.60 VDC with an extremely strong input signal. The negative-going voltage starts turning off the bases of the associated transistors.

The basic diode AGC is usually found in AM-only radios. This limits the amount of AGC voltage

FIGURE 4-23
AUDIO-DERIVED AGC
(Cobra 19XS)

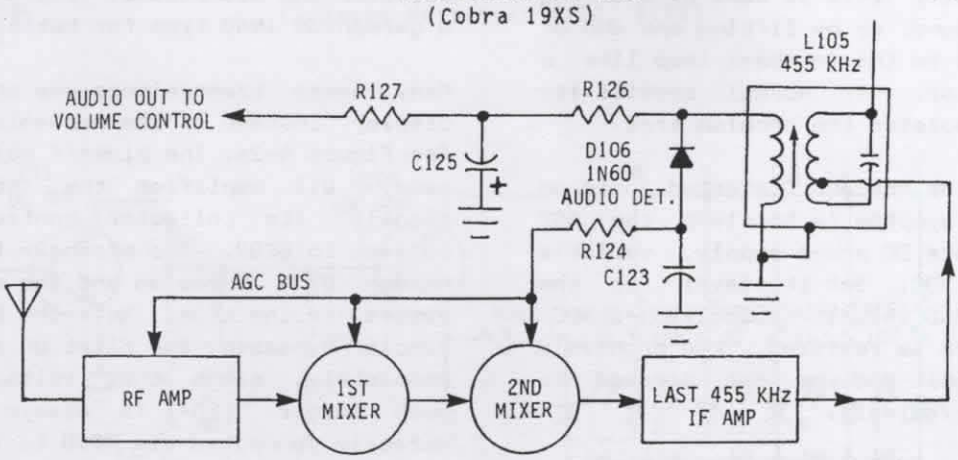
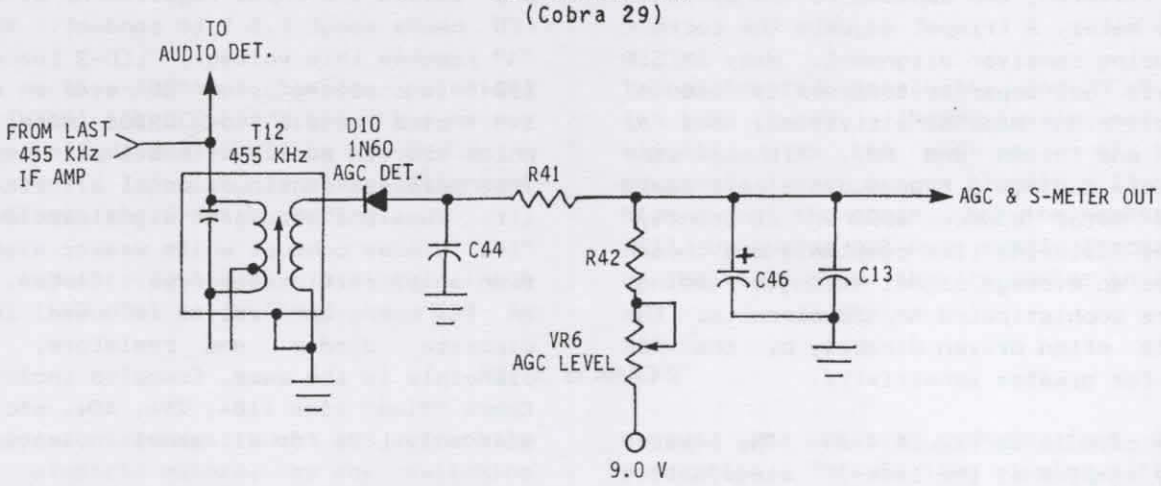


FIGURE 4-24
ADJUSTABLE AGC
(Cobra 29)



that can be extracted, which also limits the dynamic range. A better method uses several stages of DC amplification to develop a large control voltage; this voltage can also be shared with the squelch and S-Meter for improved sensitivity in those circuits. This is called "amplified AGC" and is always used in AM/SSB transceivers for superior performance.

AGC TROUBLESHOOTING

Troubleshooting is best done by monitoring the AGC bus while injecting signals of different strengths. The AGC voltage should change. Depending upon your measuring point, it will get either more positive or more negative as signal strength increases, with the no-signal level usually around 1-2 VDC. Since AGC is negative-going, a defective part could produce the symptom of "No Receive" or "Weak Receive" due to excess gain reduction, or conceivably cut off an amplifier completely. With no AGC action at all, signals would blast in with severe audio distortion because the receiver gain is running wide open all the time.

Any self-oscillation in an IF stage also causes full AGC action, characterized by a very strong S-Meter reading even when the antenna has been disconnected. (Assuming the S-Meter circuit and its adjustment are working correctly.) Such oscillations may be due to changing capacitor values, an open negative feedback capacitor, misalignment, or IF transistor replacement with the wrong type. These possibilities will be evident by unusual 'scope or bias measurements.

With the "No Receive/Weak Receive" symptom, you can disable the AGC and recheck for proper sensitivity. Usually this is done by shorting the AGC bus to ground, or by lifting one end of a series component in the feedback loop like a diode or resistor. If normal sensitivity returns, you've isolated the problem area.

A technique for the "No AGC/Distorted Audio on Strong Signals" symptom is to clamp the AGC line with a separate DC power supply, variable from perhaps 1-5 VDC. Set its level for the normal no-signal AGC value, typically 1-2 VDC. If proper reception is restored, the problem's in the AGC circuit and you can proceed to localize it more precisely.

THE S-METER CIRCUIT

The S/RF meter movement requires DC to operate. A signal sample is tapped off and rectified by a diode, filtered, and applied to the positive end of the meter. A trimpot adjusts the correct reading during receiver alignment. Many AM/SSB transceivers use separate trimmers to account for the different mode sensitivities; one for SSB, and one for AM (and FM). Although the diode detects audio, a true audio signal could make the meter bounce around constantly. Instead the filtering time constants are chosen to produce an average signal strength reading. In the more sophisticated AM/SSB circuits, the S-Meter is often driven directly by the AGC amplifier for greater sensitivity.

A typical circuit is Figure 4-25. The S-Meter is usually sampled at the last IF stage, like the detector and AGC. A 455 KHz IF signal from T10 is rectified by D8 and filtered by C79 to remove RF. R56 may or may not be present, depending upon the sensitivity of the meter and the required deflection voltage. Like the detector and AGC diodes, the S-Meter diode is a germanium 1N60 type for better sensitivity.

Many newer transceivers use an LED bar/graph display instead of the mechanical S/RF meter. See Figure 4-26. The pickoff point is still the same. Q11 amplifies the sampled receiver signal; its collector controls the base current in Q209. The stronger the signal, the harder Q209 turns on and the more current it passes to the LEDs. Note the RF Meter voltage sample bypasses the first DC amplifier (Q11) completely, since that voltage is normally much larger. LED-1 is always on, since it's directly connected via R250 to V_{CC}.

R251-R255 form a resistive ladder. Diodes CR206-CR210 also control how many LEDs other than LED-1 and LED-2 will turn on, since each one raises the input requirement by 0.6 V. An LED needs about 1.5 V to conduct. When point "A" reaches this voltage, LED-2 turns on. For LED-3 to conduct, point "B" needs an additional 1.5 V plus the 0.6 V of CR206 (total of 2.1 V) which is in series with its path to ground. This process continues until all six LEDs are lit. Thus the strongest signal would make all five diodes conduct while weaker signals would turn on proportionally fewer diodes. Nowadays an IC bar/graph driver is used instead of discrete diodes and resistors, but the principle is the same. Examples include the new Cobra "Plus" line (18+, 29+, 40+, etc.), which uses only LEDs for all panel indications.

Troubleshooting the S-Meter is a matter of tracing the signal continuity from the sampling point to the indicating device itself. If

FIGURE 4-25
TYPICAL S-METER CIRCUIT
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)

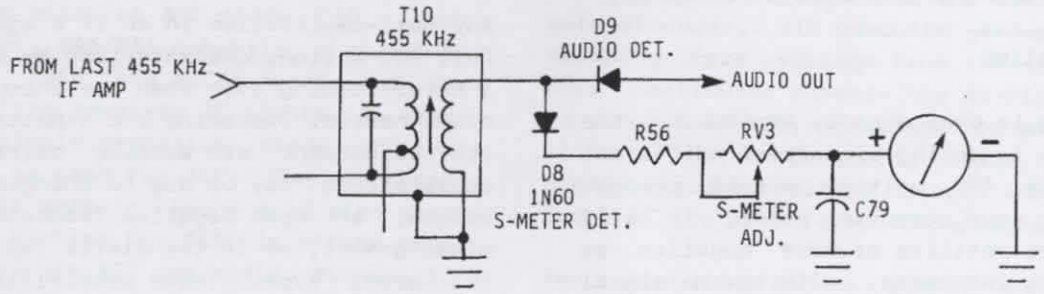
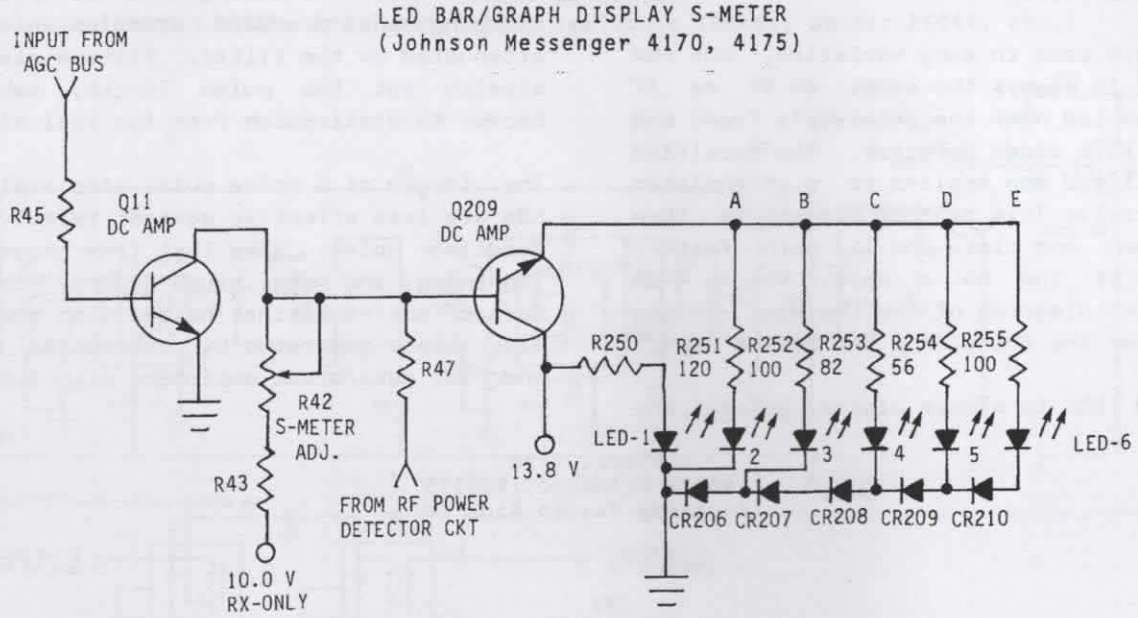


FIGURE 4-26
LED BAR/GRAPH DISPLAY S-METER
(Johnson Messenger 4170, 4175)



driven by active AGC amps they're potential problems. With the LED bar/graph, the driver circuit and all diodes should be checked in a logical order. Improper receiver alignment directly affects the S-Meter reading.

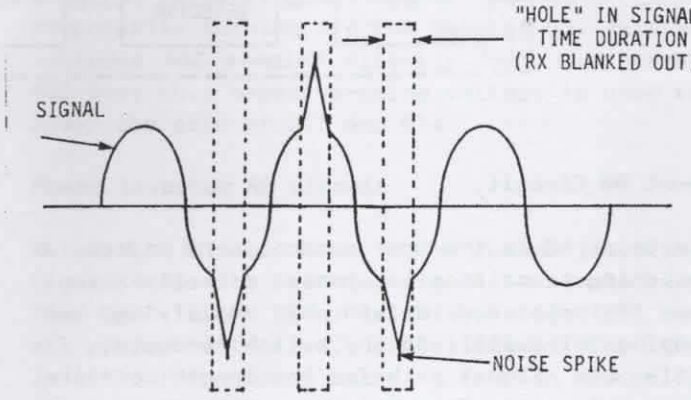
By general industry agreement, a signal input of 100 µV (-67 dBm) is defined as "S9" in transistorized receivers, and 50 µV (-73 dBm) in tube types. These levels set "S9" at slightly over the mid scale of the meter movement; very strong signals will crowd the high end of the scale, but the weaker signals will be spread out more evenly across the rest of the scale where they're easier to interpret.

NOISE BLANKERS

Man-made noise sources such as automobile ignitions, electric motors, or any switching high-current load are very troublesome in HF receivers. The noise impulses are amplitude-modulated and although they're of short duration compared to the signal, it's not unusual for them to have amplitudes 1,000 times greater than the desired signal. The diode type limiter can only remove the most obvious noise above a predetermined amplitude. That leaves plenty of lower-level noise to get through and irritate the listener.

A circuit more sophisticated than a diode clipper is needed. See Figure 4-27. While ANL works on noise amplitude, the Noise Blanker works on noise time duration. It takes advantage of the fact that most noise pulses generally have a much shorter time period than signals. Reception is "blanked out" during the time of the noise pulse, literally punching holes in the signal. But it sounds continuous because the gaps are much too fast for human perception. This is like viewing a flourescent light which is actually flashing on and off at

FIGURE 4-27
HOW NOISE BLANKERS WORK



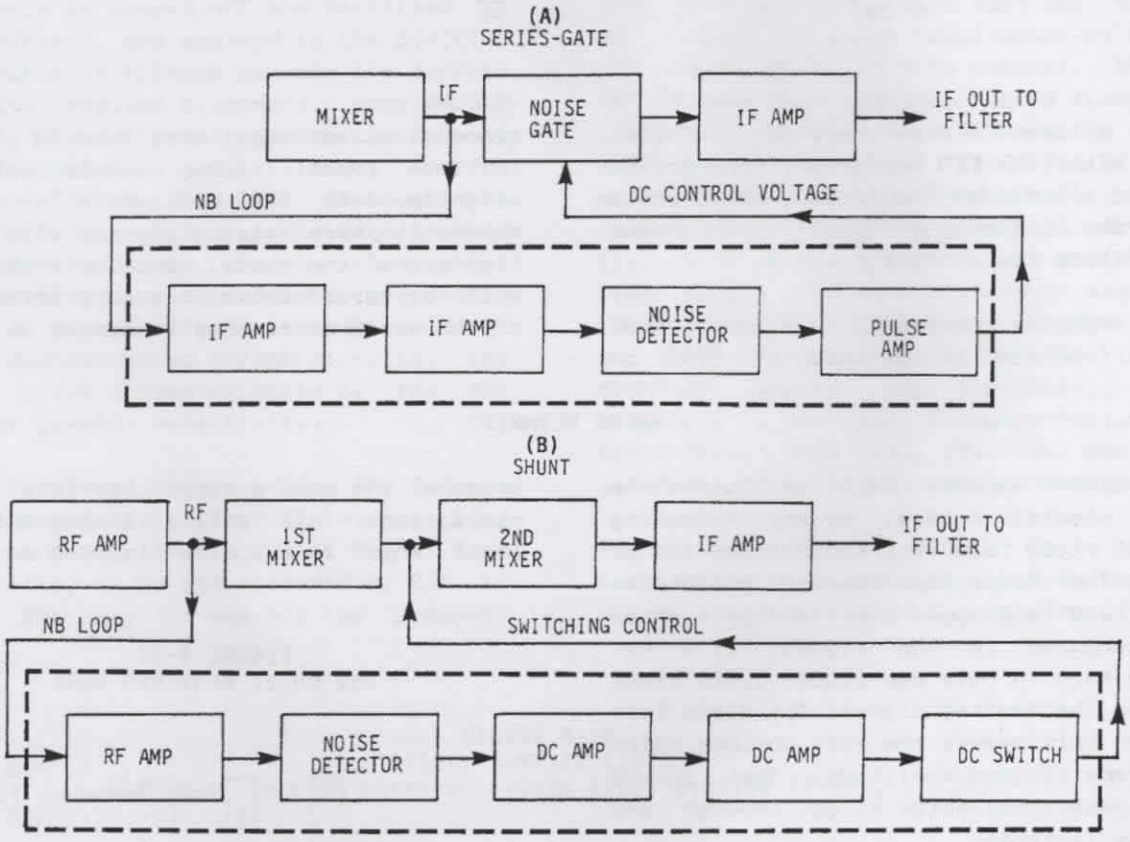
50/60 Hz; you perceive only a constant light, not a blinking light.

Noise Blankers come in many varieties, but the basic idea is always the same: an RF or IF signal is sampled near the receiver's front end and applied to a diode detector. The rectified DC is amplified and applied to a transistor switch control. This control element is then used to open and close the IF path further downstream, at the noise rate. Figure 4-28 shows block diagrams of the two most common blanker types: the Shunt, and the Series Gate.

Note the NB loop is always placed before any highly selective IF devices like a crystal filter, since blanking is actually a form of clipping that produces harmonics which can be attenuated by the filter. Filters also tend to stretch out the pulse length, making them harder to distinguish from the real signals.

The length of a noise pulse also explains why NBs are less effective against relatively long-duration noise, like that from power lines, lightning, and motor brush arcing. Blankers are most effective against noises with short times, like those generated by automobile ignitions and fast make/break switching circuits.

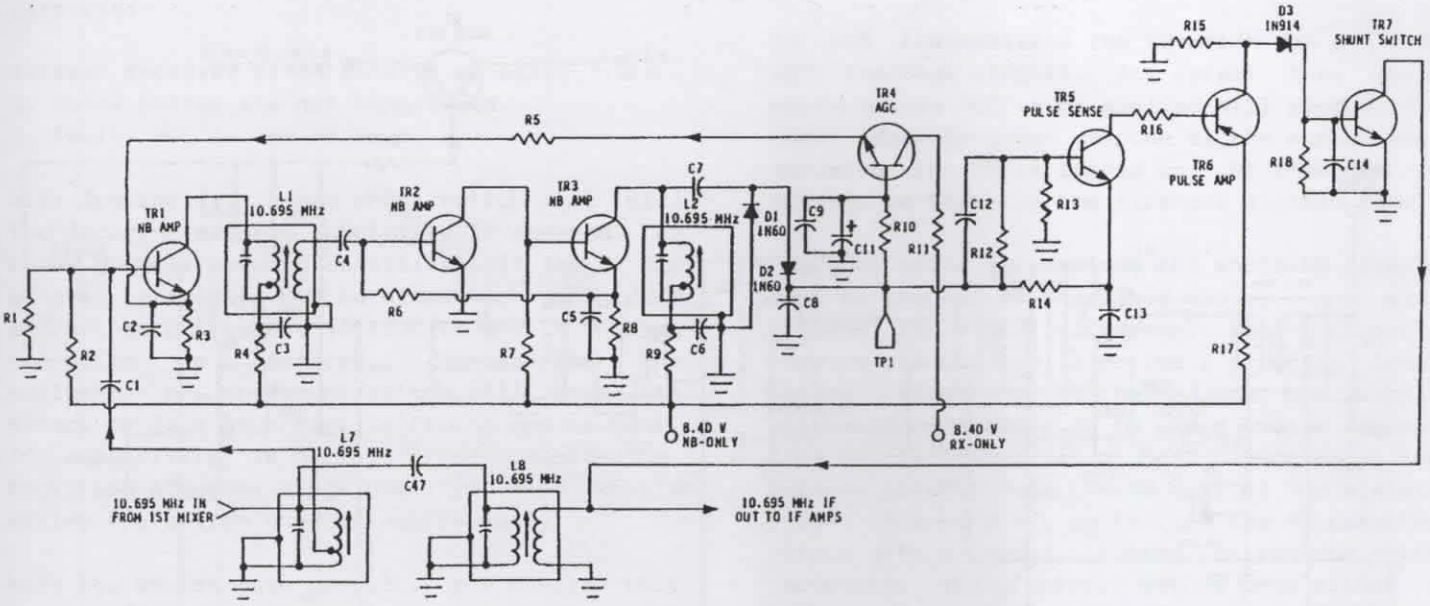
FIGURE 4-28
NOISE BLANKER CIRCUITS
(Courtesy Hayden Book Co.)



Shunt NB Circuit

The Shunt NB is the most common in CB radios. A switching transistor is shunted directly across the IF path and driven by amplifying and shaping circuits. As the switch conducts, it kills the signal path for the length of the noise pulse. In Figure 4-29, a 10.695 MHz IF sample is taken from L7 and amplified by TR1. L1 is adjusted for maximum noise transfer. The noise is further amplified by TR2 and TR3 and peaked by L2. D1/D2 form a voltage doubler which rectifies the noise to positive-going DC. They're germanium diodes for good voltage sensitivity. The DC is further amplified and shaped by TR5 and TR6. When a noise pulse

FIGURE 4-29
SHUNT NB CIRCUIT
(Cobra 146GTL, President AR144, Realistic TRC451, Uniden PC244, etc.)



appears, TR5 conducts and its collector voltage goes lower. This turns on TR6 and its current flow through D3 turns on TR7. TR7 is shunted directly across the IF path, cutting off the input for the duration of the noise pulse.

In all similar Uniden NB circuits, AGC is always included. This prevents extremely strong signals from triggering the NB switch. Otherwise the radio would be blanked by strong signals as well as noise pulses. TR4 is the AGC amp and is wired much like a Series-Pass voltage regulator. C9 and C11 have time constants chosen to separate IF signals from noise pulses. When enough base bias develops at TP1, TR4 conducts and passes current to the emitter of TR1. This raises TR1's emitter voltage, reducing its gain.

Series Gate NB Circuit

A less common circuit found in some Johnson and other radios is the Series Gate type, Figure 4-30. Instead of shunting the noise to ground, a transistor gate is placed in series with the IF path. It's normally conducting but turns off when a noise pulse occurs. Since noise is broadband in nature, the NB circuit can be tuned to any frequency close to 27 MHz, like the 23.5 MHz used here. The signal is sampled at the output of the Mixer but <u>before</u> the 4.3 MHz tuned circuits, so 23 MHz noise is still present there. Any noise at 27 MHz is virtually identical to noise at 23.5 MHz, but by doing it this way the extremely weak 27 MHz signal at the Mixer won't be loaded down by shunting a 27 MHz NB input directly across it.

The noise loop is sampled at the Mixer and amplified by Q13 and Q14. R49, R52 and R56 lower the Q of T11, T12, and T13 respectively since highly-selective tuned circuits are undesirable here. The noise is detected by CR10, filtered by C45/R58, and reamplified by Q15. Note the large value of C47, since the detected noise is now mostly DC. Some final RF filtering is provided by C49 and RF choke L2. Q3 is a PNP noise gate which is connected as a Series-Pass transistor and normally forward-biased by R11/R12/R13. When a noise spike occurs, the collector of Q15 goes LOW, temporarily turning off the base of Q3. This NB includes AGC sampled directly from the normal AGC bus; this negative-going voltage is used to lower the gain of Q13 and Q14.

Phase Inverter NB Circuit

A third NB circuit type is the Phase Inverter, Figure 4-31. The incoming signal is sampled and fed back to the RF or 1st Mixer stage 180° out of phase, effectively cancelling it for the length of the noise pulse. You can identify this circuit from the lack of any detector

FIGURE 4-30
SERIES-GATE NB CIRCUIT
(Johnson Messenger 4170, 4175)

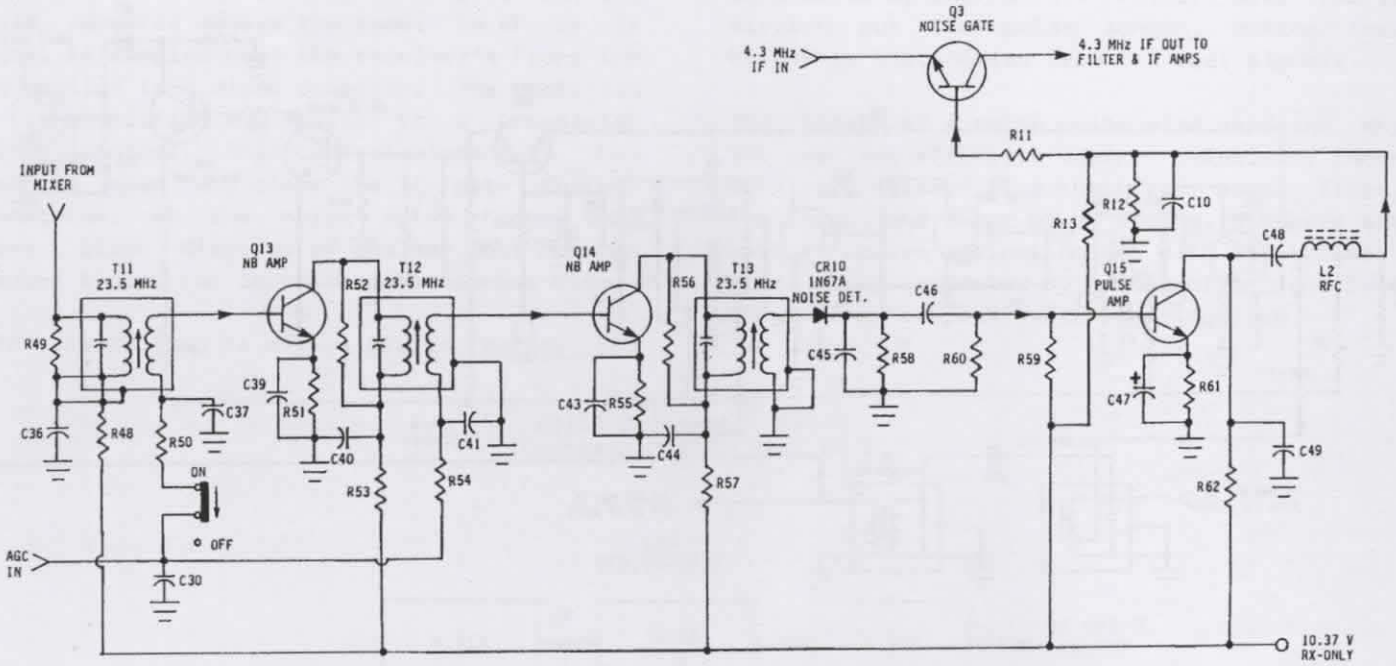
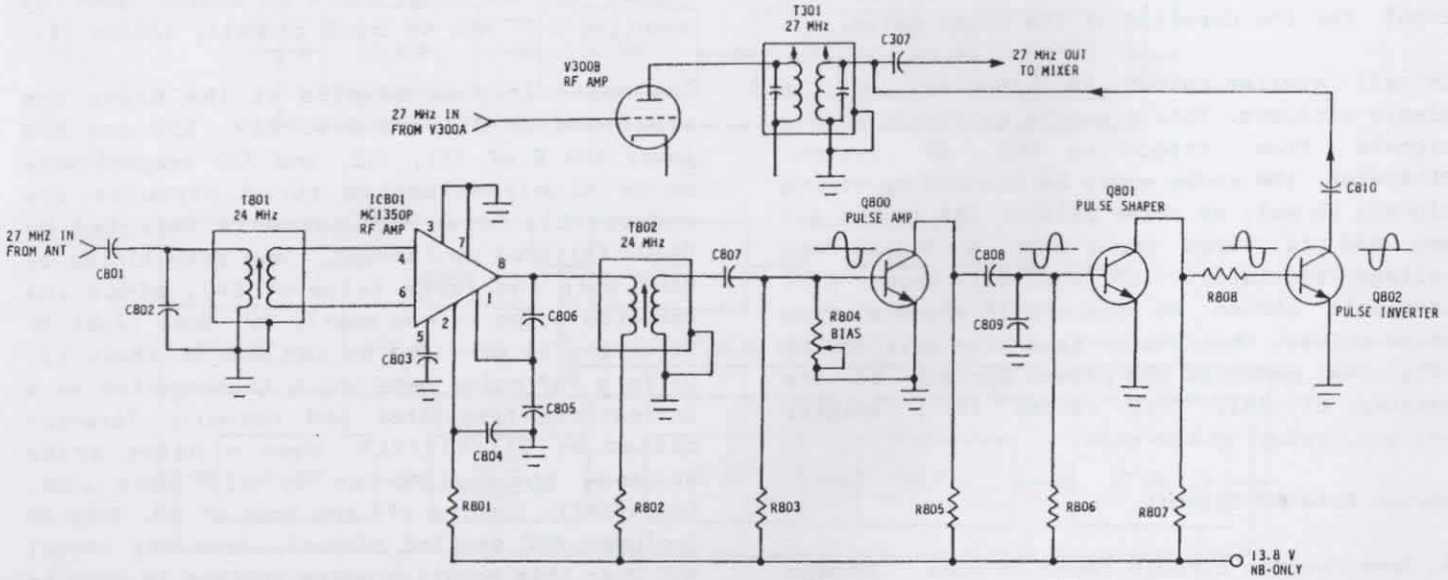


FIGURE 4-31
PHASE INVERTER NB CIRCUIT
(Tram D201/D201A)



diode in the loop. The NB input sample comes directly from the antenna. Again the NB strip is tuned to a slightly lower frequency (24 MHz) by T801 and T802, effectively forming a separate 24 MHz front end.

IC801 amplifies the 24 MHz noise. Three Common Emitter amplifier/shaper stages follow, each having the characteristic 180° phase shift from base to collector. With an odd number of transistors, the amplified output at the collector of Q802 will be inverted 180° from what it was at the antenna. This inverted output is coupled back into T301 to cancel reception for the time of the noise pulse. R804 sets the correct conduction bias level on Q800 relative to the incoming noise voltage. IC801 is a common broadband IF Amp/Detector of the type found in FM receivers and TV sound IF stages. (MC1350 = ECG746/SK3234.)

NOISE BLANKER TROUBLESHOOTING

There are several problems associated with NB circuits:

1. Weak Receive, or no Receive at all.
2. Noise pulses are not suppressed.
3. Faulty AGC in the NB loop.

With Symptom #1, a bad shunt switch will kill the incoming signals completely if shorted, or cause greatly reduced sensitivity if leaky. The general procedure is to disconnect the input and/or output to the NB loop to see if normal reception is restored. Unsoldering the collector of the shunt switch will test its effect or lack of effect in fixing the problem. If sensitivity is normal after unsoldering, backtrack stage by stage until you find what's making the switch conduct continuously.

With the series gate circuit, any problem that turns off the gate causes a "No Receive" symptom and must be investigated by similar backtracking, stage by stage. If the gate is shorted, reception may be normal but noise pulses won't be blanked out.

An internal short in the NB IC of a shunt or phase-inversion circuit will have the same effect as a shorted shunt transistor switch. Check IC voltages and replace it when questionable.

In SSB transceivers the NB often has its own AGC feedback circuit. Any defect that would cause excess AGC to be applied will produce the same "Weak Receive" symptom as the normal AGC, assuming the NB is turned on. Or the lack of AGC may be blanking the stronger signals too.

For poor noise supression, the whole NB circuit must be checked as described above, and also checked for proper alignment. With a properly working circuit you'll notice a slightly lower volume with the NB turned on. A simple alignment procedure is to use a noise source like an electric drill or hair blowdryer at the antenna socket. Tune the NB coil(s) for minimum noise. A second way is to view the NB detector output with a 'scope, tuning for maximum noise reduction. The factory method uses either a noise generator, or an RF signal generator modulated with a 60 Hz square wave, tuning for minimum noise. When a diode detector is used in the NB loop you can probe the diode(s) with a DC voltmeter, tuning for maximum detected DC voltage. In the newer Uniden SSB radios this detector output is conveniently made a Test Point, like "TP1" in Figure 4-29.

THE FM DETECTOR

Many CB radios now use the FM mode, either as part of a multimode export transceiver, or an FM-only radio like those of the British or Dutch services. It's a narrow-band system with about ±2.5 KHz being the maximum usable FM deviation. There's little difference in operation between the two categories; multimode radios with FM added are mostly re-works of existing AM designs. This is a lot cheaper than starting from scratch with an FM-only design. Because of this, the UK and European (CEPT) CB systems that were specifically designed for FM from the ground up often perform better, particularly the receivers.

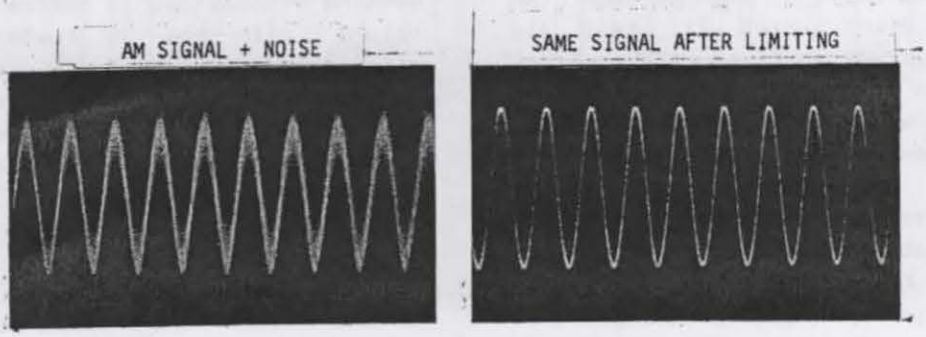
FM receivers don't need AGC. Instead multiple peak clipper stages are used to limit all amplitude-modulated signal components. The limiters are part of the FM Detector IC and have varying time constants to act on different types of incoming noise. Like AGC though, the purpose is to keep the audio level constant over a wide range of input signals. Unlike AGC, with FM it's desirable to run RF and IF stages with as much gain as possible in order to drive the AM peak limiters properly. The limiters are biased so they'll easily overload even on signals as low as 0.5 µV. This sharp reduction in amplitude-modulated noise is what gives FM its superior sensitivity and S+N/N ratio.

Figure 4-32A is a graphic illustration of the effects of amplitude limiting on a sine wave input to remove noise. Figure 4-32B shows how an AM signal is sharply limited in the FM limiter/detector circuit. Note how peak clipping starts even at low input levels; the more the input level increases, the greater the amplitude limiting.

FM receivers also don't need ANL or Noise Blanker circuits, since FM by definition removes amplitude-modulated noise. And of course the FM-only radios don't need the other circuitry required in AM and SSB equipment. In spite of these differences, both FM radio groups use exactly the same methods of FM demodulation and even the same IC chips. The

FIGURE 4-32
EFFECT OF FM LIMITER ON AM SIGNAL

(A)
REMOVING AM NOISE FROM SINE WAVE
(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)



(B)
AM LIMITING VS. INPUT SIGNAL LEVEL
(Courtesy Heinemann-Newnes Books)

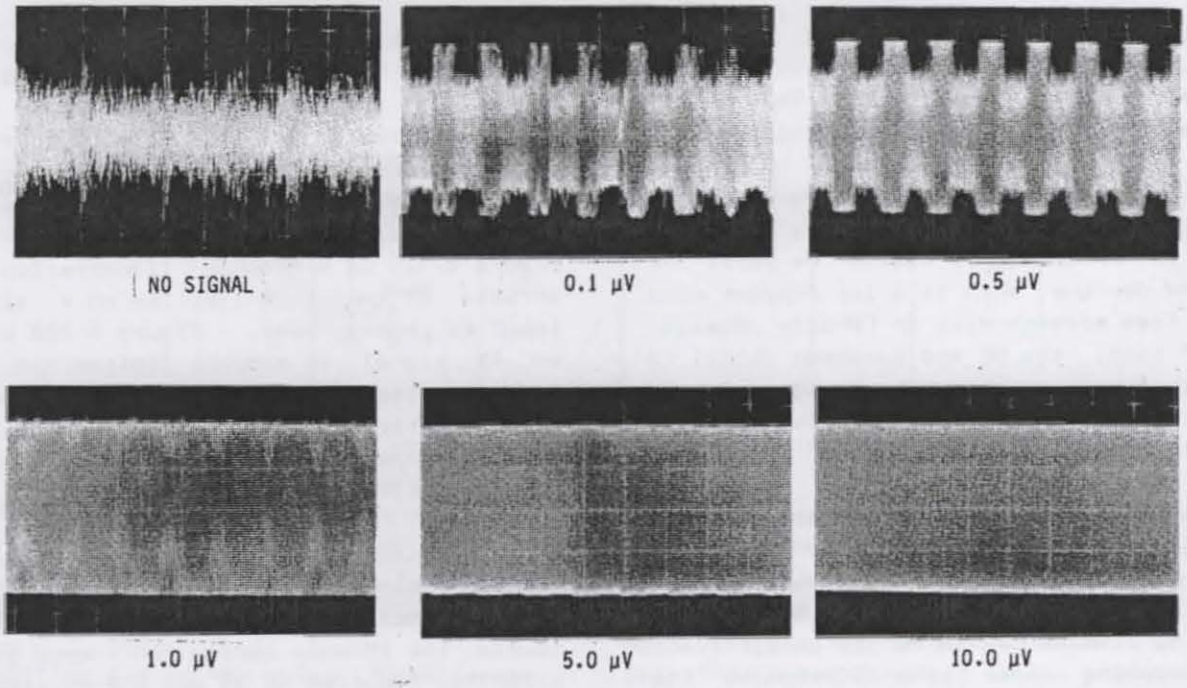
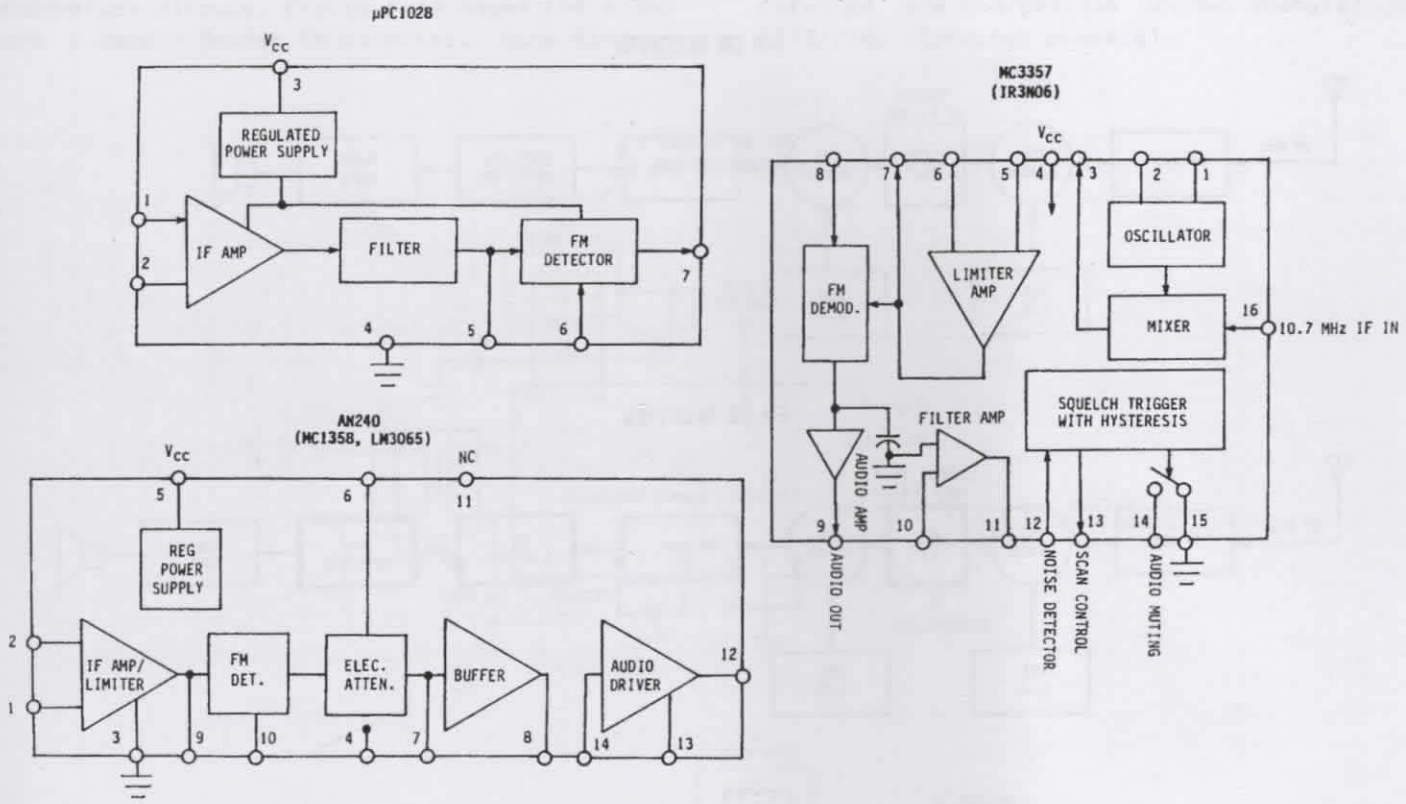


FIGURE 4-33
COMMON CB FM DETECTOR ICs



functional block diagrams of the most common CB-FM ICs are shown in Figure 4-33.

There's little difference in any receiver stages preceeding or following the detector. FM does require limiter stages, but these are included in the same IC that serves as the FM detector. The RF and IF amps, mixers, audio amps and squelch are the same. As shown in Figure 4-34, the most significant difference is the detector circuit and (sometimes) the IF filter. Instead of a simple diode which recovers audio riding on the RF carrier, the FM detector converts frequency variations to amplitude variations, which are then applied to the standard audio amplifier chain. The need for a wider IF filter explains why FM isn't practical in single-conversion AM/SSB radios; they use a very narrow filter which couldn't pass a standard 5 KHz wide FM signal. (Such radios only detect <u>one</u> 2.5 KHz AM sideband.)

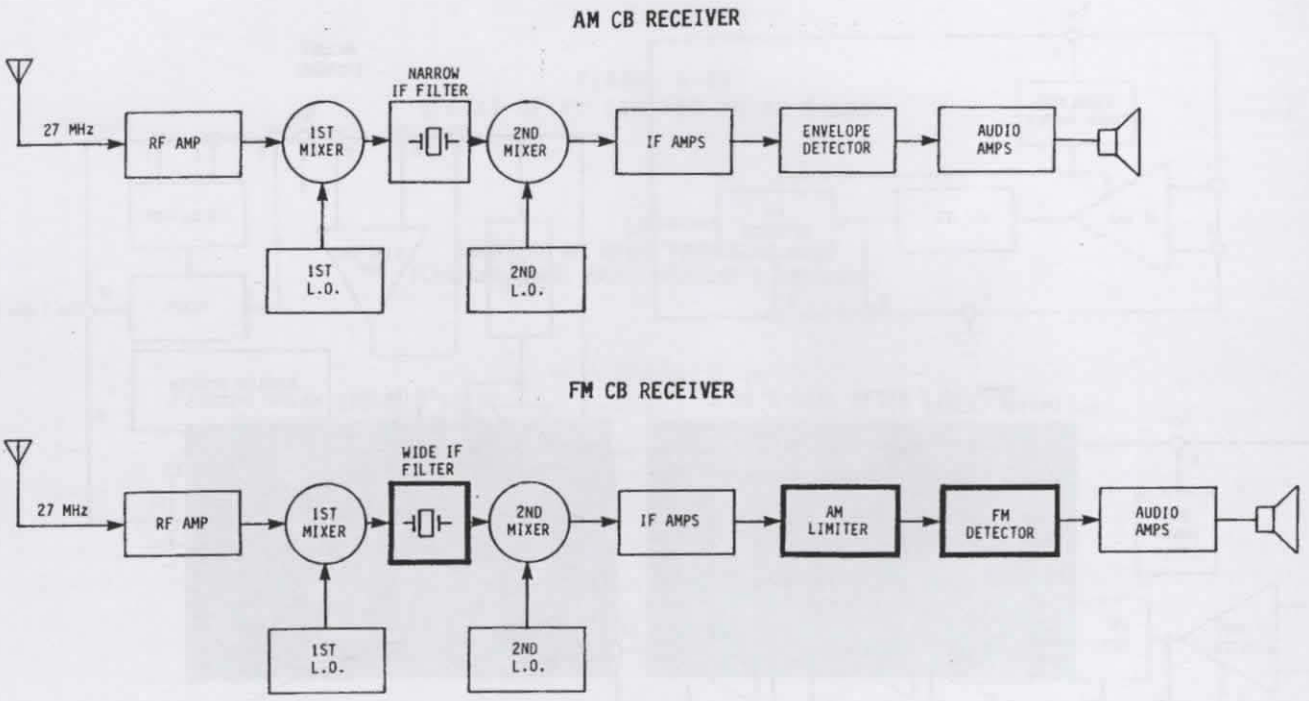
In the Uniden/Uniden clone multimode models, a separate wide FM IF filter is used; the sharper AM filter would chop the fully-deviated FM signal. The Cybernet multimodes don't bother with this, passing both FM and AM through the same 455 KHz IF filter. (Note that the Cybernet chassis which are designed to be FM-only do use the wider IF filters.)

Because an FM demodulator is much more complex than an AM demodulator, ICs are always used for FM detectors. In addition the gain of an FM IF strip ahead of the detector must be fairly high for good AM limiting. Such gain is easily achieved by ICs, which also save space in the radio. The overall gain of a typical FM CB is about 130 dB from antenna jack to speaker. The detector chips are the same ones used for TV audio circuits (TV audio is FM) and scanners. Troubleshooting consists only of checking the detector alignment and measuring voltages and input/output signals on the IC to determine if it's working correctly.

Pre-Emphasis and De-Emphasis

FM requires special audio shaping networks to reduce the amount of thermal noise and loss of

FIGURE 4-34
AM VS. FM RECEPTION



the higher audio frequencies. The higher audio frequencies tend to be of lower amplitude anyway, which means they produce less deviation and poorer noise reduction properties. In the FM transmitter a simple RC network is used to "emphasize" or boost the higher audio frequencies while rolling off the lower ones. An RC time constant of about 50-150 µS results in a more even spread of energy within the communications audio band.

At the receiver end, this effect is converted back or "de-emphasized" to its original modulating form with another RC filter. Since the de-emphasis works equally on both the high-frequency signal and the high-frequency noise, there's no effective change in the S/N ratio. In Figure 4-35, the de-emphasis networks are C178/R165 (AN240) and C28/C29/R36 (µPC1028H). If these parts values changed, the received audio would have more treble or bass, depending upon the direction of change.

Typical CB FM Circuits

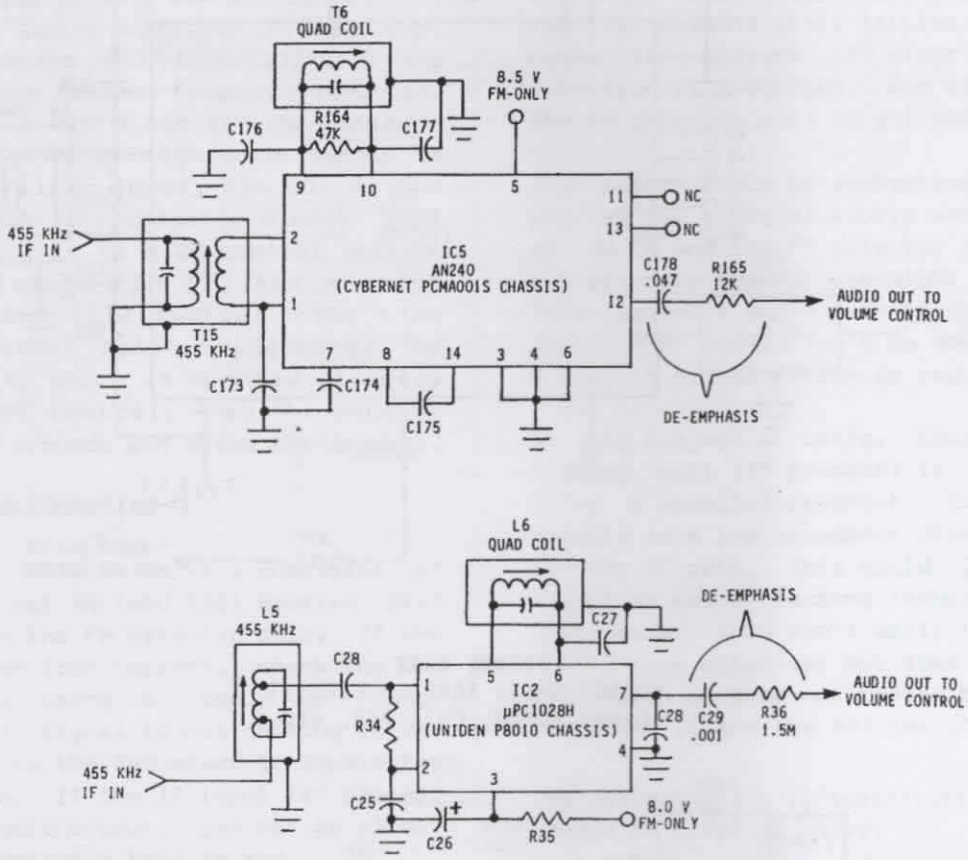
FM reception involves coupling a 455 KHz signal from the last IF stage to the FM Detector IC. A resistive divider or a 455 KHz transformer is used for the coupling. The AN240 circuit in particular uses a tuned input to boost the signal level, while most other FM ICs skip this. In the multimode radios, the audio output from the FM IC is routed through the "FM" part of the MODE switch to the audio amplifier chain. In FM-only transceivers it goes directly to the audio stages.

A single tuning adjustment peaks the detected audio. In the "quadrature" FM detector, it's called the quadrature coil. The name comes from the fact that the tuned circuit produces a 90° (i.e., 1/4-wave) phase shift at the center IF frequency, and the circuit is phase-sensitive. Since the phase shift changes anywhere off the center IF, the detector audio output also changes. Thus the detected audio is a linear reproduction of the incoming phase shifts, which are changing at an audio rate.

Another FM detector is the "differential peak detector" like the popular AN240. In this circuit a balanced set of active peak detectors is combined in a differential amplifier stage; the audio output is the result of changing peak

voltage levels instead of the phases. This detector also has a tuned circuit like the quadrature circuit. Figure 4-35 shows the AN240 and a common Uniden FM detector. Note R164 is used in the AN240 circuit to lower the Q of the coil, improving audio response. The de-emphasis networks are C28/C29/R36 (Uniden chassis) and C178/R165 (Cybernet chassis).

FIGURE 4-35
CB FM DETECTORS



MC3357 Multifunction FM IC

Figure 4-36 shows an interesting use of the Motorola MC3357 chip, whose functional block diagram was shown back in Figure 4-33. The IC contains an oscillator and mixer in addition to a five-stage limiter, an FM detector, and a scan control/squelch trigger. The chip was originally designed for scanning type VHF/UHF receivers, which also have a 10.7 MHz high IF and a 455 KHz low IF. The mixer/oscillator combination is used to convert a 10.695 MHz 1st IF down to 455 KHz, where after additional bandpass filtering it's detected and passed to the normal audio chain. This eliminates all the extra parts and room which would otherwise be needed for a second mixer stage.

In the Jackson export model, the 10.695 MHz FM input is broadly shaped and filtered by FT1. The 10.240 MHz PLL Reference Oscillator signal is sampled and applied to Pin 1. Mixing results in 10.695 MHz - 10.240 MHz = 455 KHz, and is filtered again by FT2, then demodulated and the audio output is Pin 9. C25/R31 is the de-emphasis circuit. L4 is the quadrature coil; R28 again broadens its response. The AM/SSB paths are both single-conversion through individual IF filters which are so narrow they'd severely chop the FM audio, but are OK for AM and SSB. By the way, the "IR3N06" number for IC1 on the Jackson schematic is simply an in-house part number for this Motorola device.

Another feature of the MC3357 is its ability to use the superior noise squelch method rather than simple carrier squelch. (See SQUELCH section.) Unfortunately it's not even used in

FIGURE 4-36
MC3357 FM DETECTOR IC
(Uniden Jackson)

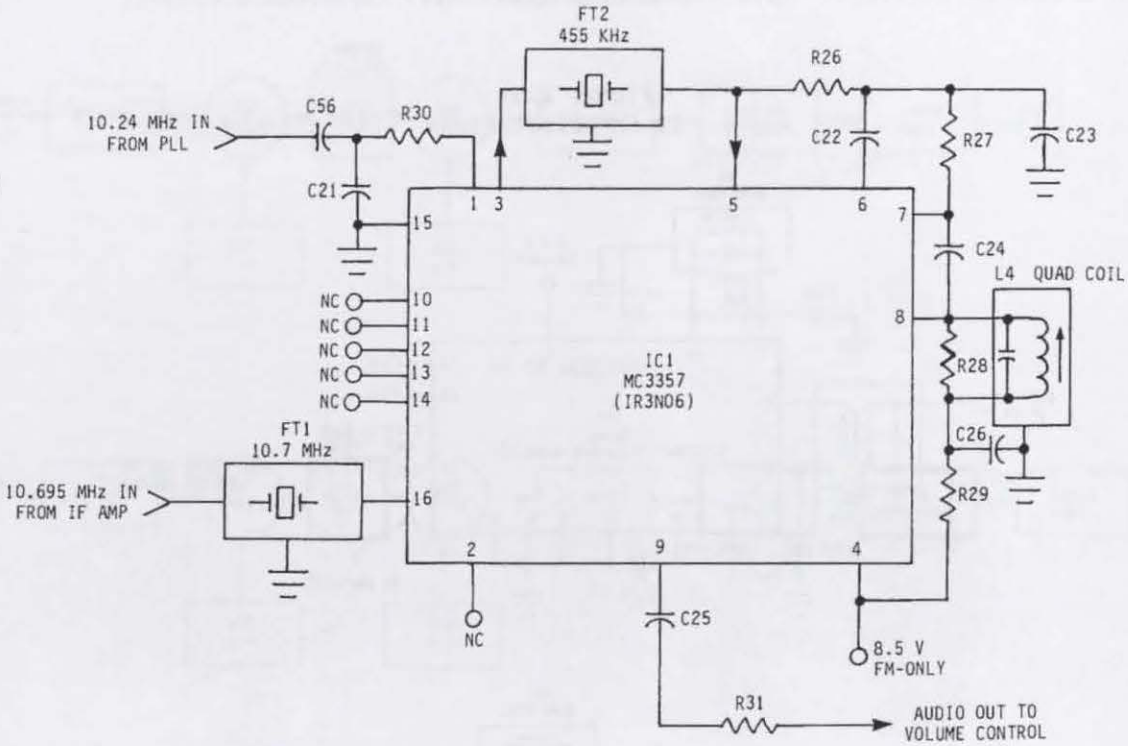
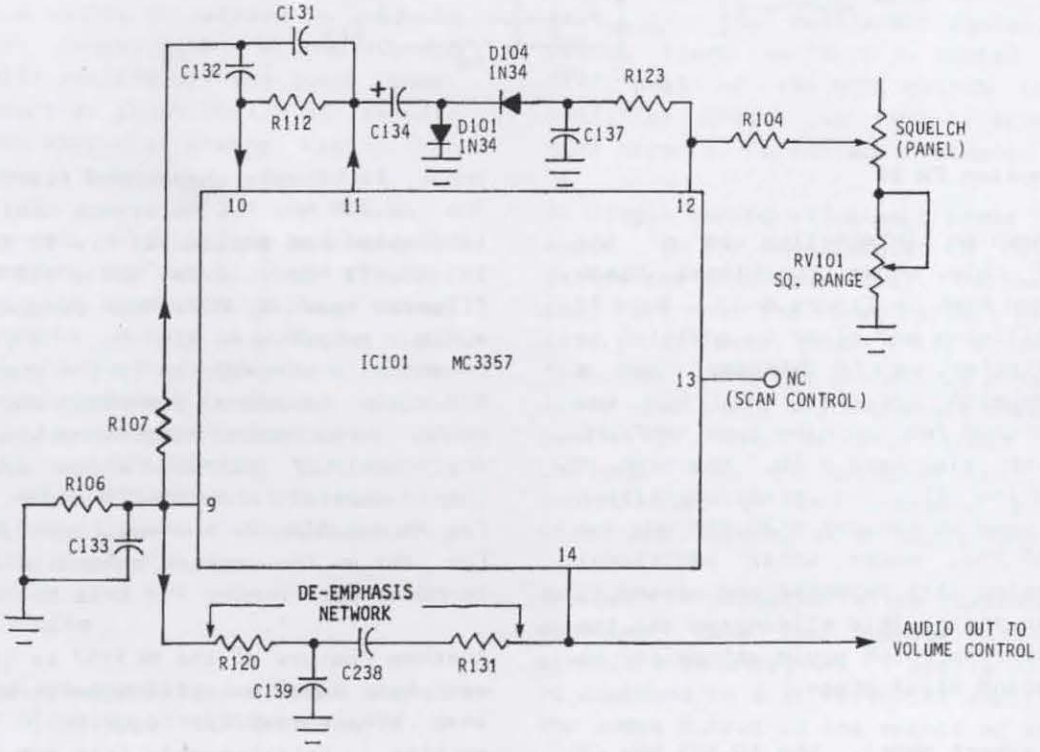


FIGURE 4-37
MC3357 NOISE SQUELCH CIRCUIT
(Cobra 21FXM, Colt 295, etc.)



the Jackson, since that radio must also receive AM and SSB. IC Pins 10-14 are left unconnected. However this feature as well as the scan control are used in many UK and other European FM-only radios. Examples are the Korean-made Maxon chassis (Colt 295, Cobra 21XFM, Midland 4001, etc.) and the DNT LCL-2740FM.

The optional circuitry is shown in Figure 4-37. Since the chip has a built-in filter amp, external RC networks R107/R106/C132/C133 and R112/C131 shape the desired frequency response. Detected audio is Pin 9 and the de-emphasis network is R120/C139/C238. An audio sample is applied to the filter input, Pin 10. At the filter output (Pin 11), detector diodes D101 and D104 convert this to a DC control voltage which is applied to Pin 12, the squelch trigger. R123 and C137 control the time constant to prevent false triggering. The output is Pin 14, which is shunted directly across the VOLUME control; when the squelch operates, Pin 14 grounds and mutes the speaker.

FM RECEIVER TROUBLESHOOTING

It's relatively easy to solve a complaint of "No FM Receive, but AM (and SSB) Receive OK." Check voltages on the FM detector chip. If the specified voltages look correct, check for the IF input signal using a 'scope or signal tracer. If the IF signal is not getting to the chip, backtrack to the 2nd mixer to locate the open signal path. If the IF input is present but there's no audio output, you can be almost positive the FM Detector chip is bad.

Before pulling the IC though, make sure the detector coil is tuned properly and you're checking with a true FM signal source, like a commercial FM generator or a second FM CB. It's very easy to slope-detect an FM signal on an AM receiver. "Slope" detection means receiving an FM signal by tuning slightly off the center carrier frequency with the Delta Tune or Clarifier. With true FM the centered carrier will produce almost no audio output, because FM sidebands cancel each other out in AM detector circuits. Also, slope detection of FM in an AM receiver doesn't limit impulse noise; if such noise is present it might indicate slope detection is occurring, and simple retuning of the FM detector coil is all that's needed.

This point should be emphasized again: if all you had for a signal source was an AM generator or AM CB and the FM detector was defective or not properly tuned, you might hear what sounds like passable audio even though the radio was in the "FM" mode. You'd be hearing AM, not FM. A true FM signal source is required here.

On the subject of coils, make sure the input peaking coil (if present) is properly tuned; being a parallel-resonant circuit, mistuning results in a low impedance directly across the 455 KHz IF path. This could load down the AM signal as well, causing reduced sensitivity in that mode. This won't apply to the μPC1028 or MC3357 type circuits, but does matter in nearly all Maxon or Cybernet radios because they use the AN240 IC and the 455 KHz IF input coil.

The following are IC substitutions for the most common FM detector chips:

AN240 = MC1358, CA3065E
μPC1028H = TA7130P
MC3357 = See Newtone substitution book
LA1230 = See Newtone substitution book

SQUELCH CIRCUITS

A receiver's background noise while at full sensitivity is very irritating with no signal present. The purpose of squelch is to silence the speaker when no signal is being received, or when the incoming signal is too weak for good communications. The level at which the squelch "breaks" is adjustable by the operator from the radio's front panel. It could also be adjusted so only signals of a predetermined signal strength will operate the speaker. When the control is set for its maximum effect (full clockwise), it's called "tight" squelch. The squelch range is often specified by the manufacturer, like "0.7 μV to 300 μV." There's normally a second internal adjustment to set the squelch range within the specified limits.

All CB squelch circuits work on the same principle: with no input signal, a transistor switch cuts off the audio amplifier chain by shunting the audio to ground, or because the switch is in series with the detected audio and the audio amplifiers. The circuit may use an IC, a single transistor, or several DC-coupled

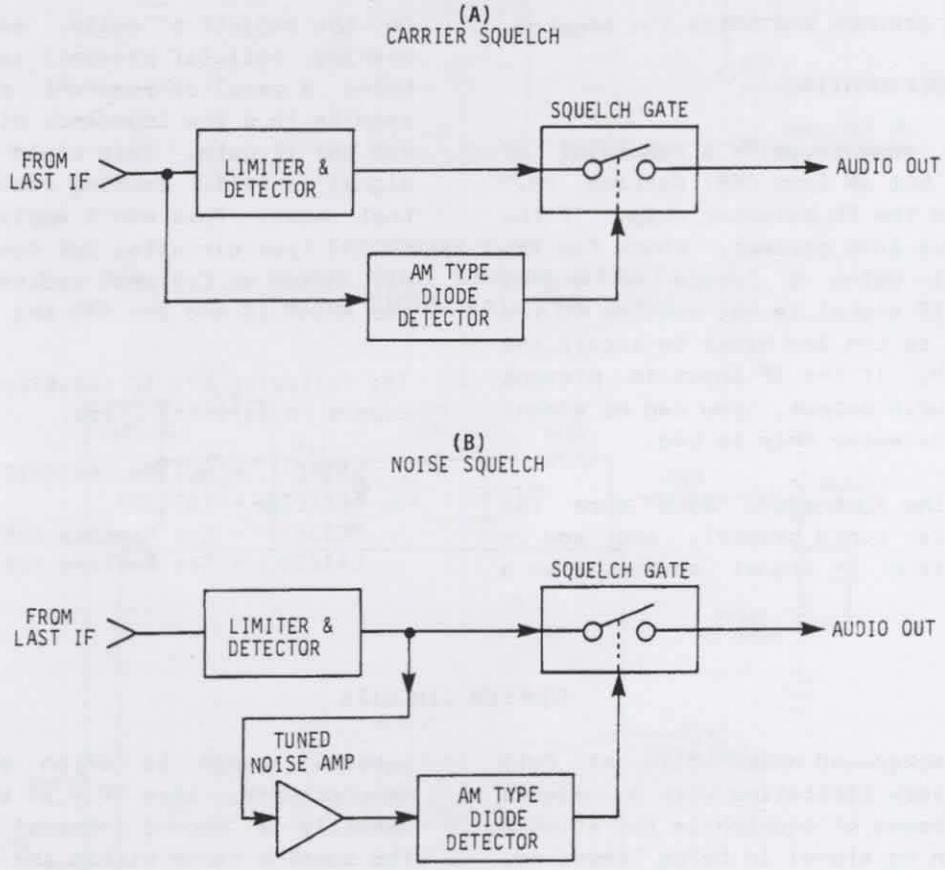
transistors for greater sensitivity and control. The squelch input is normally taken from the same point as AGC; i.e., right after the detector. In a few 23-channel radios it was sampled at the 27 MHz front end, which wasn't nearly as effective.

Carrier Squelch vs. Noise Squelch

There are two squelch methods common to CBs, "carrier operated squelch" and "noise squelch." Virtually all AM and SSB CBs and FM types with the simpler AN240 or μPC1028H detectors use carrier squelch. In this system, a DC control signal is developed that corresponds to the amplitude of the carrier, similar to AGC.

By contrast, the noise squelch system senses the noise present at the detector output to develop its control signal. Thus the control signal depends directly upon the receiver's S/N ratio. A special tuned noise amplifier in the 5-10 KHz range is used; being above the voice frequency range, it acts only on the noise present. The result is superior sensitivity and immunity to squelching on general background noise or strong bleedover. This method is found in UK-FM equipment using the MC3357 IC. The basic differences are shown in Figure 4-38.

FIGURE 4-38
SQUELCH CIRCUITS
(Courtesy Heinemann-Newnes Books)



Carrier Squelch Methods

Figure 4-39 shows a simple carrier-controlled circuit. Q13 is connected as a saturated ON/OFF switch. VR2 (front panel adjustment) and RV1 (internal adjustment) preset the bias on the base of Q13. Whenever this bias exceeds about 0.6 VDC Q13 turns on, pulling its collector down near 0.0 volts. Since the collector is wired directly across the input to the audio amp at IC4 Pin 5, the audio is shunted to ground and the speaker remains silent. An

incoming signal will develop a negative voltage at the anode of detector D9. When this voltage is negative enough to overcome the preset positive bias, Q13 stops conducting and the audio amplifiers work normally. R63/C85 filter audio, and R62/C115 filter any remaining RF so the squelch control voltage is pure DC.

A more sophisticated and effective circuit is shown in Figure 4-40. The main difference is the addition of two DC amplifier stages, TR12 and TR11. TR13 is still the cutoff switch which is shunted across IC4 Pin 4. The forward bias is again preset by VR202 and VR3. At the squelch "threshold" (where it just silences) the base of TR12 is HIGH, turning it on and pulling its collector and the base of TR11 LOW. This pulls the collector of TR11 HIGH through R41, which turns on TR13 to shunt the audio to ground. An incoming signal will develop a negative-going voltage at the anode of AGC diode D6. This cuts off TR12 and reverses the HIGH/LOW bias sequences of TR11 and TR13, allowing the speaker to be heard.

FIGURE 4-39
CARRIER-OPERATED SQUELCH
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)

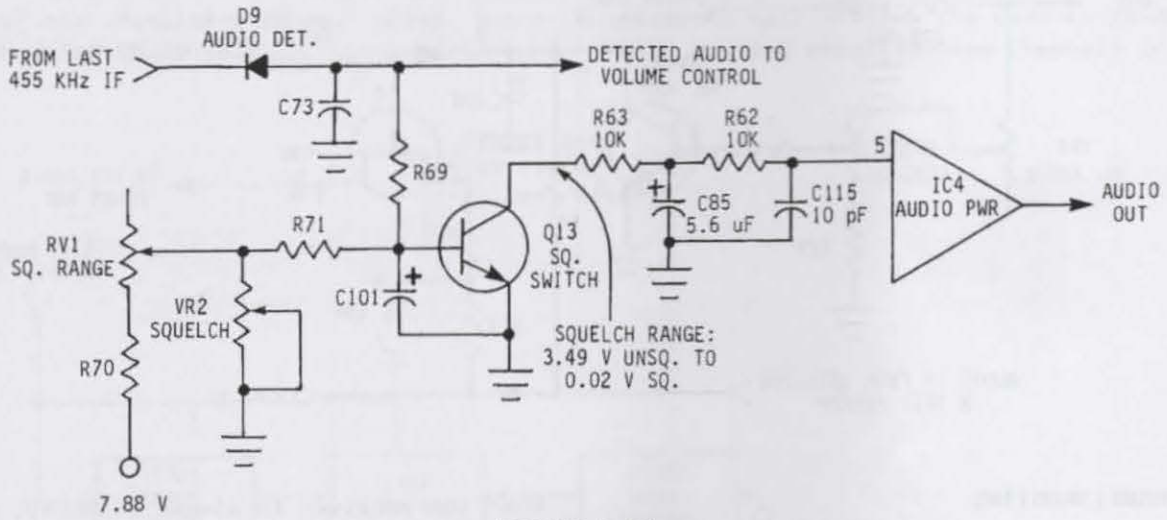


FIGURE 4-40
AMPLIFIED CARRIER SQUELCH
(Cobra 29GTL, 29LTD, etc.)

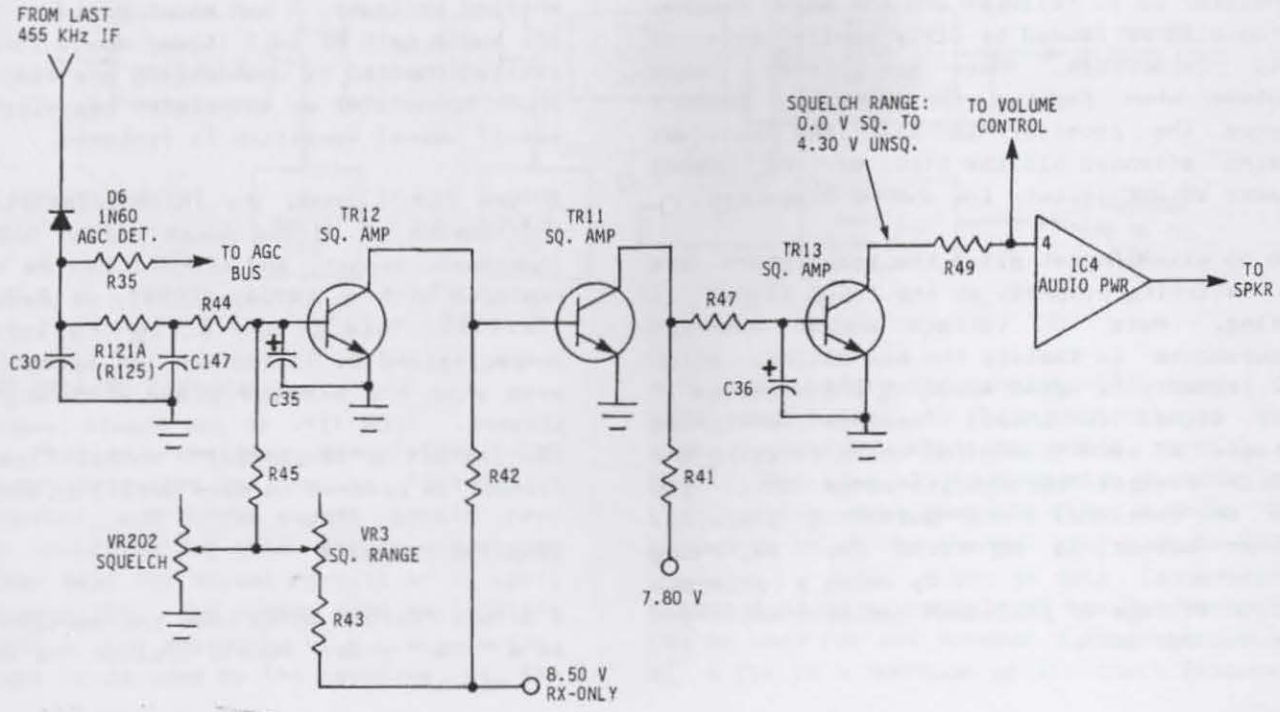
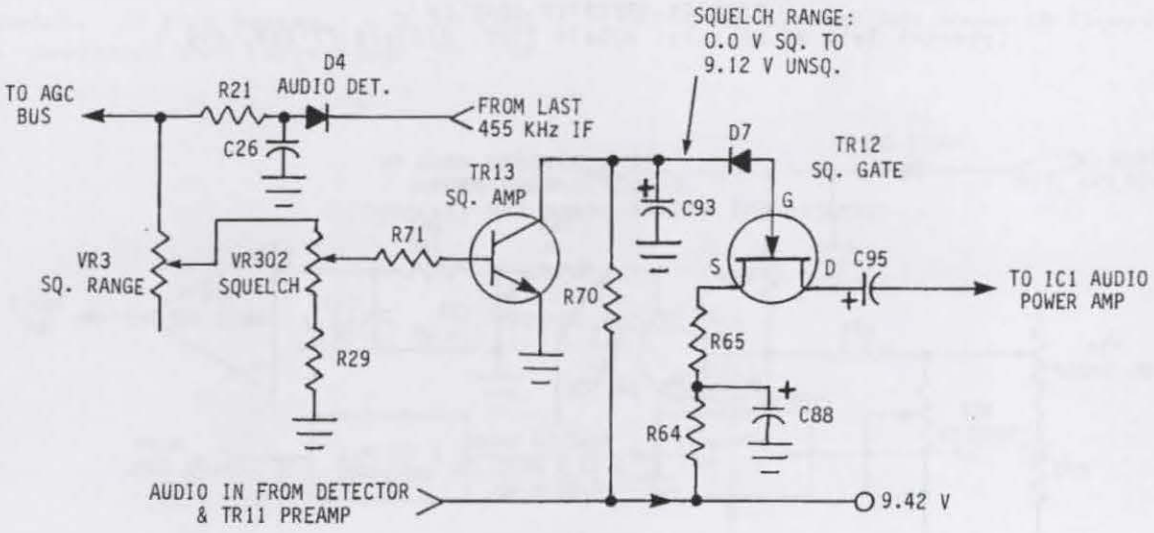


Figure 4-41 shows another type of carrier squelch, the "series gate" circuit. In this circuit the squelch switch, an FET, is in series with the audio path from detector to audio amplifier. The switch must be closed for audio to pass, which it normally will be until the gate of TR12 goes sufficiently negative to pinch off the current flow between source and drain. This pinchoff happens when the collector of TR13 goes LOW. TR13's collector is LOW in the squelched position of VR302. When a large negative-going voltage from a detected signal at the anode of D4 overcomes the preset forward base bias, it stops conducting and its collector goes HIGH, restoring the audio path.

FIGURE 4-41
SERIES-GATE CARRIER SQUELCH
(Cobra 29XLR, 89XLR, etc.)



SQUELCH TROUBLESHOOTING

Squelch problems are relatively easy to isolate once you understand the switching involved. Transistor or IC failures are the main source. A few will be caused by dirty control pots or leaky capacitors. There are three basic symptoms when faulty: the squelch doesn't silence the receiver at all, the receiver remains silenced all the time, or the normal speaker VOLUME is very low and/or distorted.

With no silencing at all, the transistors are not switching properly or the input signal is missing. Make DC voltage and/or ohmmeter measurements to isolate the bad device, which will probably be open. Assuming the detected IF input signal is there, measure switching voltages of each transistor while rotating the SQUELCH control through its range until you find the one that's not switching properly. Another method is to force the switching transistor(s) HIGH or LOW by using a separate pull-up voltage or pull-down resistor until you find the bad switch.

When the receiver is always silenced, distorted or at low volume, and the radio's S-Meter or a signal tracer at the detector shows otherwise normal reception, the active device may be shorted or leaky. A bad shunt device will kill the audio path or pull it way down. This can be easily checked by unsoldering one lead of the shunt transistor or associated capacitor(s) to see if normal operation is restored.

If you didn't know, the TA75902/TA6324/NJM2902 AGC/Squelch IC in the newer Uniden SSB radios (American, export, and clones) can be directly replaced with an LM324, ECG987, or Radio Shack 276-1711. This IC has a high failure rate, characterized by little or no speaker volume even when the S-Meter shows a strong signal present. TECH TIP: If you should replace the IC, install a 14-pin DIP socket first. This circuit is covered in more detail in CHAPTER 6.

SCANNING CIRCUITS

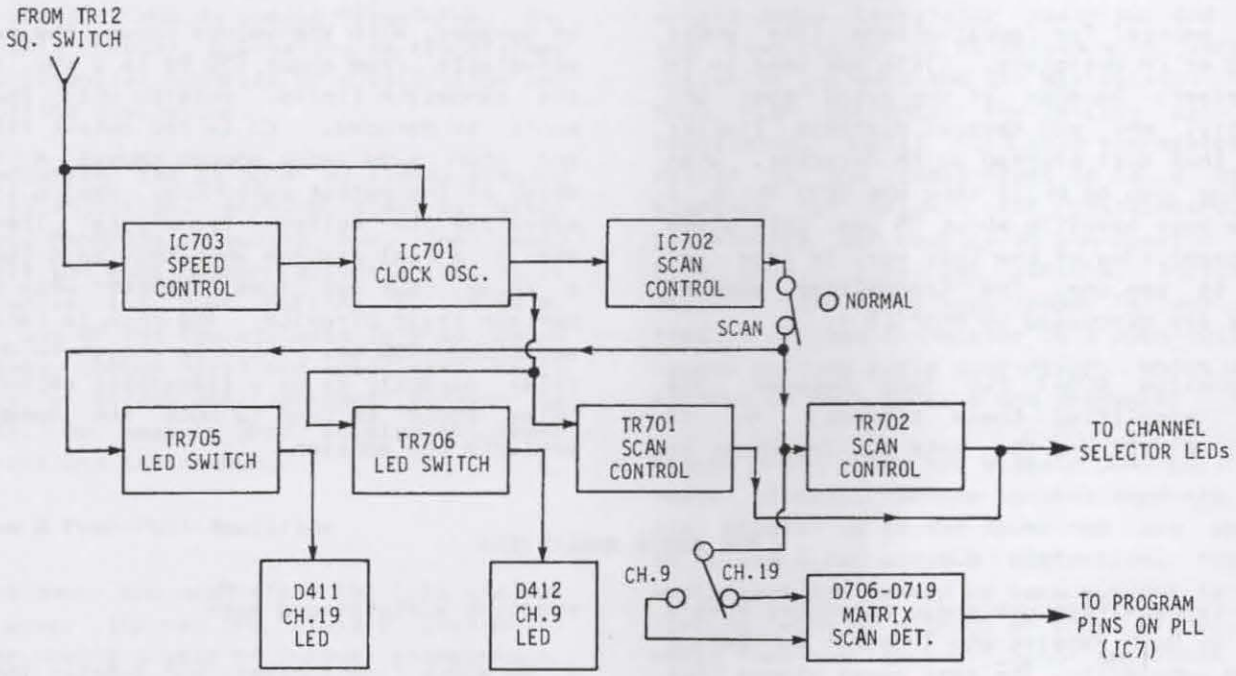
A deluxe feature which uses the squelch circuit is a "scan" mode. Models include the ARF-2001,

President Adams, SBE "Key-Com," Sidebander V, Console V and VI, and Realistic TRC459. In the ARF-2001 and TRC459, a microprocessor allows a choice of programmable frequencies to be scanned and/or memorized; the simpler circuits only scan up and down the CB band, or they scan Ch.9 and Ch.19 only.

This circuit is basically the same as the remote UP/DOWN PLL controller discussed in CHAPTER 3. The main difference here is that the squelch signal controls the scanning, rather than programming within the synthesizer. When a signal appears, the same squelch transistor used for audio muting causes the scan circuit to stop. Figure 4-42 shows a simplified block diagram of the President Adams, which scans between Ch.9 and Ch.19 only.

Standard "4000" series CMOS ICs are used. IC701 and IC703 form a clocking oscillator driven by the squelch transistor. They control IC702, a dual J-K Flip-Flop. This IC simply oscillates back and forth like a multivibrator, but at a speed slow enough so the Ch.9/19 LEDs can be seen flashing. The output of IC702 is disabled in the "NORMAL" mode, but in the "SCAN" mode it controls the PLL lines through a diode switching matrix. The matrix presets the correct BCD program codes for Ch.9 or Ch.19 directly, bypassing the Channel Selector. A signal on Ch.9 or Ch.19 will break the squelch and be heard. IC702 also drives individual transistors for the Ch.9/Ch.19 LEDs. Uniden cleverly planned this scanner so wire jumpers in the matrix allow the user to re-program it for any two other desired channels instead.

FIGURE 4-42
SCAN CIRCUIT
(President Adams)

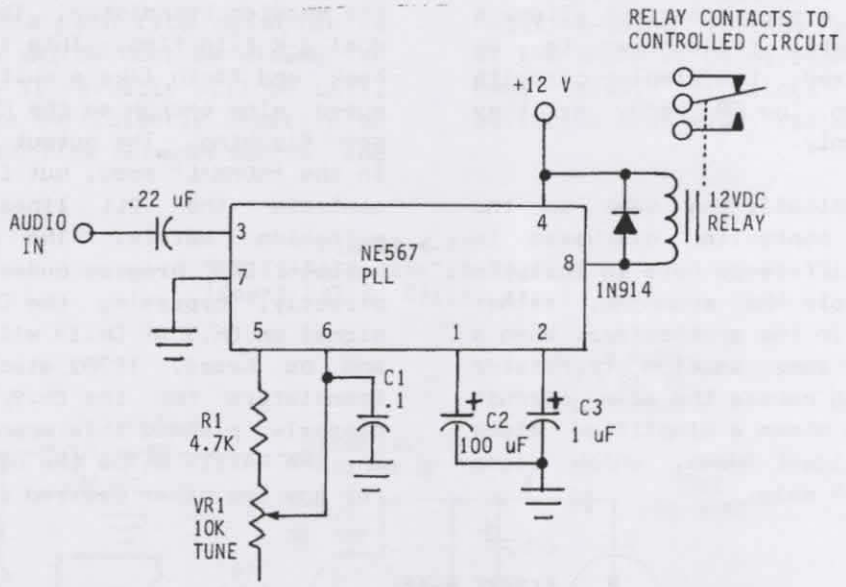


SELECTIVE CALLING (SEL-CALL)

Another feature sometimes associated with squelch is Selective Calling or "Sel-Call." Many Cybernet and Uniden export models have built-in provision for this option, although I've never seen the actual circuit so I can't be more specific. The system adds an audible tone burst at the beginning of a transmission, which must be decoded by the receiver at the other end before the squelch will open. This adds some privacy to the communications link, since undesired stations won't normally be heard. But like all tone squelch systems, once the squelch does open all other signals that happen to be on the channel will also be heard.

Figure 4-43 is an example of how PLL technology can be used for the decoder. Since the output of a PLL is a function of its input frequency,

FIGURE 4-43
PLL TONE DECODER
(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)



it's a natural for applications like audio decoding or FM detectors. (It's not used in FM CB receivers because of the extra cost and complexity; why add several discrete limiter stages that must preceed an FM detector, when everything can be built into one IC?) While I can't be more specific about CB use, this shows the general idea of how they work in case you happen to see one. The transmitter encoder circuits are discussed in CHAPTER 5.

The Signetics NE567 PLL Tone Decoder has greatly simplified these systems. An RC network, R1/VR1 and C1, sets the frequency to be decoded. With the values shown, the range is adjustable from about 670 Hz to 2 KHz. C2 sets the bandwidth limits, outside which the tone won't be decoded. C3 is for output filtering and when made large enough causes a turn-on delay of the output switching, making it less sensitive to voltage transients. Transients aren't a real problem when driving a load like a relay, but may cause "chatter" when driving certain logic circuits. The chip is capable of switching 100 ma, which is enough to drive a relay directly or by a transistor switch. The relay could be used to mute the speaker or activate the squelch.

THE AUDIO AMPLIFIERS

Most CB transceivers use audio circuitry that's shared by both Receive and Transmit to reduce cost and complexity. The same power stages that drive the speaker will often be used for transmitter modulation on AM or FM. The audio path is switched between Receive and Transmit by a relay or diodes and the PTT mike switch. SSB radios have some unique differences, including the current trend towards separate transmitter modulators and receiver audio power amps. The receiver audio stages amplify the detected signal enough to operate a speaker.

Symptoms associated with problems in the receiver audio stages are:

1. No audio from speaker, but S-Meter indicates normal reception otherwise.
2. Low or weak volume.
3. Distortion.
4. Motorboating noises, or hum.
5. Blows fuses.

Dead receiver audio stages are easily diagnosed by touching the wiper of the VOLUME control with your finger or a probe; a normal working amplifier chain will produce a hum in the speaker. Of course this assumes the squelch

doesn't have it cut off, since even a properly working stage wouldn't be heard then!

The audio chain usually consists of one to three stages of amplification after the detector and a power amplifier. Many of these are transformer-coupled to the speaker, although the newer IC output stages are usually transformerless. There are three main types of power amplifiers: the single-ended tube or transistor, the push-pull amplifier, and the IC amplifier, in order of evolution.

The single-ended and push-pull types are only found in older American models, since they're considered obsolete technology. (I.e., not cheap enough!) The tube radios always used single-ended audio amps, and so did a few early transistorized radios like the Pace 2300. As production methods improved, the push-pull output came along. Both methods required the use of expensive input and output transformers. The current CB technology uses just a single plastic power IC and no output transformer. Not only is this cheaper, but having no transformer means no potential magnetic core saturation and its resulting distortion.

Troubleshooting can be done by signal tracing or signal injection, working stage by stage until you find the defective one. The power stages are the most common failure point, since they handle the most current or voltage. They're one of the few circuits in a CB radio having heavy enough wires and associated parts to carry a direct short without burning up instantly. So keep a good supply of power transistors and ICs on hand!

The Class B Push-Pull Amplifier

The audio power amp used after the tube era but before power ICs was the "Class B push-pull" amplifier using a pair of output transistors. Push-Pull means two power transistors operate on alternate half cycles of the input signal. This is done by splitting inputs and outputs equally with center-tap transformers to create a balanced circuit. This cancels even-order harmonics (2nd, 4th, etc.) as well as AC hum caused by power supply ripple in base transceivers. The high DC current flowing through a single-ended amplifier can magnetize the transformer core and cause distortion. A further advantage of the push-pull amplifier is that the currents of each tube or transistor are always flowing in opposite directions, which prevents core saturation.

In the Class B amplifier, the transistors are biased at approximately cut-off. Base current flows only when the driving signal is high enough to overcome the existing bias, which for an AC signal means exactly half the time. Because of this, the load on its driving stage is constantly changing from a higher impedance when no current flows to a lower impedance when it does. The driving stage must therefore have good voltage regulation to minimize distortion. You'll generally find the collector supply to the driver transistor heavily filtered by about 100 µF. Since electrolytics tend to dry out and these circuits appear in older models, suspect this capacitor in cases of poor audio quality. Bridge a good one across it to confirm.

Push-pull audio amps weren't used in tube CBs, since a single-ended circuit provides plenty of audio power compared to transistors. But the push-pull circuit is much more efficient than a single-ended transistor power amp and allows the transistors to be driven with very high collector currents and low distortion. To run such high currents, the devices are always heatsinked. You'll find this transistor pair bolted to the radio frame or to a separate aluminum "L" bracket for heatsinking. The transistors are usually in the plastic TO-220 type case, like the 2SC1014, 2SC1096, or 2SC1173, and are a very common failure point. Failure of one transistor in a push-pull pair causes extreme audio distortion, which will be evident on both Receive and Transmit.

Figure 4-44 shows the classic push-pull audio power circuit. Common Emitter amps are used. The stages up to the power amp are operated in Class A for minimum distortion. "Class A" amplifiers are biased so base current is always flowing with or without an input signal. This makes them the least efficient amplifier type, since they only work on the linear part of the input signal waveform. But they have the cleanest output signal. Since they're the least efficient, two stages (TR6, TR7) are needed to increase the level enough to drive the power amp stage. The audio input from the detector goes to the high side of the VOLUME control. It's amplified by TR6 and coupled by C32 to the base of TR7, the Audio Driver stage. The output of TR7 is coupled across T9 to the push-pull power amplifiers TR8 and TR9.

The push-pull power amp, having balanced input

FIGURE 4-44
DISCRETE PUSH-PULL AUDIO POWER CHAIN
(Courier Rebel 23+, Fanon Fanfare 100)

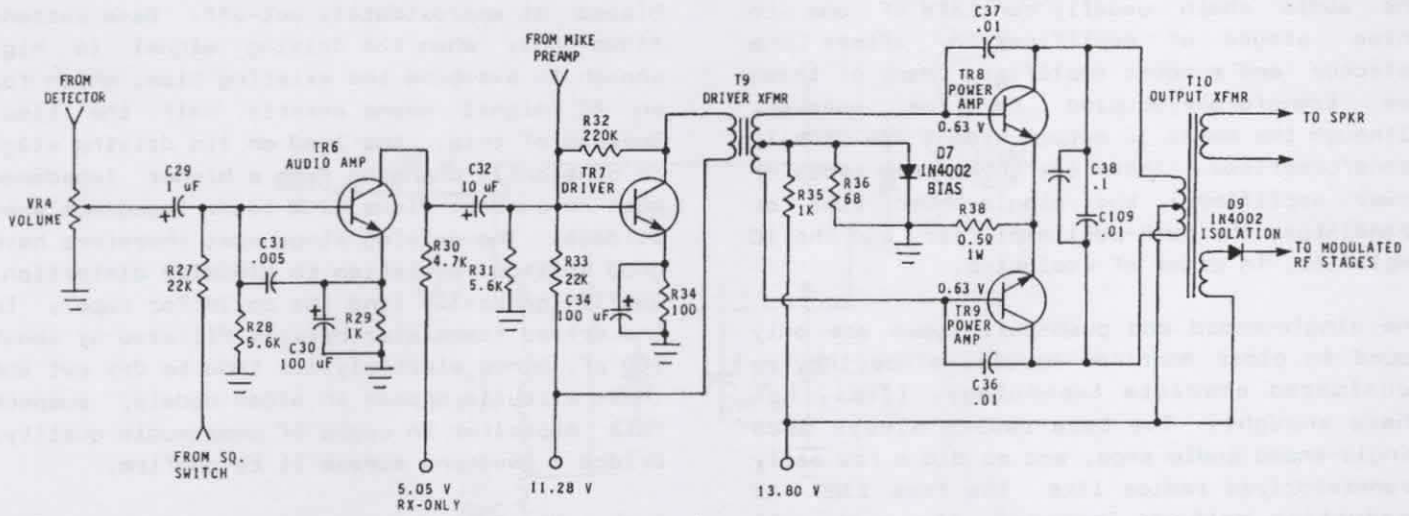
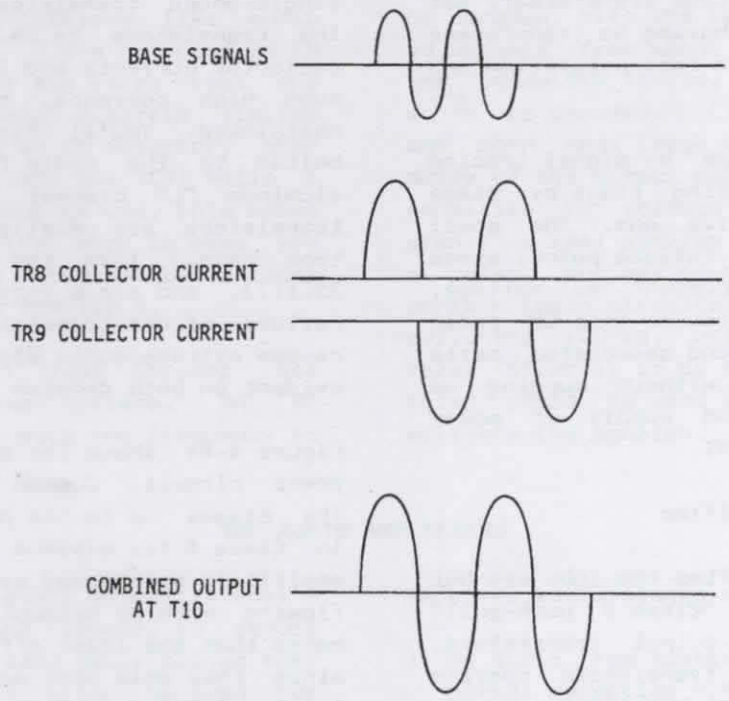


FIGURE 4-45
CLASS B PUSH-PULL AMP OPERATION



and output circuits, means at any given instant each end of T9's secondary will have the opposite polarity with respect to the emitters. One transistor base goes positive at the same time the other goes negative. Their voltages and currents are 180° out-of-phase with each other, since only one transistor conducts at a time. The even order harmonics (2nd, 4th, 6th, etc.) are balanced out, reducing distortion.

Figure 4-45 illustrates how the two halves of the audio cycle will combine to produce a faithful but amplified copy of the original. Class B audio operation always requires a pair of amplifiers working on alternate half cycles. (This operation differs from that of an RF amplifier, which can operate on just a single Class B stage. The flywheel effect restores the complete waveform; see CHAPTER 5.)

Returning to Figure 4-44, C31, C36 and C37 provide some degenerative feedback to stabilize the gain and roll off the higher audio frequencies and harmonics. This maintains a narrow voice bandwidth without splatter to adjacent channels. R38 provides emitter bias stabilizing and current limiting, since a direct ground could cause thermal runaway and destroy the transistors. As the transistor warms up it passes more current and increases the resistor's voltage drop, producing more reverse b-e bias which reduces the current flow. This resistor is usually under 1Ω, with a 1 or 2 watt rating. Sometimes each transistor has its own emitter resistor, a good practice that aids reliability.

R35, R36, and D7 provide the forward bias for Class B operation, since D7 (a silicon diode) is conducting hard. This drops about 0.65 VDC, close to cutoff with no input signal. Such bias is considerably less than Class A amplifiers, which are always conducting and normally run about 1.5-2.5 VDC base bias. Excess bias with Class B causes distortion, which is something to check when troubleshooting that particular symptom. Sometimes you'll see a "thermistor" (thermally-sensitive resistor) in place of D7. The thermistor is a ceramic semiconductor whose resistance changes as its temperature changes. With the negative-coefficient (NTC) type, the more the power transistors (and it) heat up, the lower its resistance and the more voltage it drops away from the bases. This lowers transistor conduction and prevents thermal runaway which could otherwise destroy TR8 and TR9. An open bias diode or thermistor causes severe audio distortion, and the power transistors won't last long either.

C38 and C109 filter some high-frequency audio components and provide some transient spike protection. If either of these is open you may never know it except by out-of-circuit tests. D9 is often called an "isolation" or "limiter" diode and is very important. It helps prevent overmodulation and keeps RF out of the power supply. If it's open there's no Transmit. If shorted, there may be mild distortion, overmodulation, or self-oscillation from RF coupling back into the power supply. Since this diode carries the full transmitter collector current of over 1 A, always replace it with a 2-3 amp device. (1N5400 family, ECG156, etc.) T10 is a dual-secondary output transformer; one winding is for the modulated transmitter audio and the other for the speaker. In newer transceivers this has been further simplified with a single tapped secondary winding.

If either (or both) power transistor shorts, it will most often blow the fuse, since it's directly powered from the 13.8 VDC input. If open, there's extreme distortion, obvious to a listener or on a 'scope. When you find a bad transistor in a push-pull circuit it's smart to replace both; the bad one often weakens the good one. These transistors are very cheap, and may save you potential service callbacks.

IC Audio Power Amplifiers

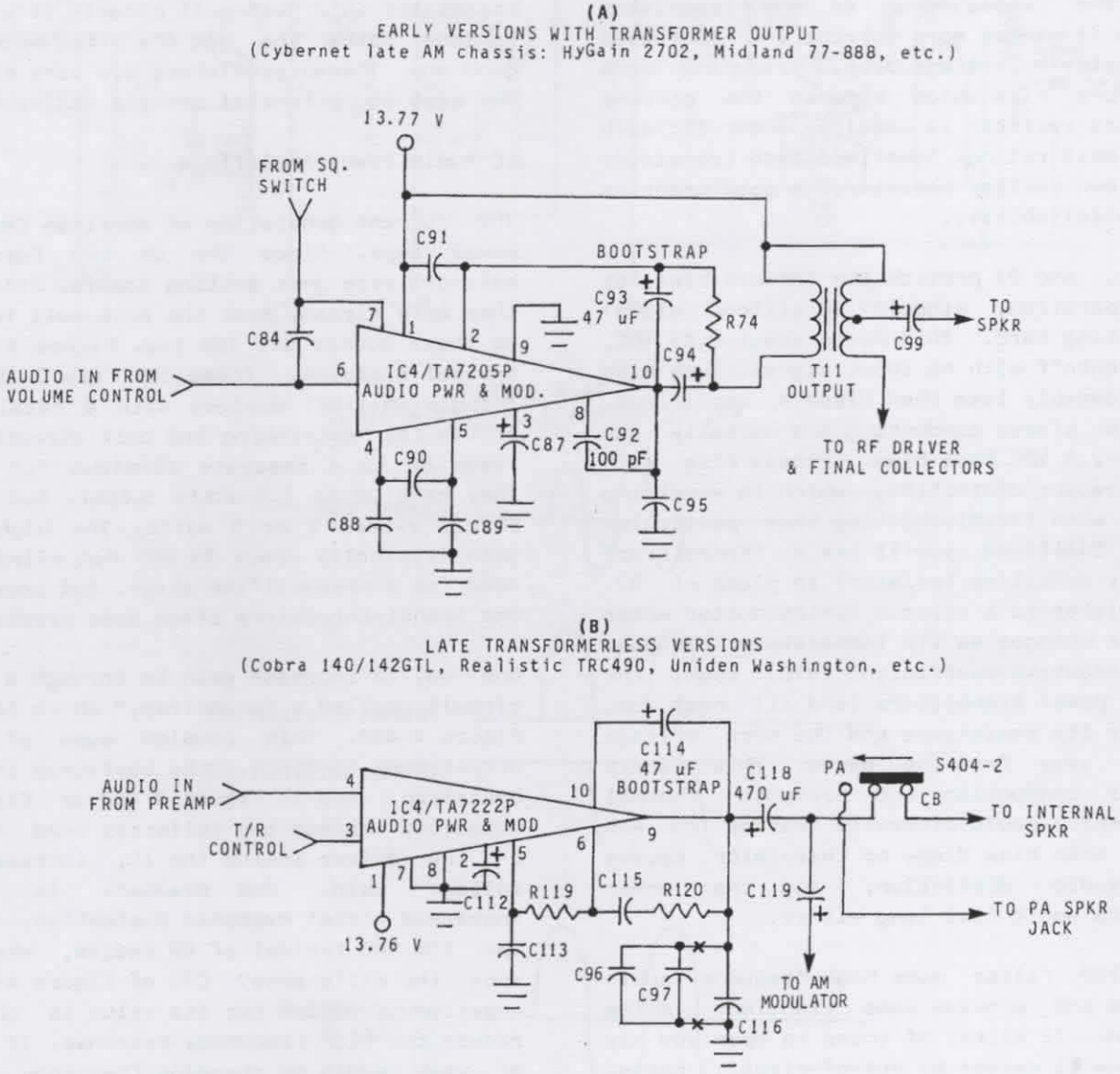
The current generation of American CBs use IC power amps. Since the UK and European CB services were just getting popular around 1980, they were already past the push-pull technology so their models use ICs too. Figure 4-46 shows typical examples. These ICs are 7-10 pin SIL (single-in-line) devices with a metal surface or tab for heatsinking and bolt directly to the frame or to a separate aluminum "L" bracket. They have up to 5.5 watts output, but most CBs rarely exceed 2 or 3 watts. The high voltage gain (typically about 55 dB) can eliminate the need for a preamplifier stage, but occasionally one transistor driver stage does preceed it.

One way to increase gain is through a feedback circuit called a "bootstrap," which is C93 in Figure 4-46A. This couples some of Pin 10's output back to Pin 2, the bootstrap input. The bootstrap used in Figure 4-46B is C114. This capacitor raises the collector load impedance of the driver inside the IC, increasing its voltage gain. One drawback is slightly increased Total Harmonic Distortion, but with the 10% THD typical of CB radios, who'd ever know the difference? C92 of Figure 4-46A adds negative feedback but its value is chosen to reduce the high frequency response. If symptoms of weak audio or changing frequency response occur you should check these capacitors; the electrolytic types do dry out.

Audio power ICs eliminate the need for the input transformer of the push-pull amplifier. The dual-secondary transformer winding has also been replaced with a single center-tapped winding. In Figure 4-46B even the transformer itself has been eliminated. Output coupler C118 is now a very large value, since it's looking directly into a low-impedance speaker circuit. The evolution of ICs has greatly reduced the cost, bulk, and need for audio transformers.

In CBs these ICs are always pushed to their limits, and very often blow out. Note they're almost direct-coupled to the speaker; the wrong speaker impedance or a shorted or open speaker can cause sudden IC failure.

FIGURE 4-46
IC AUDIO POWER AMPS



AUDIO TROUBLESHOOTING

Since almost all Receive audio circuits are shared by Transmit, the tips in this section also apply to modulation problems. The only unique receiver audio circuit is the signal path from the power amp to the speaker itself. This path is switched between the speaker and the RF power stage in AM radios, and the speaker and the FM modulator in multimode radios. So it's a question of audio problems on both Receive and Transmit, or one mode only. To proceed logically, you must first answer that question. The circuits associated with T/R switching are often the cause when the audio problem only affects one mode. In relay radios, check for continuity of the relay contacts. The speaker jacks are another common fault, particularly in the newer radios that use cheap sub-miniature types. Most are meant to be self-shorting when the plug's removed but may not be making good contact. The jack wires are only #24 or #26 gauge and can break from excess handling or metal fatigue; you may never even

know it, since they're hard to spot unless the broken wire moves while you're watching.

Never underestimate mike wiring as the fault. This is especially true with electronic T/R switching, because the speaker is usually grounded only with the mike plugged in and its PTT switch making a complete circuit through the cable. A few 5-pin DIN mike sockets include a self-shorting contact so the speaker can be heard even with the mike unplugged. This contact can open up too. Broken wires inside the mike cable, mike plug, or mike PTT switch are extremely common CB problems.

Assuming the audio problem is common to both the Receive and Transmit modes, you'll have to check the audio amplifier chain itself. Troubleshooting audio amplifiers is very straightforward. In the case of ICs, check voltages and input/output signal pins with a 'scope or signal tracer. If the input is present with no output and specified voltages are off, you can be pretty sure it's bad. It may short or open internally. A short can blow the radio fuse, since the chip is directly powered from the main 13.8VDC supply.

Below are the most common CB audio power ICs and their equivalent American parts. Remember: NewTone now includes the ECG and SK lines, so these parts will say either "NTExxxx" or "TCGxxxx." (Also applies to top of Page 147.)

AN7140	=	ECG1365
BA521	=	ECG1166, SK3827
HA1339	=	ECG1169, SK3708
HA1366WR	=	ECG1261, SK3872
KIA7205P	=	ECG1155, SK3231
KIA7217P	=	ECG1370
MB3712	=	ECG1423, SK7600
MB3713	=	ECG1424, SK7601
TA7205P	=	ECG1155, SK3231
TA7217P	=	ECG1370
TA7222P	=	ECG1278, SK3726
TBA810S	=	ECG1115, SK3917
μPC1156H	=	ECG1194, SK3484
μPC1182H	=	ECG1286, SK3923
μPC1242H	=	contact radio manufacturer, NewTone Electronics, or MCM Electronics. (Addresses on Pages 21 and 24.)

NOTE: The specs on these devices indicate power outputs of about 5.0 to 5.8 watts. But they never run this high in CB radios, since some reserve power is always included to prevent distortion at the lower specified levels.

A shorted push-pull output transistor or IC can draw enough current through a transformer winding to burn it open before the fuse blows. So after you replace the active device, there's still no audio. In older circuits with separate secondary windings for both the speaker and modulated RF stages, one winding could open up while the other still functioned normally.

Transformer problems can be subtle. Windings can short together to change the impedance. This is quite difficult to analyze unless you have very precise DC winding resistance information and a digital VOM to check it. Symptoms include distortion and low volume and/or modulation. Since a transformer is often specially-made, expensive, and hard to replace, save your doubts about it until all other possibilities have been logically eliminated. Power transformer failure is relatively rare.

The speaker itself can cause the "No Receive Audio" problem. The simple way to check is by substitution. I use a cheap PA speaker on my bench, which when plugged into the "EXT SP" jack of the test radio will verify its speaker as good or bad. Speakers do burn open and this can be checked with an ohmmeter; it's quite common when the radio puts out 3 or 4 watts of audio into a speaker often rated at only 1 or 2 watts! Apparently some manufacturers think the full power will never be used. But in locations like an 18-wheeler cab, an airplane, or a boat, the VOLUME may often be up full blast.

Sometimes instead of an open voice coil there's a scratchy VOLUME control, defective capacitor in the power amp stage, or partially shorted or stuck voice coil. In coastal areas, the paper diaphragm may go limp from the humidity. Substitution will confirm the problem. In tube radios a common problem is that the heat eventually dries out electrolytic capacitors. To check this, bridge a good one across the suspected one; it's quick and saves unsoldering if the original wasn't the problem after all.

The symptom of "motorboating" or excessive hum This always caused by poor power supply filtering. Suspect dried out electrolytics here too. The power amps receive their voltage directly from the main input source in tube and solid-state radios. Check the schematic to locate all the audio electrolytics and bridge a good one across any that you suspect. Since electrolytics are also used for interstage coupling and emitter or cathode bypassing, any

drastic capacitance change can cause hum as well as low gain or distortion. Hum may also be caused by a broken shield connection in those radios using shielded audio cable. This is especially true in tube radios or ceramic mike circuits, which being high-impedance must always be carefully shielded.

LED CHANNEL DISPLAYS

All CB transceivers having 40 or more channels use a 2-digit, 7-segment LED channel readout display. There's nothing very complicated about its operation when analyzed logically.

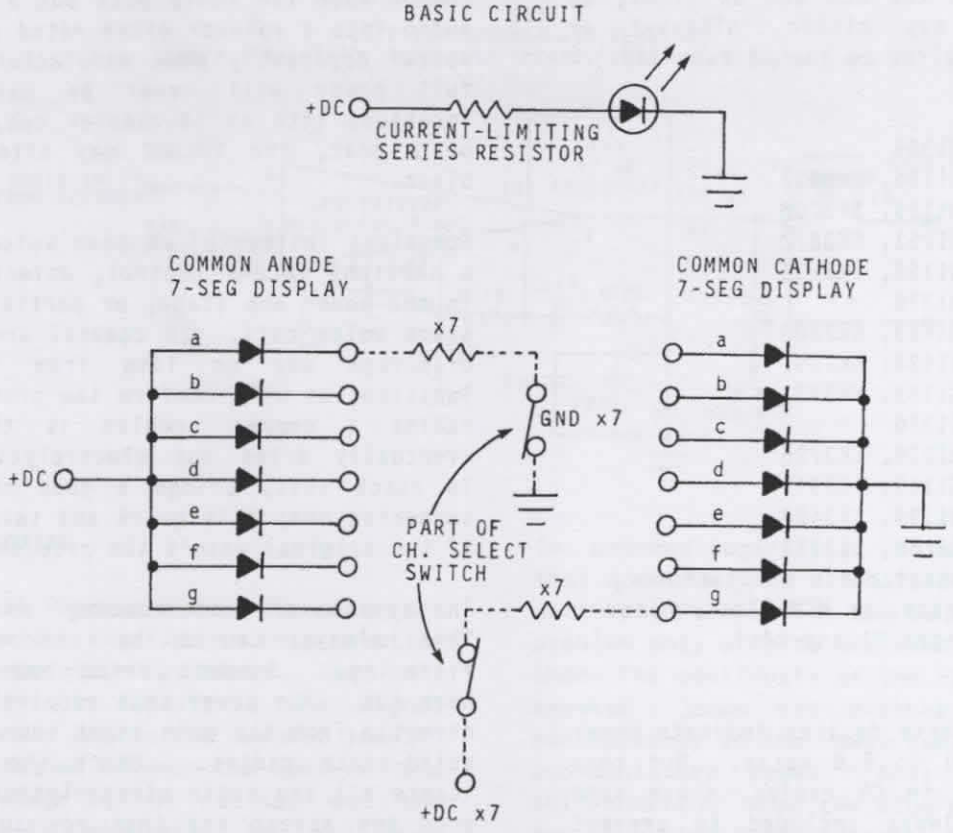
Problems associated with LED channel displays include:

1. Dead or dim segment within a digit.
2. Dead or dim digit.
3. Dead display, both digits.
4. BRITE/DIM control doesn't work.
5. Displays wrong channel number or "garbage."

Figure 4-47 shows the basic LED principle. An LED is a semiconductor using special compounds in the junction that can emit light when forward-biased. Instead of being completely covered like an ordinary diode, the junction is visible through a plastic lens. Different chemicals emit different colors. The higher the forward current, the brighter the light, until saturation occurs. So like all forward-biased diodes, the current must be limited with series resistance or they'll self-destruct.

By placing seven such diodes in a plastic cube, one digit is created. LED displays are either called "common-anode" if the ground returns are switched, or "common-cathode" if the voltage supplies are switched. Both are found in CBs. The limiting resistors may be discrete for each segment, or contained in an IC-type resistor pack on the PC board, like an SIL IC package. They're in series with the voltage or ground side of the segments. By turning the correct

FIGURE 4-47
OPERATION OF 7-SEGMENT LED DISPLAY

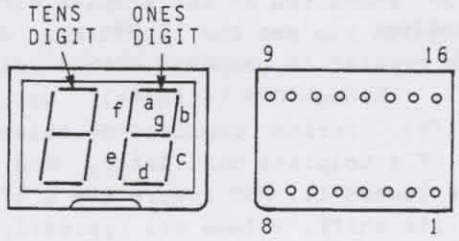


segments on and off, a number is created. The Channel Selector switch usually has an extra wafer to control the LED segments. Radios with scanners or microprocessors use special decoder ICs to control the actual segment switching.

There are two 7-segment blocks for the CB channel display. The left-hand block is the "TENS" digit, and the right-hand block is the "ONES" digit. See Figure 4-48. For the first nine channels, only the right-hand block is needed. For Ch.10 (and up) both blocks will be used: the left for the "1" and the right for the "0." For example to make a "1," segments "b" and "c" must be conducting. The switching continues up to Ch.40. Some export models display directly up to Ch.80. The segment names "a" to "g" are standard among LED manufacturers regardless of the specific device.

Figure 4-48 is the UR202 common-anode display used in many radios. Both digits are contained in a single 16-pin unit. The left-hand "TENS" is defined as Digit 1 and the right-hand "ONES" as Digit 2. Some displays use two separate side-by-side digit blocks. Segments are always labelled "a" through "g." The common-anode type has a regulated voltage applied to the common anode bus (pins 4 and 5), and segments light by grounding the appropriate cathode pins.

FIGURE 4-48
UR202 COMMON-ANODE 2-DIGIT LED DISPLAY



PIN #		PIN #	
1	c-1	9	g-2
2	e-1	10	a-2
3	d-1	11	f-2
4	common-1	12	b-2
5	common-2	13	b-1
6	d-2	14	f-1
7	e-2	15	a-1
8	c-2	16	g-1

For example to display Ch.40, the "4" requires segments "f," "g," "b," and "c" of the left-hand TENS unit, so pins 14, 16, 13, and 1 respectively would be grounded through the Channel Selector switch. For the "0," the switch would ground segments "a," "b," "c," "d," "e," and "f" of the right-hand ONES unit via pins 10, 12, 8, 6, 7, and 11 respectively.

Shown below is a partial logic Truth Chart for this 7-segment display. A "1" indicates a lit segment. Use this idea to troubleshoot any specific segment. First decide which segments should be lit; then backtrack to the switching source of the voltage or ground connections to find the open path.

	TENS							ONES						
	a	b	c	d	e	f	g	a'	b'	c'	d'	e'	f'	g'
Ch.1	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Ch.2	0	0	0	0	0	0	0	1	1	0	1	1	0	1
.				.							.			
.				.							.			
.				.							.			
Ch.39	1	1	1	1	0	0	1	1	1	1	0	0	1	1
Ch.40	0	1	1	0	0	1	1	1	1	1	1	1	1	0

Troubleshooting is relatively easy because the segment blocks and resistor packs must be treated like ICs; if one segment is bad you must replace the whole unit. Dead or dim segments must be traced for continuity with a voltmeter from the supply voltage source to ground via the resistor pack and LED pins to find the bad connection. A poor solder joint is a very likely cause for such problems.

The problem of uneven segment brightness within a digit can be caused by a faulty IC resistor pack (or discrete resistors), or a bad solder connection again. Try reheating all solder joints and measure the segment pins to check for unequal supply voltages. If this doesn't indicate or solve the problem, it's internal and you'll have to replace the digit or resistor pack. Some resistor packs are unmarked on the schematic, but you can always jumper discrete resistors across the correct PCB holes in a pinch. Values range from about 680-1.8KΩ. The Channel Selector is unfortunately a special sealed unit and must be replaced if it's bad.

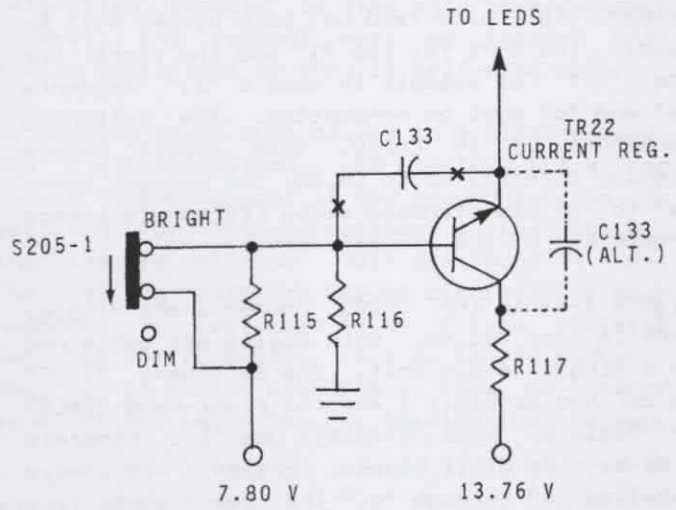
The plastic ribbon cables currently used for interconnections are very delicate; if a trace breaks a segment or a whole digit can be dead. If both digits are dead but the radio works normally otherwise, check the common power source, which is probably missing, or a poor ground to the display common point. Because many newer radios (Cobra "Plus" line, Uniden

"PRO" line, new Midlands and Realistics, etc.) are now substituting LEDs for the meters and other expensive parts, LED problems are also increasing. The greater use of ribbon cables means these problems will ultimately be traced to ribbon breaks or poor soldering of the ribbon cable to the PC board(s) it connects.

Many radios have BRITE/DIM display controls. Figure 4-49 shows a typical circuit. TR22 is a series-pass regulator. Brightness is controlled by changing its bias with the resistive divider R115/R116. The higher the base voltage, the harder it conducts and the more current it passes from the main 13.76 VDC source to the display. Sometimes this regulator is connected to the metering lamps to control them too. If the BRITE/DIM switch or control doesn't work, troubleshoot this regulator circuit.

In radios with scanners, special driver ICs are inserted between the scanner IC and the LED display input. Unlike the previous circuits which are directly driven by a branch of the power supply, the scanner ICs can't source enough current to drive the LEDs directly. The driver IC contains multiple transistor current amplifiers. Obviously with the driver IC in series, it's a potential failure point for the "No LED Channel Display" symptom.

FIGURE 4-49
LED BRIGHTNESS CONTROL CIRCUIT
(Cobra 29GTL, 29LTD, etc.)



DELTA TUNE CIRCUITS

The Delta Tune is an optional receiver feature used to compensate for signals slightly off frequency. It's left over from the days of crystal-controlled synthesizers, when accuracy wasn't always consistent and predictable. With the more accurate PLL synthesizers it's really not even needed, but is still included as an option in many AM and FM radios.

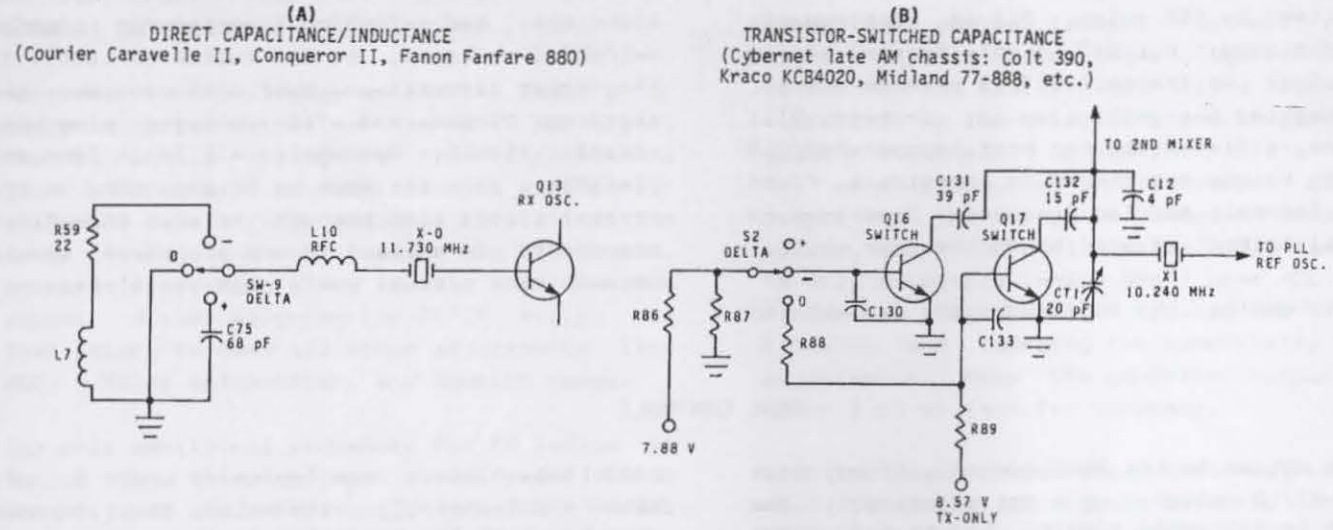
Another reason it's not found as often in newer radios is because improved IF selectivity methods make the skirt response rather flat around the center frequency. If the Delta shift falls within the flat part of the passband, there's nothing to be gained anyway.

The Delta Tune and SSB Clarifier are identical in operation, and circuits range from simple to complex. A front panel control shifts the L.O. frequency slightly. The typical Delta Tune range is ±1 KHz from center knob position. In older radios with individual Receive and Transmit crystal oscillators, it's usually placed right across the Receive crystal bank using capacitors and/or inductors to pull the crystal frequency slightly. Older radios have a fixed 3-position detent knob with [+], [0], and [-] shifts. As varactors appeared they took over the shift function, and the control is now a pot that changes the varactor bias and therefore the shift continuously.

Figure 4-50 shows two of the simpler circuits. In Figure 4-50A you see the 11.730 MHz Receive oscillator crystal is grounded either directly (no shift), through C75 (+ shift), or through L7 (- shift). Series capacitance raises the frequency of a Colpitts oscillator, and series inductance lowers it. R59 lowers the Q of L7 to stabilize its shift. Values are typically under 82 pF or 10 µH. Often this circuit uses three different series capacitors for the same effect.

A more complex method is shown in Figure 4-50B, where individual transistor switches control the amount of shunt capacitance. In the [+] position, the crystal grounds only through C12 and CT1. In the [0] position Q17 turns on, adding the value of C132. In the [-] position Q16 turns on to add the value of C131. Switching from [+] to [0] to [-] will add an increasing parallel capacitance of 4 pF to 15 pF to 39 pF respectively, which lowers the crystal frequency. A Transmit-only voltage turns on Q17 in that mode to maintain just the

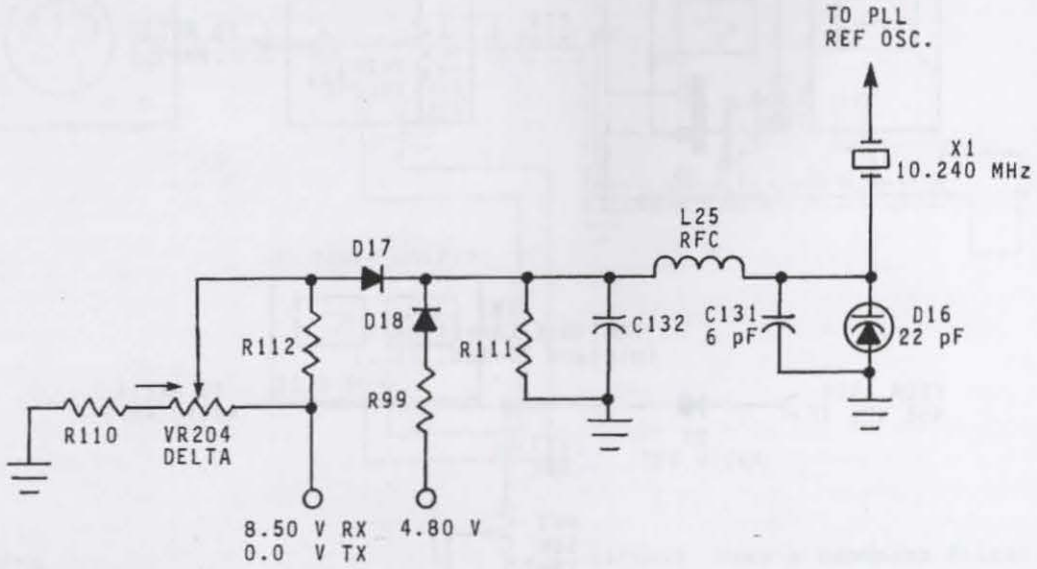
FIGURE 4-50
DELTA TUNE CIRCUITS



center frequency via the "0" capacitance of C132; this is required by FCC rules.

Figure 4-51 is the more sophisticated PLL shift control, virtually identical in operation to an SSB Clarifier control. Varactor D16 shifts the frequency of the 10.240 MHz crystal as its bias changes. R110 and R112 form voltage dividers with VR204 to smooth the resistance taper and tuning action. They also provide current limiting for the 8.5 VDC source; without them the current could be excessive with VR204 at its minimum resistance setting. L25 is an RF choke and with C132 keeps oscillator RF out of the power supply. C131 smooths the varactor range and provides temperature compensation by dividing RF currents between both capacitors to reduce heating of any one capacitor. Without C131 the shift range would be greater but less stable. This capacitor should never be removed!

FIGURE 4-51
MODERN DELTA USING VARACTOR TUNING
(Cobra 29GTL, 29LTD, etc.)



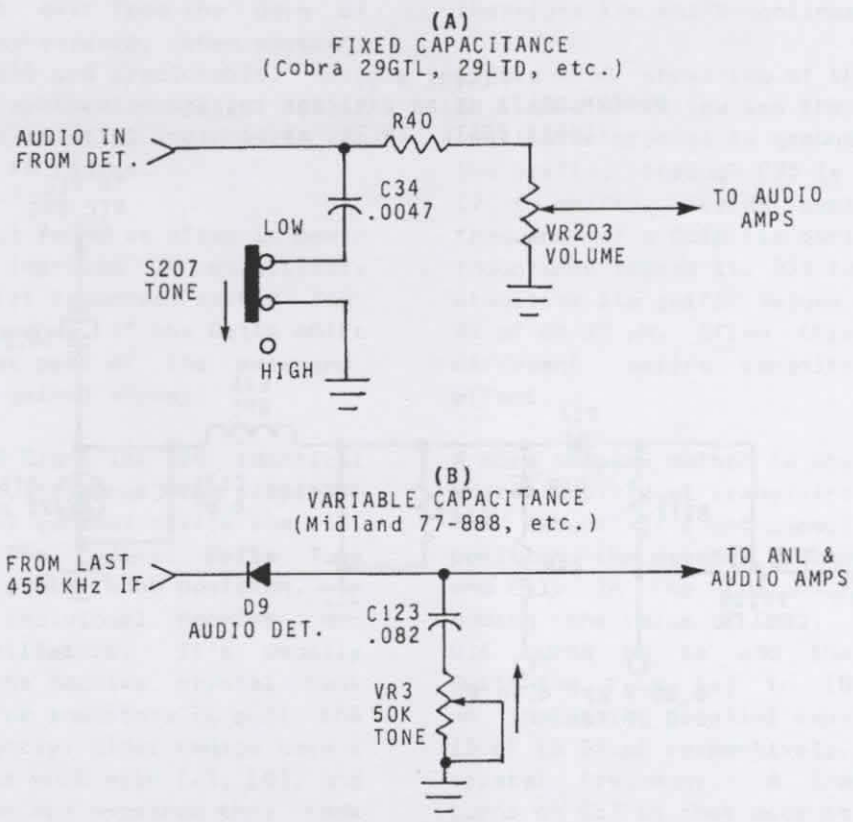
D17 and D18 are steering diodes to disconnect the Delta Tune on Transmit, since this is prohibited by FCC rules. D18 is continuously forward-biased, but D17 is only forward-biased on Receive; on Transmit D17 is reverse-biased, disconnecting the shift circuit. Instead R111 provides a fixed varactor bias through R99/D18 and the values are chosen to provide a fixed center Transmit carrier frequency. Sometimes an internal trimpot is used to do the same thing.

Troubleshooting the older circuits amounts to checking for RF continuity from crystal to ground, looking for open capacitors or inductors, bad switching transistors, missing switching voltages, or bad switch contacts. In the newer circuits you must also consider the steering diodes and T/R voltages plus the varactor itself. Remember, all Delta Tune and Clarifier circuits work by RF grounding on the crystal's cold side through variable and fixed components in series; if any of these should open up, the circuit won't even oscillate.

TONE CONTROLS

Another option is the TONE control. It may be a fixed HI/LO switch, or a pot adjustment. The circuit is extremely simple. Figure 4-52 shows both versions. It always follows the detector stage. A capacitor is shunted across the audio line and when engaged, rolls off some of the higher audio frequencies. Attenuation is determined by the capacitance value; the larger the capacitance, the greater the high-frequency reduction. Values are typically under 0.1 µF. With a pot control, attenuation also depends upon how high the capacitor is above ground at any given setting. That's all there is to it; no amplification or anything complicated. Troubleshooting is a matter of checking circuit continuity from sample point to chassis ground, and possible capacitance value changes.

FIGURE 4-52
TONE CONTROLS



General Guidelines

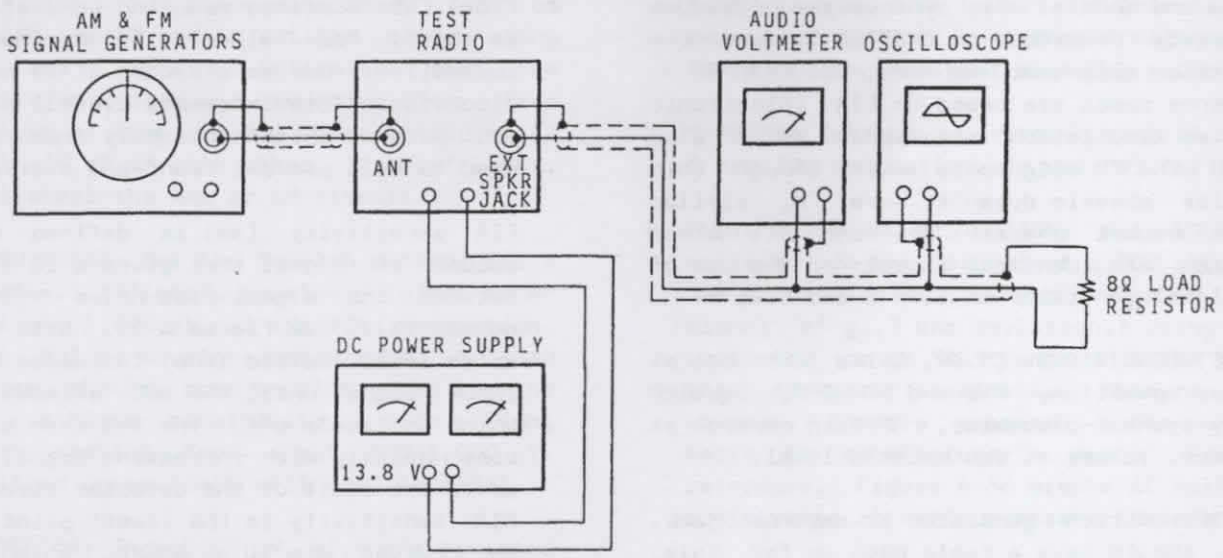
Receiver tuning is easy unless the radio's so badly misaligned that not even a 27 MHz signal can be pushed through it from the antenna jack. The general method (assuming synthesizer alignment was already done) is to start at the last IF stage and work towards the front end, peaking everything along the way for maximum output. After aligning the RF/IF strip, you then return to make all other adjustments like AGC, S-Meter calibration, and Squelch range.

The only additional procedure for FM radios is tuning the detector input transformer (when present) and quadrature coil, after the normal AM RF/IF alignment. The input can easily be tuned by placing a 'scope probe on the IC input pin and tuning for maximum RF voltage. The detector coil itself is tuned by 'scoping the VOLUME control and adjusting it for maximum audio output with minimum distortion. It's a good idea to re-check this with an on-the-air FM signal, adjusting for best audio quality.

You can use any convenient measuring equipment, since all you're looking for are relative signal strenth indications. Figure 4-53 is a review of the test set-up. Use a 'scope or AC voltmeter at the detector diode or across the speaker terminals, or use the radio's S-Meter. The main precaution is to reduce generator output as the radio is peaked to avoid AGC action, which would give false indications. For FM-only receivers (which don't have AGC), this minimizes the chance of driving the IF into limiting and lowering the sensitivity of the adjustments. Keep the generator output under about 1 µV or less for accuracy.

With the receiver extremely mistuned, you might need to inject IF signals directly into the appropriate stages and then work your way towards the front end. For example in a dual-conversion radio, you would inject a modulated 455 KHz signal at the 1st 455 KHz IF amp, peak those stages, then inject the 10.695 MHz (or other) high IF ahead of the 2nd mixer, peak everything downstream from that, and finally inject 27 MHz directly at the antenna jack for the front end RF amp alignment.

FIGURE 4-53
RECEIVER ALIGNMENT TEST SET-UP



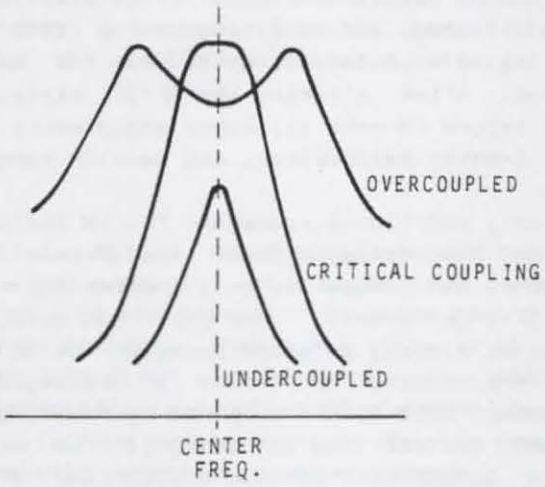
Bandpass Tuning

In the unlikely event sensitivity isn't equal across all 40 (or more) channels and the circuit uses a bandpass filter, try "stagger tuning" the coils. The bandpass filter consists of two or three capacitively-coupled coils, and is found in the 27 MHz and/or high IF stages.

(Review Figure 4-14.) Peak one coil for the low end of the band, one for the high end, and the third (if present) for the middle. Or try increasing the coupling capacitance between the transformers slightly. Remember though, the IF by definition is a fixed frequency regardless of whether the radio has 40 channels or 240 channels; you want the response to be as narrow as possible for good selectivity.

Not all radios use bandpass tuning. Many use a single tuned transformer at each receiver stage. As shown in Figure 4-54, the bandpass circuit gives a much flatter frequency response than a single tuned stage, and a sharper roll-off from the skirt. That's one reason they're used in most export radios and the better American types like the Cobra 140/142GTL or 148/2000GTL chassis. The tuned circuits are capacitively-coupled with a small ceramic disk capacitor of 5 pF or less. The coupling is critical. Under-coupling lowers signal output and sharpens the response too much. (I.e., high Q.) Over-coupling causes passband ripple, although it's sometimes used purposely to broaden the response. Always replace a bad coupling capacitor with another of the same value, unless broadbanding is needed.

FIGURE 4-54
RESPONSE CURVE OF BANDPASS FILTER FOR VARIOUS DEGREES OF COUPLING
(Courtesy Heinemann-Newnes Books)



A SAMPLE ALIGNMENT

The following is a typical alignment procedure for the radio whose layout and schematic are on Pages 144 and 145. This particular chassis (Cybernet PTBM049A0X) is one popular 40-channel PLL02A AM radio, which is marketed under dozens of makes and models. Its synthesizer procedure was already described in CHAPTER 3, and the transmitter alignment appears in CHAPTER 5. Performance specs are based on EIA (Electronic Industries Association) standards. We've also included the FM alignment; even though this particular chassis doesn't have FM, similar Cybernet export chassis do, and all other procedures are identical except for the use of an FM signal generator in Step 6 and Step 8.

1. PRESET CONDITIONS: Ch.19, Delta Tune set at center position, ANL and NB OFF, Squelch fully counter-clockwise, RF Gain control at maximum. Volume at comfortable level.

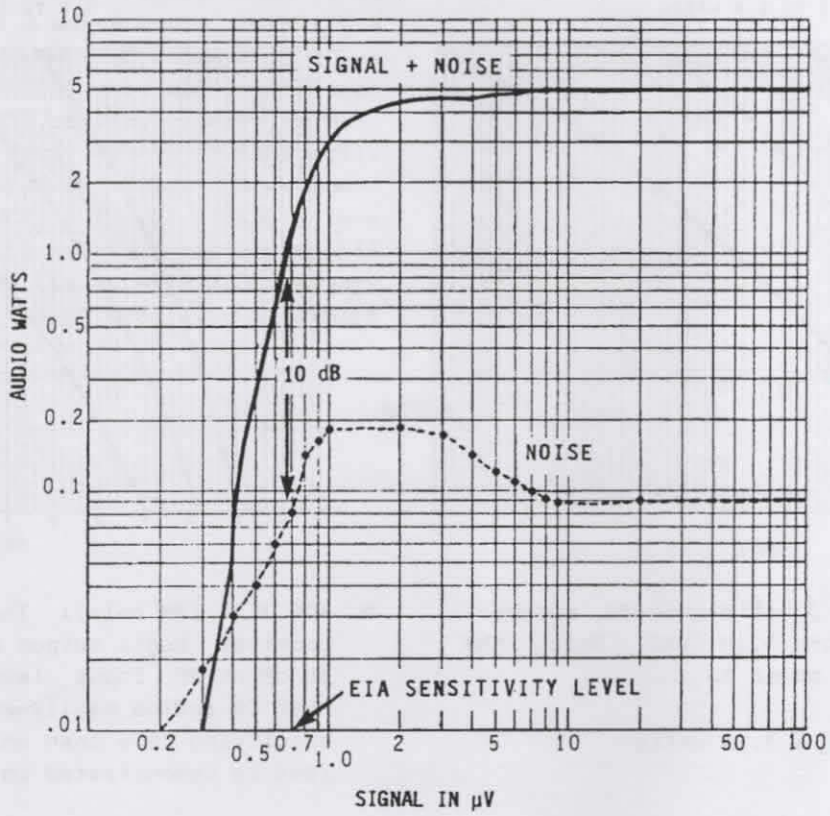
2. LOW IF: Attach generator to antenna jack. (You should have a cable made up for this, with push-on coax connector on one end and suitable connector on the other for the generator output.) Inject Ch.19 (27.185 MHz) 1000 Hz 30% modulated signal. Use minimum signal level to prevent AGC action. Adjust T8, T9, and T10 for maximum output.

3. HIGH IF: Using same or lower signal input to minimize AGC action, peak L14 and T7 for maximum output indication.

4. FRONT END: Continue reducing generator level as above. Peak T5 and T6 for maximum output indication. Now rotate core of T5 one turn clockwise. This increases overall stability and detunes antenna slightly from center of band to help prevent front-end overloading.

   EIA sensitivity (AM) is defined as that amount of signal that gives a 10 dB ratio between the signal-plus-noise (S+N) and noise (N). See Figure 4-55. Note how the noise level (dotted line) increases with the input signal until the AGC attacks, after which it levels off. The S+N then builds up very quickly with increasing signal input, up to the limit of the detector circuit. The EIA sensitivity is the lowest point where the curves are 10 dB apart, which is the same as a power factor of 10. The example shows that at 0.7 µV, when the noise (N) is producing 0.08 watt audio output, the signal plus noise (S+N) produces 0.8 watt output, which is 10 times (10 dB) greater. Thus the rated sensitivity is 0.7 µV.

FIGURE 4-55
TYPICAL EIA RECEIVER SENSITIVITY RESPONSE CURVE
(Courtesy Sencore Inc.)



NOISE LIMITER TEST (AM only): If a noise generator and mixing pad are available, this function can also be checked. Note the rated sensitivity from preceeding step. Turn on the ANL or NB and inject the noise along with the signal. Determine the new sensitivity floor and new noise floor from the chart of Figure 4-55. These should still be with 10 dB of each other. If they're not, troubleshoot the ANL or NB circuit.

5. SQUELCH RANGE: Set the Squelch control fully clockwise. ("Tight" squelch.) Inject an RF signal of 1,000 µV, 1 KHz 30% modulation. Adjust RV1 so squelch just breaks. A good receiver should open squelch close to the rated minimum sensitivity, with tight squelch peaking from about 300-1,000 µV. (Specified upper limit will vary by model.)

6. FM DETECTOR: Inject 10 µV, ±1.5 KHz deviated FM signal at antenna, modulated with 1 KHz audio tone. The AN240 usually has an input coil; peak this for maximum RF voltage with 'scope at Pin 2. Connect 'scope to output of FM Detector IC, audio power IC, or hot side of speaker. Tune detector coil for maximum undistorted audio. (I.e., the biggest and best looking sine wave.) If there's no FM generator available, transmit using another FM CB, tuning for best sounding audio.

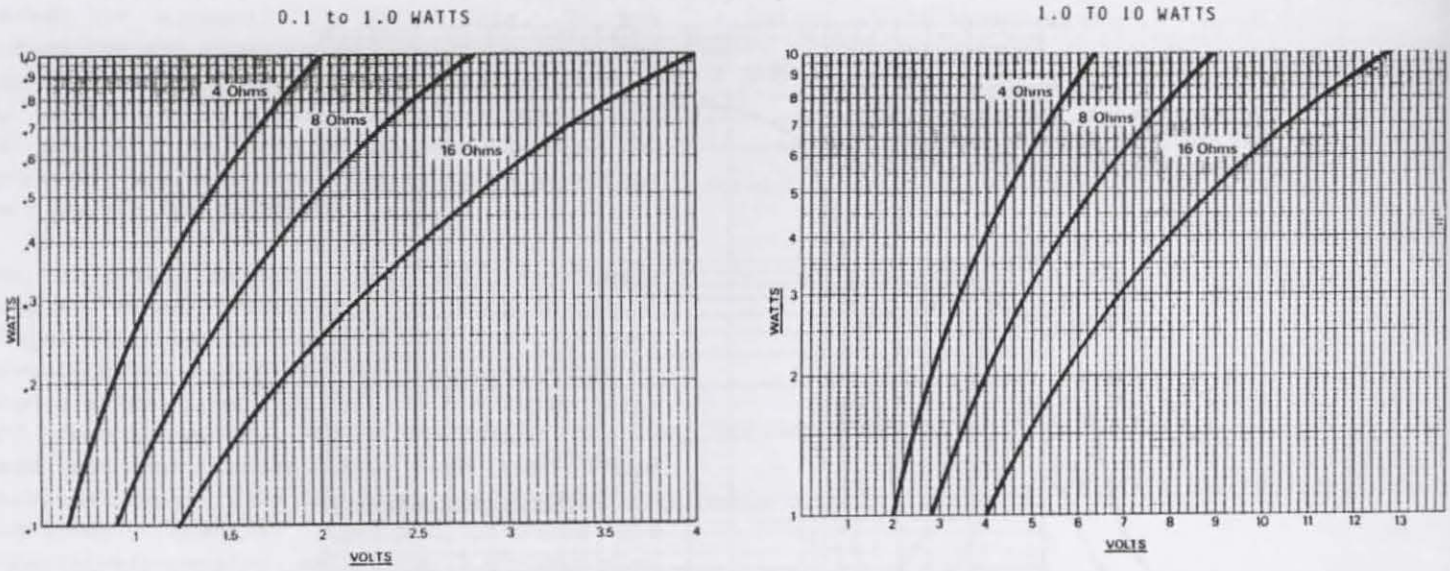
7. S-METER: Set the generator output at 100 µV, 1 KHz 30% modulation. Adjust RV3 for "S9".

8. AUDIO POWER AND DISTORTION: Set VOLUME to maximum. Inject signal of 1,000 µV, 1 KHz 30% modulation at coax jack. (For FM, inject signal of ±1.5 KHz deviation.) Using audio voltmeter or an "AC" range of a VOM across the speaker terminals, measure audio voltage. Compare measured audio power in watts to manufacturer's spec. For your reference, Figure 4-56 graphs AC volts vs. audio watts at various speaker impedances.

   You can also use the formula,

$$P = \frac{E^2}{R}$$

FIGURE 4-56
AUDIO VOLTAGE-TO-POWER CONVERSION CHARTS
(Courtesy B&K Precision)



Example: Spec is 3 watts into 8Ω speaker. Suppose you measure 5.10 VAC. Using the formula, the audio power is

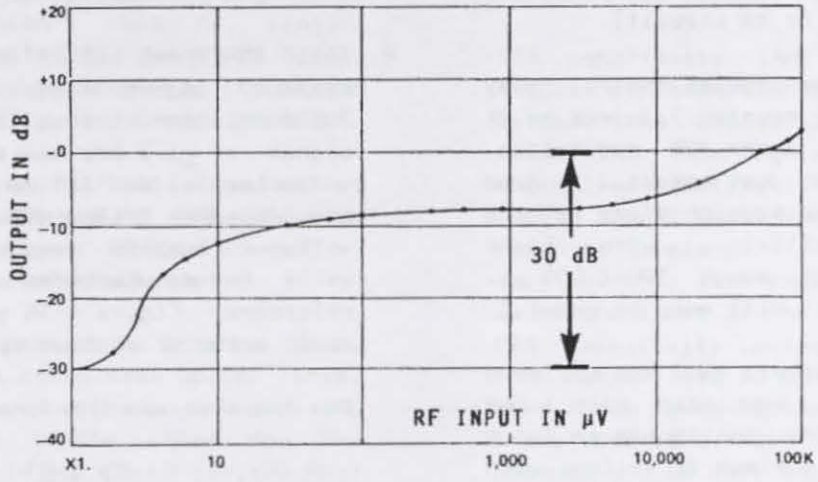
$$\frac{5.10 \times 5.10}{8} = 3.25 \text{ watts}$$

Compare output response at 1 KHz to response using inputs of 400 Hz and 2.5 KHz. Outputs should be within +3 dB @ 400 Hz and -6 dB @ 2.5 KHz. This indicates the receiver's overall ability to pass audio frequencies within the standard transceiver voice band.

9. AGC TEST (AM only): The EIA specifies the receiver audio output should remain within 30 dB at RF input levels from 1-50,000 µV. Most CB radios easily exceed this, typically specifying less than only 10 dB change. This idea is demonstrated in Figure 4-57.

For example, the Cobra 29GTL/29LTD chassis specifies "less than 10 dB audio change for input levels from 10-50,000 µV." (Slightly different input range from the EIA spec.) Using a 50,000 µV RF input signal modulated 30% with a 1 KHz tone, and the VOLUME pot at

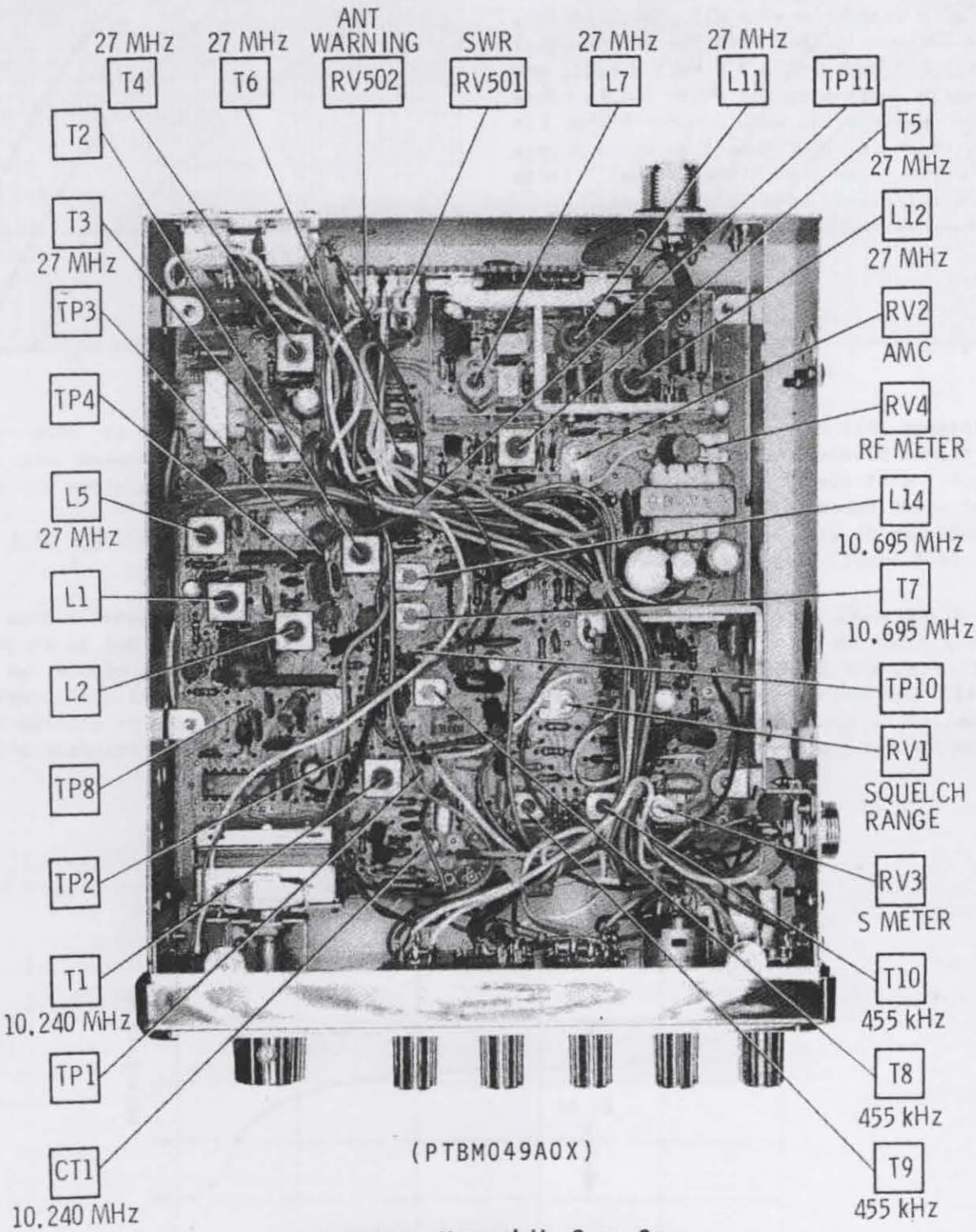
FIGURE 4-57
TYPICAL AM CB RECEIVER AGC RESPONSE
(Courtesy Sencore Inc.)



maximum, I measured about 8.04 VAC across its 16Ω speaker. From Figure 4-56, this converts to about 4 watts audio output. A change less than 10 dB when reduced to 10 µV means the audio output must remain at least 1/10 of 4 watts (10 dB = x10 power ratio), or 0.4 watts. In fact with the VOLUME still at maximum I measured a 3.3 watt output, and 1.9 watts with only a 1.0 µV input. This greatly exceeds the manufacturer's and EIA specs, which is why Figure 4-57 shows a very flat curve even though the actual limits allow a relatively wide 30 dB spread.

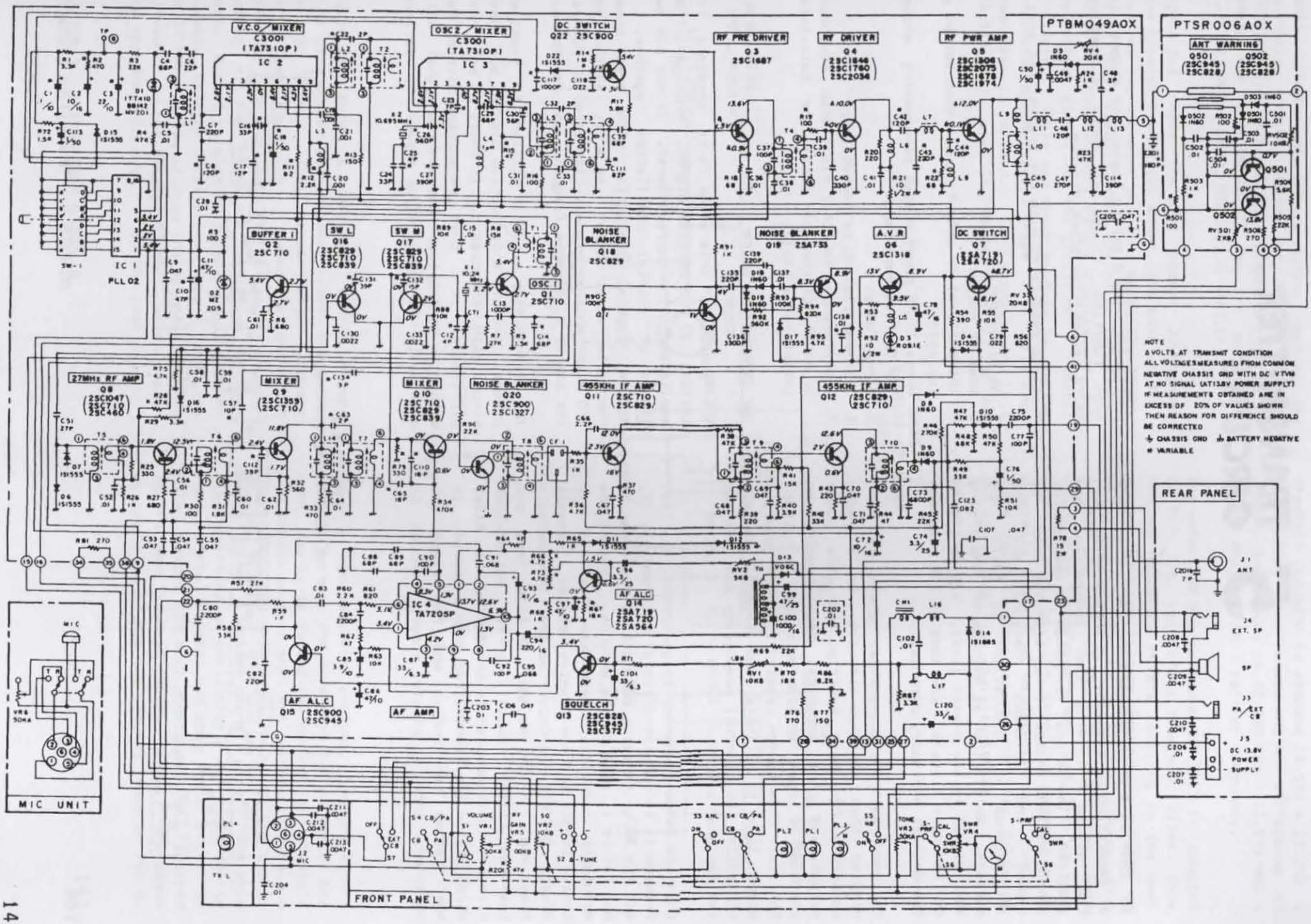
NOTES

ALIGNMENT LOCATIONS FOR TRANSCEIVER DESCRIBED IN TEXT



Courtesy Howard W. Sams Co.

SCHEMATIC OF TRANSCEIVER WHOSE ALIGNMENT IS DESCRIBED IN THE TEXT



5 TRANSMITTER CIRCUITS

In CHAPTER 3 we discussed the various methods of generating CB signals. In this chapter all the stages following that generation are analyzed. The signal frequency is useless for communications unless it has both the power to travel the intended distance and the intelligence or "modulation" to carry the message. We'll look at methods of amplifying the signal to the 4-watt level, adding the AM or FM voice signals, and some of the various transmitter accessory circuits.

In many ways the transmitter chain is much simpler than receiver circuits. By law each country's CBs have exactly the same power output and other technical requirements, so there's no room for manufacturers to stray. Contrast this to the receiver, where quality specs like sensitivity and selectivity are controlled by circuit complexity and cost at the designer's option.

Once the basic frequency is generated, all that remains is to convert it to 27 MHz, amplify it, add the AM or FM voice modulation, and clean it up before it goes to the antenna. Besides the modulator circuits, there are five or six active stages and one passive stage: Transmit Mixer, Buffer, Pre-Driver or IPA (Intermediate Power Amp), RF Driver Amp, RF Final Amp, and Low-Pass Filter. Usually a PLL out-of-lock circuit is connected to the Buffer or Mixer which kills the transmitter when unlocked. In most radios the Buffer and Pre-Driver are combined into a single stage. Uniden in particular uses discrete transistor stages for each function. Figure 5-1 shows a complete AM/FM transmitter block diagram.

Problems associated with the transmitter are:

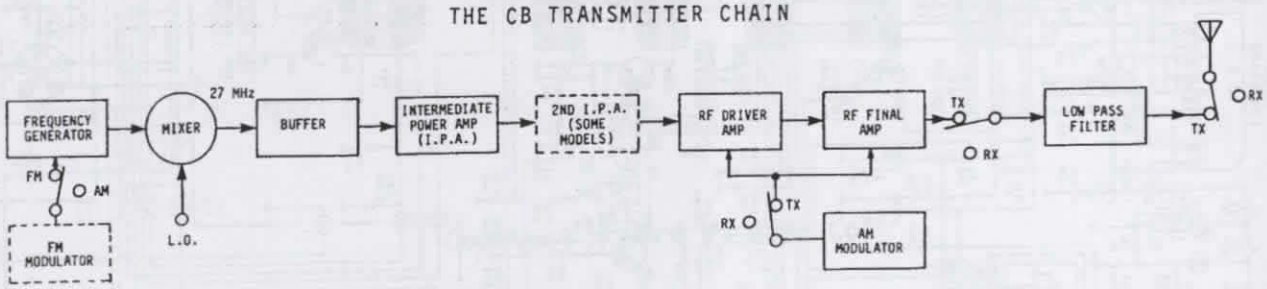
1. No RF output.
2. Weak RF output.
3. Intermittent RF output; quits when warmed up (or cold).
4. Unequal RF power output progressing across the CB frequency band.
5. Blows fuses.
6. Self-oscillation or instability.
7. Interference to other electronic equipment or nearby CB channels (RFI), or television interference (TVI).

THE TRANSMITTER MIXER

The purpose of this stage is to generate the initial 27 MHz carrier signal, which is then amplified to the correct level. It may mix two groups of crystal oscillators together, a single crystal oscillator with some other composite mixer output, or a PLL synthesizer VCO with another signal. Like receiver mixers, the sum or difference frequency may be chosen.

The transmitter mixer is similar to receiver mixers, except only active mixers are used since gain is needed. If there's any real difference, it's that transmitter mixers can afford to be "dirtier" because the signal will eventually be cleaned up anyway by various

FIGURE 5-1
THE CB TRANSMITTER CHAIN



tuned circuits and filters before reaching the antenna. Active mixers for CB use bipolar transistors or FETs, or ICs. Almost all current AM models use the TA7310 IC or its equivalent. (KIA7310, AN103, C3001, NTE1192, or TCG1192.)

Figure 5-2 shows the most common 23-channel type bipolar transistor mixer. The base of TR17 receives two signals: one is a composite 38 MHz signal that results from mixing of the 23 MHz and 14 MHz crystal synthesizer oscillators, and the other signal is the 11.275 MHz Transmit Oscillator. (This was shown on Page 54 as the 12-crystal synthesizer.) Here the difference frequency is chosen. For example on Ch.1 (26.965 MHz), the 14.950 MHz and 23.290 MHz crystals combine to produce 14.950 + 23.290 = 38.240 MHz; when mixed and the difference is chosen, the result is 38.240 MHz - 11.275 MHz = 26.965 MHz, the Ch.1 carrier frequency.

The output at the collector of TR17 is coupled to T15, T16, and T17, a bandpass filter. This removes harmonics before coupling to the next stage. Bandpass filters consisting of one to three series-coupled coils are always used between the Transmit Mixer and the Buffer. When two or more transformers are used, they're very lightly coupled. The coupling capacitor is generally under 5 pF to minimize coil loading, since larger values would lower the filter Q and its selectivity characteristics.

FIGURE 5-2
BIPOLAR RF MIXER
(Cobra 29)

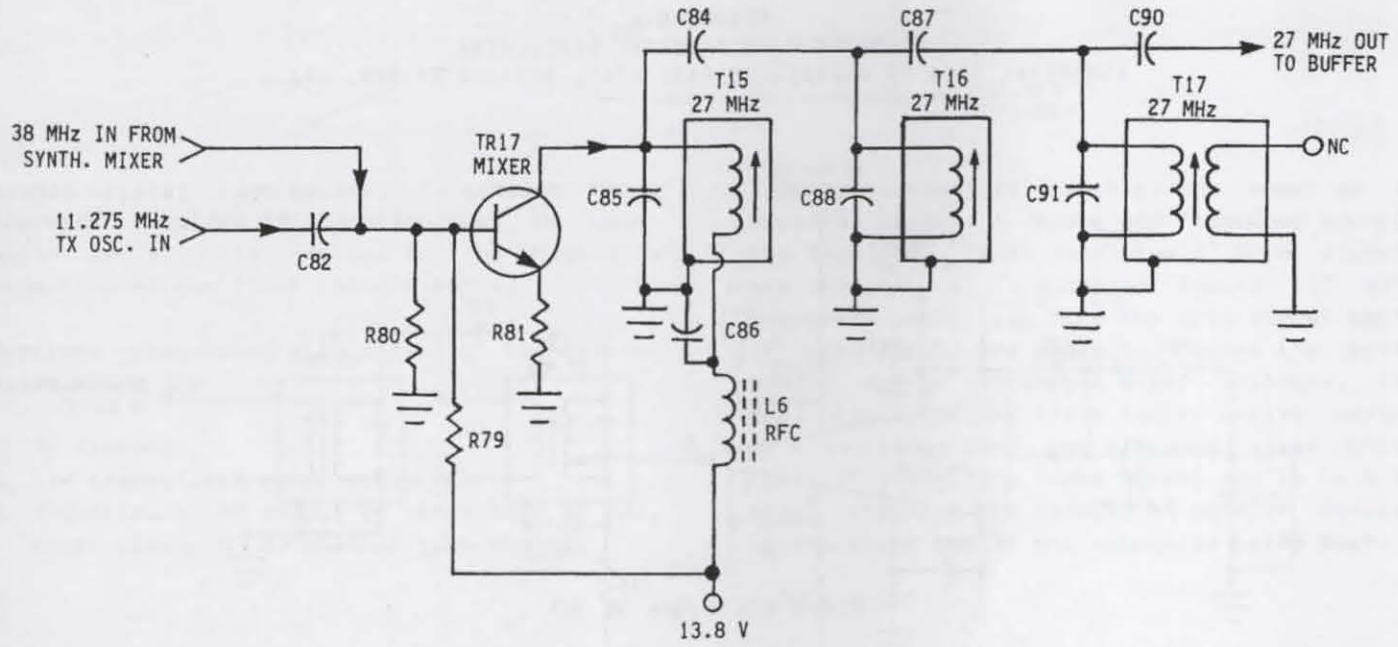


Figure 5-3 shows a dual-gate MOSFET mixer. While less common than bipolar types, they make superior mixers. They handle larger signals with less distortion, harmonics and IMD products. The dual-gate FET makes mixing easy because of the excellent isolation between gates. Gate 1 couples to a separate 10.695 MHz Transmit Carrier Oscillator. Gate 2 supplies the 37 MHz VCO signal from the synthesizer. The difference is the desired 27 MHz, which passes from the drain through L17 to the next stage.

As PLL synthesizers evolved, manufacturers looked for more and more ways to cut costs. One such way is to reduce the number of crystals and active devices that are needed. Figure 5-4 simplifies the transmitter Mixer by the use of a TA7310 IC. Besides being a mixer, the chip also contains an oscillator. All it needs is the external crystal and some capacitors. In this example IC3 both generates the required 10.695 MHz Transmit carrier signal, and mixes it with the 37 MHz VCO signal input at Pin 4.

FIGURE 5-3
DUAL-GATE MOSFET MIXER
(Cobra 29XLR, 89XLR, etc.)

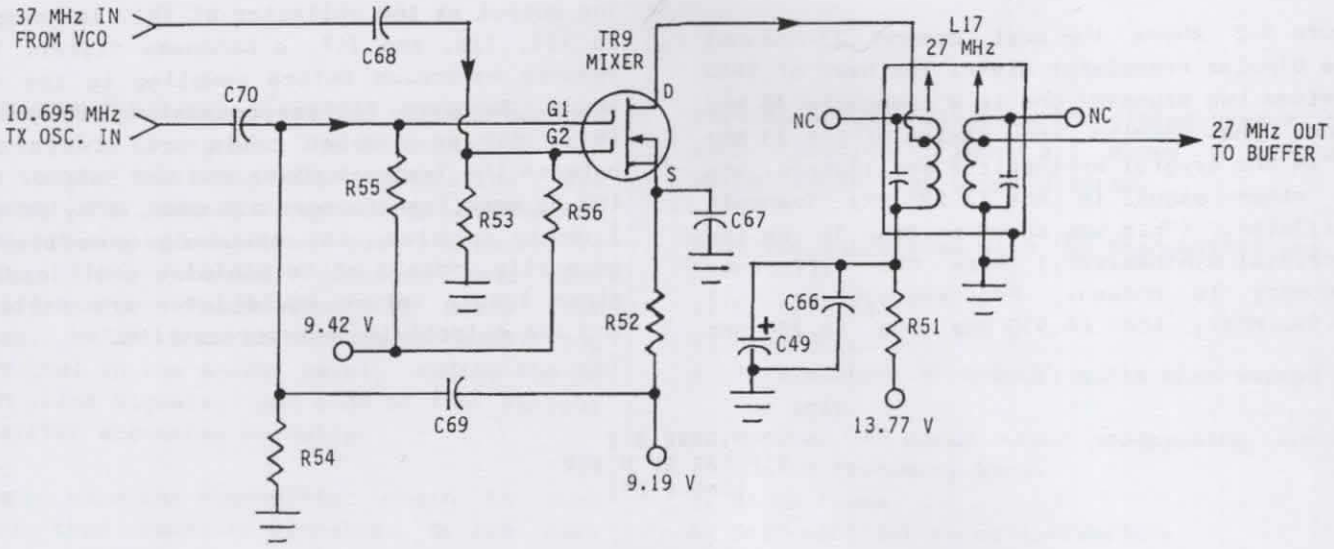
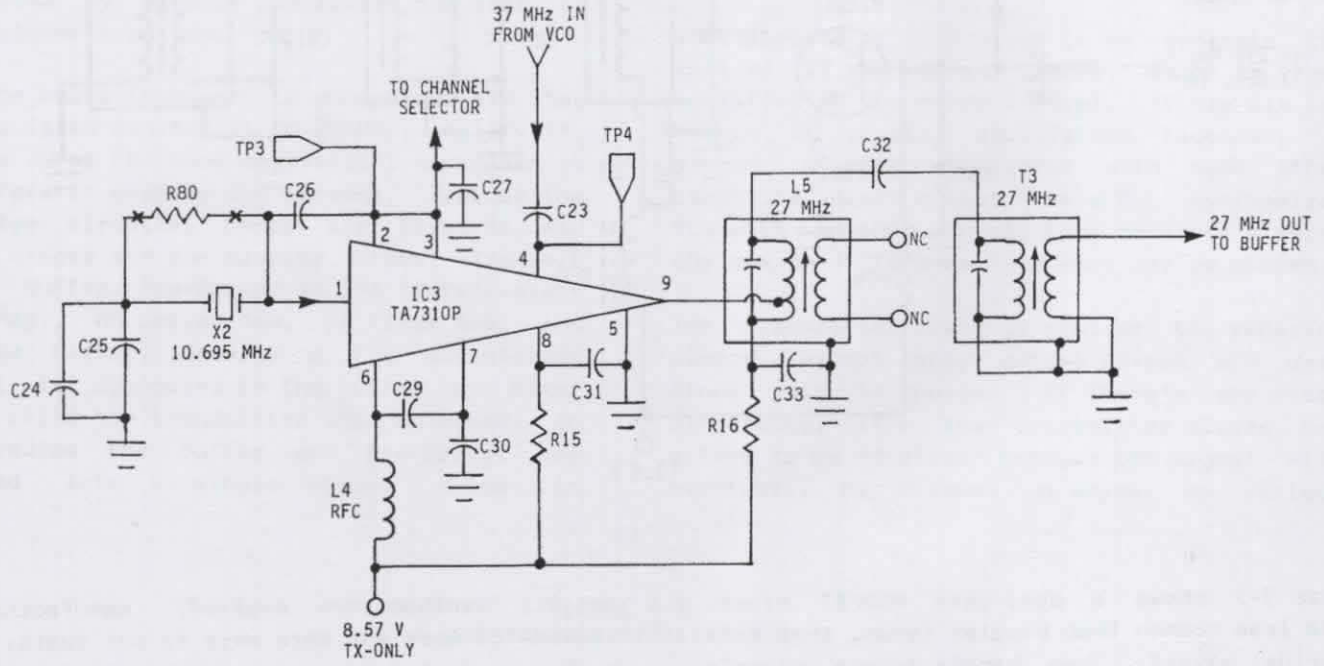


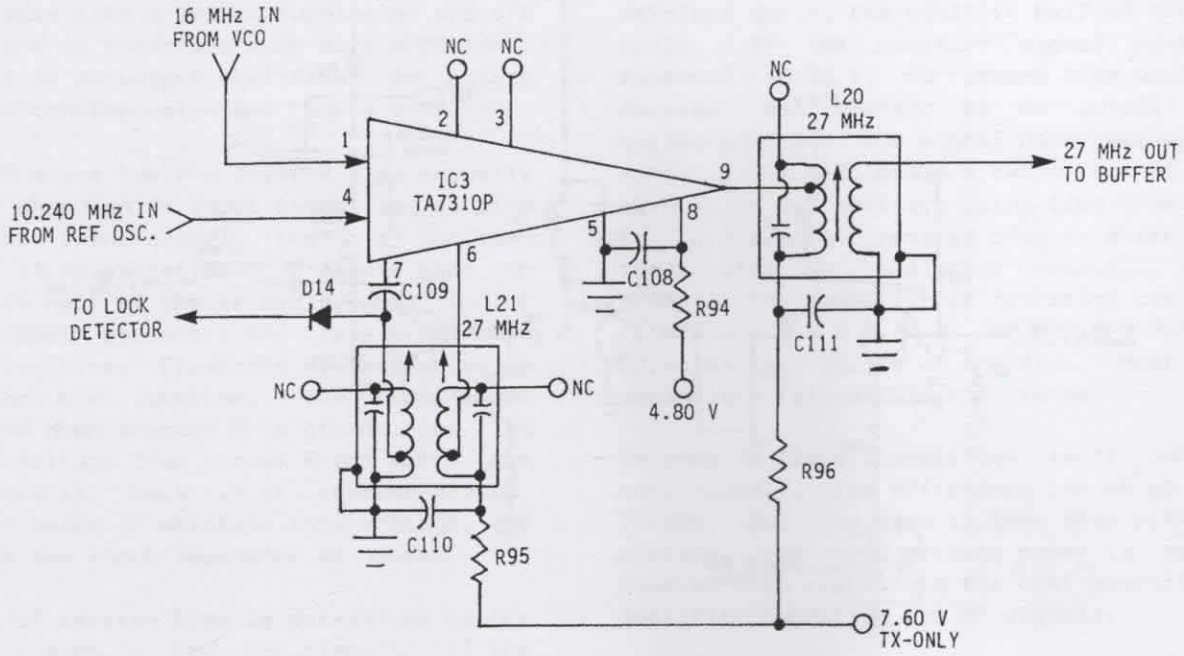
FIGURE 5-4
IC MIXER WITH INTERNAL OSCILLATOR
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)



The 27 MHz difference frequency is Pin 9, and couples out through bandpass filter L5/T3.

A last example shows the final evolution of mixers. In Figure 5-5, the TA7310 IC becomes part of the PLL circuit itself. It mixes a sample from the 10.240 MHz PLL Oscillator with the 16 MHz VCO. For example, the Ch.1 Transmit VCO signal is 16.725 MHz; mixing this with 10.240 MHz and choosing the sum gives the required 16.725 MHz + 10.240 MHz = 26.965 MHz, which is coupled through L20 to the next stage. The advantage is that a discrete 10.695 MHz oscillator (and its expensive crystal) is no longer needed. This mixer circuit represents the most current trend in AM/FM CB design: the

FIGURE 5-5
SIMPLIFIED IC MIXER WITH CRYSTAL L.O. ELIMINATED
(Cobra 29GTL, 29LTD, etc.)



single-crystal synthesizer. To achieve this, low-side receiver IF injection must be used, which is slightly inferior to the high-side injection of the first three examples.

Symptoms associated with a faulty transmitter mixer stage are:

1. No Transmit.
2. Low transmitter power output.
3. Significant RF output on other than 27 MHz, particularly in 23-channel type radios.

Troubleshooting is exactly the same as in receiver mixers. A 'scope and frequency counter are required. First determine if both signals are present at the mixer inputs. If not, backtrack until you find the open signal path. If both inputs are present, 'scope the mixer output and/or interpret mixer voltages. The most likely causes are a faulty active device or a shorted, open, or mistuned mixer output coil. If everything looks normal you'll have to start checking the associated passive devices to see where the 27 MHz output is being lost.

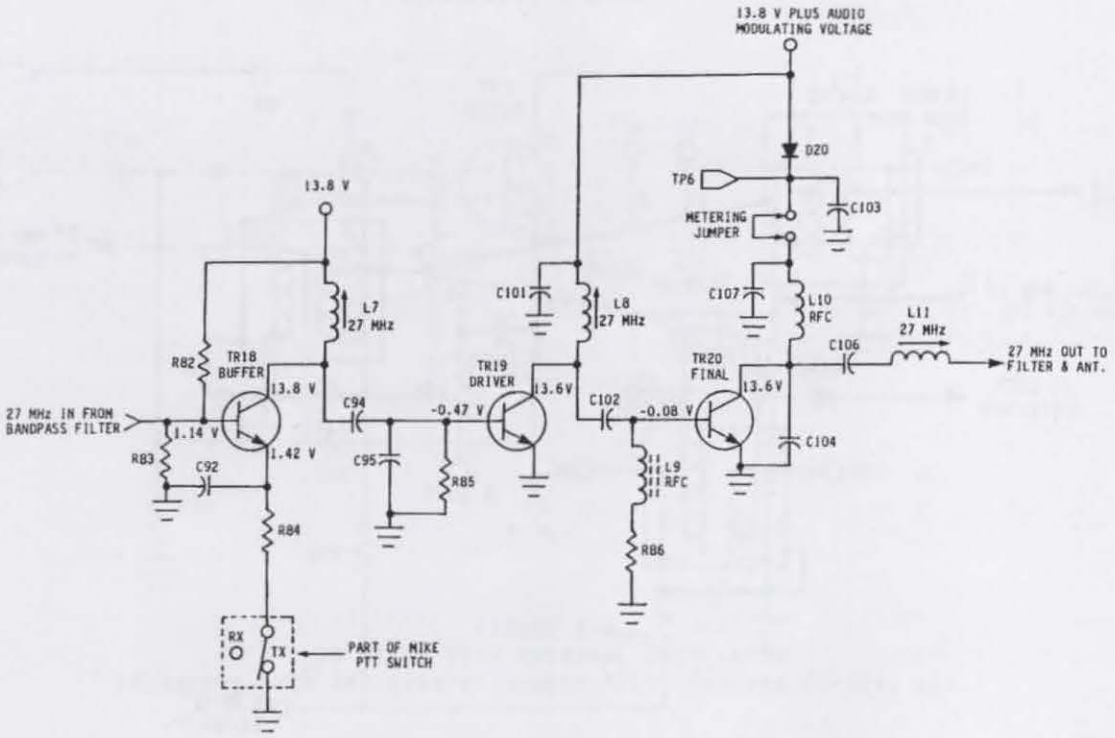
THE RF AMPLIFIER CHAIN

Once the 27 MHz signal is developed at the mixer, it must be amplified to the correct power and delivered to the antenna. That's the purpose of the transistor stages (Buffer, Predriver/IPA, Driver, Final) following the mixer. These stages are operated under different bias conditions. The RF Driver and Final stages are always operated Class C for AM and FM, and the preceeding stages are Class A or Class B. (SSB uses the special Class AB_1 for "linear" power amplification in the Driver and Final stages.) There's little difference between transmitter and receiver RF stages except that a larger forward bias is needed on Receive due to its much smaller input levels. Figure 5-6 is a typical transmitter chain.

THE BUFFER STAGE

The main purpose of the Buffer is to isolate the mixer from the succeeding power amplifiers, since the large current swings of power stages could effect frequency stability. The Buffer stage is run with Class A bias. In Figure 5-6 this is reflected by the +1.14 V base bias on TR18; TR19 and TR20 are the Class C RF power amplifiers and have reverse base bias.

FIGURE 5-6
TYPICAL AM (OR FM) RF AMPLIFIER CHAIN
(Cobra 29)



Like all Class A amplifiers, the Buffer has some voltage gain but no power gain. Depending upon the actual power gain following the Buffer, there may or may not be an extra transistor stage between the Buffer and the RF Driver stage. (This is the extra block shown in dotted lines, Figure 5-1.) The current trend is to use two buffer/amp stages in AM/SSB radios due to the more critical frequency stability and larger power swing of SSB. For straight AM or FM radios, there's generally only one Buffer between the Mixer and Driver stages.

Class A RF Amplifiers

The Class A amplifier is defined as one where collector/plate current flows all the time, regardless of whether there's an input signal. Its action is like a variable resistance and therefore it heats up a lot. Because of this efficiency is very low, about 25%. "Efficiency" is defined as the amount of power output for a given input. Each amplifier class has a different efficiency and a different ratio of signal/no-signal input times. For example, a Class A amplifier with a 10 W input would produce about 2.5 W output. This disadvantage is compensated by the fact that the output signal is a faithful or linear reproduction of the input signal; i.e., no distortion. The determining factor is the level of base/grid bias relative to the input signal level.

Class A and Class B are used for buffer and low-level amplifier stages since spectral purity is important, and because they require little input drive. This makes sense because RF levels at this point are only milliwatts in strength; the efficiency advantage of Class C would be offset by the lack of available driving power. The absolute DC biases vary greatly among circuit designs. You'll have to analyze transistor biasing from the voltage information in the service manual, which generally ranges from 0.75-2.0 VDC. If the stage is working a 'scope at the base and collector should indicate a bigger signal at the collector, since there's always some voltage amplification. Typical 'scope photos are shown later in this chapter.

Class C RF Power Amplifiers

The RF Driver and Final amplifiers for AM, FM, or CW are always operated Class C. The Class C amplifier is one where collector current flows

for less than half the time of the input drive cycle. In other words, the base-emitter (or grid-cathode) junction is reverse-biased more than half the time. It only conducts when the input sine wave is large enough to overcome the reverse bias. Unlike the Class A amplifier, this acts more like a switch turning on and off rapidly, and is therefore much more efficient. The result is an output that flows in pulses rather than continuously. See Figure 5-7A.

Figure 5-7B shows how the reverse bias actually develops. When an RF input signal is coupled across the transformer, the b-e junction rectifies it to pulsating DC. Assume that on the positive half of the RF cycle, the top of the transformer secondary and transistor base are both positive. Electrons are attracted up through the b-e junction, the transformer winding, and down through R to ground. The flow produces a voltage drop across R and makes the base temporarily negative or reverse-biased. Capacitor C helps to maintain this voltage, and also lowers the input impedance as needed.

The amount of reverse bias is determined by the total resistance in the b-e circuit. If the positive peak of the input cycle is higher than the highest reverse bias, the b-e junction will conduct on that part of the cycle exceeding the negative bias. (On the negative half of the input cycle the base remains reverse-biased anyway, since NPN transistors require positive base bias to operate.)

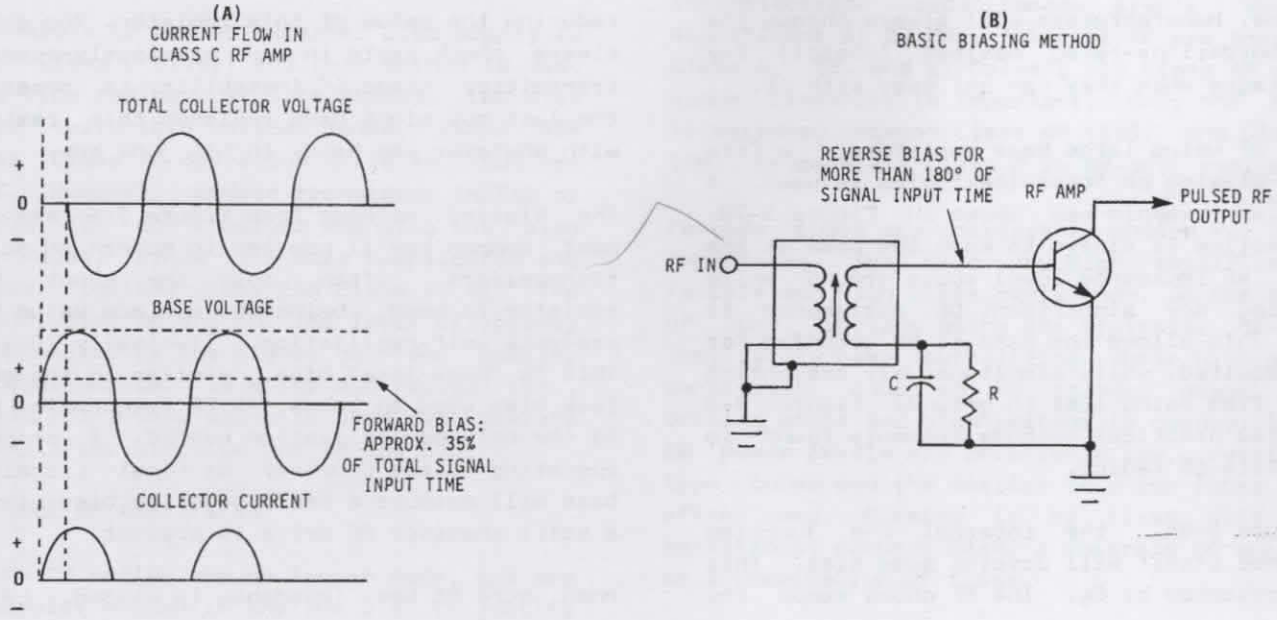
For example, assume a 2.0 V P-P RF signal is applied to the b-e junction, and the b-e resistance is such that a bias of -0.30 V develops during the positive half of the input cycle. If the positive signal peak never exceeded +0.30 V, no forward bias would ever develop and there'd be no output at the collector. But the signal does exceed that, since 2.0 V P-P means a swing from -1.0 V to +1.0 V. In the positive-going time from +0.30 V to +1.0 V, the reverse bias is overcome and there will be collector output. In this example the amplifier is operating over 0.70 V (1.0 V - 0.3 V = 0.70 V) of a 2.0 V P-P total drive cycle, or 35% of the time. Most Class C amplifiers fall within this range.

Because a Class C amplifier isn't conducting continuously, its efficiency can be as high as 75-80%. But the gain is less than with other classes, and more driving power is required. However this represents the best overall power amplifier condition for RF signals.

The Flywheel Effect

What good is a pulsed signal that looks nothing like the original input signal that created it? Obviously if it stayed in that form, the

FIGURE 5-7
RF AMPLIFIER BIASING



distortion would make communications difficult or impossible. But it doesn't, due to the phenomenon known as the "flywheel effect."

The tuned output circuit of a Class C amplifier restores the original input waveform and removes harmonics generated from the pulses. Electrons in a resonant circuit move back and forth such that at the same instant current is flowing down through its coil, a current of equal but opposite phase is flowing up through its capacitor, and vice-versa. The net result is a continuous oscillation in the tuned circuit. All it takes is an occasional pulse entering the tuned circuit to keep current flowing and reproduce the complete sine wave, which can be sampled and applied to the next stage or the antenna. Thus collector pulses become complete waveforms in the output tank circuit. The term "tank" circuit itself refers to the fact that it's a kind of "storage tank" for electrons. This flywheel effect is comparable to the mechanical flywheel of an engine crankshaft; the occasional push of each cylinder firing is what keeps it turning smoothly and continuously.

PRACTICAL CLASS C BIASING METHODS

In transistor amplifiers it's possible to develop Class C bias directly across a large enough base resistance. However this method isn't used in CB RF power amplifiers, since the negative portion of the driving signal can exceed the transistor's b-e breakdown rating. Such breakdowns cause a gradual loss of gain rather than instant burnout, which is one reason why a CB may show a loss of power output over time. Manufacturers will always choose the most borderline-rated devices (cheap!) for these stages when they can get away with it.

Instead of using large base resistors, a form of self-biasing or "base-leak" bias is used. A simplified example was shown in Figure 5-7B. The objective is always to keep the base at the correct RF impedance level above ground while minimizing any significant DC resistance to ground. This allows the base to be grounded for DC as required, while simultaneously preventing the RF from being lost to ground. Figure 5-8 shows two practical methods commonly found in solid-state CB radios.

In Figure 5-8A, the internal b-e junction resistance itself will develop some bias. This is represented by R_b. The RF choke keeps the base above RF ground. A second method is shown in Figure 5-8B, where R_b represents the internal b-e resistance, and R_e raises the emitter slightly above ground. C_e is now added to guarantee the emitter is grounded for AC. The value of R_e is generally less than 1Ω. While a very safe technique, it does lower gain and is sometimes used for exactly that purpose; i.e., to aid stability. The emitter resistor method was used in some 23-channel radios, while modern CBs use a variation of the directly-grounded emitter.

Because of the high current in RF power amps, most transistors have a built-in safety feature called "emitter ballasting." Multiple emitter resistors are included in the silicon chip to divide the RF current and prevent overheating.

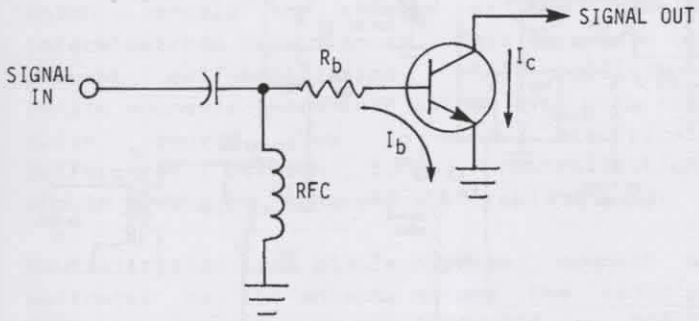
Figure 5-6 showed how a capacitive divider (C94/C95) was used as part of the Buffer's tuned collector circuit. The values were chosen for the correct interstage impedance. The DC base return was through R85, which being a pure resistance automatically has a low Q to aid stability. Note another biasing trick: the base of TR20 was returned to ground through L9 and R86. L9 has a very low DC resistance, but a large RF impedance which keeps the base above RF ground. R86 acts as a load for the preceeding driver circuit of L8/C102, and also stabilizes the amplifier by absorbing some of the driver energy and reducing gain. R86 is sometimes called a "Q spoiler," since it always lowers the Q of the associated inductor. It's common to find such resistors used across the RF chokes or tuned circuits of CB power amplifiers. Instability can be controlled by reducing the value of this resistor. You should always check parts in any previously-repaired transmitter stage if instability is observed; the last guy might have replaced this resistor with whatever was handy in his junk box.

The biasing methods from Figure 5-6 are the most common you'll now see in modern AM or FM transceivers. Often only the shunt base resistor is used, being the minimum value that prevents self-oscillation. (Typically 10-22Ω.) This is "base-leak" bias, similar to the grid-leak bias used in tubes. At CB frequencies this is the only neutralization needed. A properly operating Class C Driver or Final transistor base will measure a small negative bias (under a volt) whenever RF drive is present.

When more RF base impedance is needed, L9 of

FIGURE 5-8
PRACTICAL CLASS C BIASING METHODS
(Courtesy Howard W. Sams Co.)

(A)
INTERNAL BASE-EMITTER RESISTANCE



(B)
EXTERNAL EMITTER RESISTOR

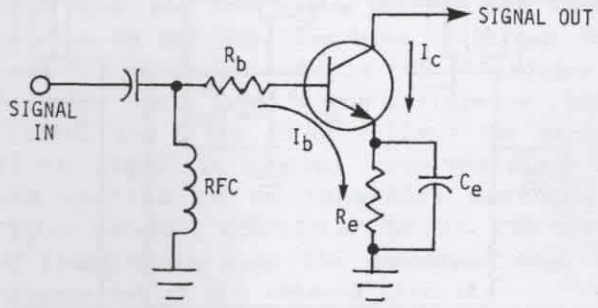


Figure 5-6 could be (and often is) replaced with a ferrite bead directly on the base lead of TR20 before soldering into the PC board. Beads are used for neutralizing at power levels over about 0.5 watt (Driver and Final), since they don't add any significant DC resistance to these high-current stages. Besides being cheaper than coils, ferrite is a low-Q material and is exactly what's needed to aid stability. Beads are relatively new to CB RF design and are found especially in the newer SSB models, where higher power levels are generated and the chance for instability increases. (And because they're much cheaper than coils and chokes!)

Fixed vs. Switchable Bias

It's possible to use an external bias supply to develop Class C bias, and this method is used in tube-type radios. If it's AM/SSB, the bias will be switchable between modes, since SSB requires Class AB operation while AM requires Class C. However, modern transistor AM/SSB or AM/FM/SSB CBs don't bother changing the bias between modes, since it's more complicated and expensive. Instead they run Class AB all the time, including AM and FM. The lower efficiency is compensated by the higher gain and smaller drive requirements. In a few old radios (Eg., Cobra 132/135), they actually used two separate Final amplifier circuits for AM and SSB.

VACUUM TUBE RF AMPLIFIERS

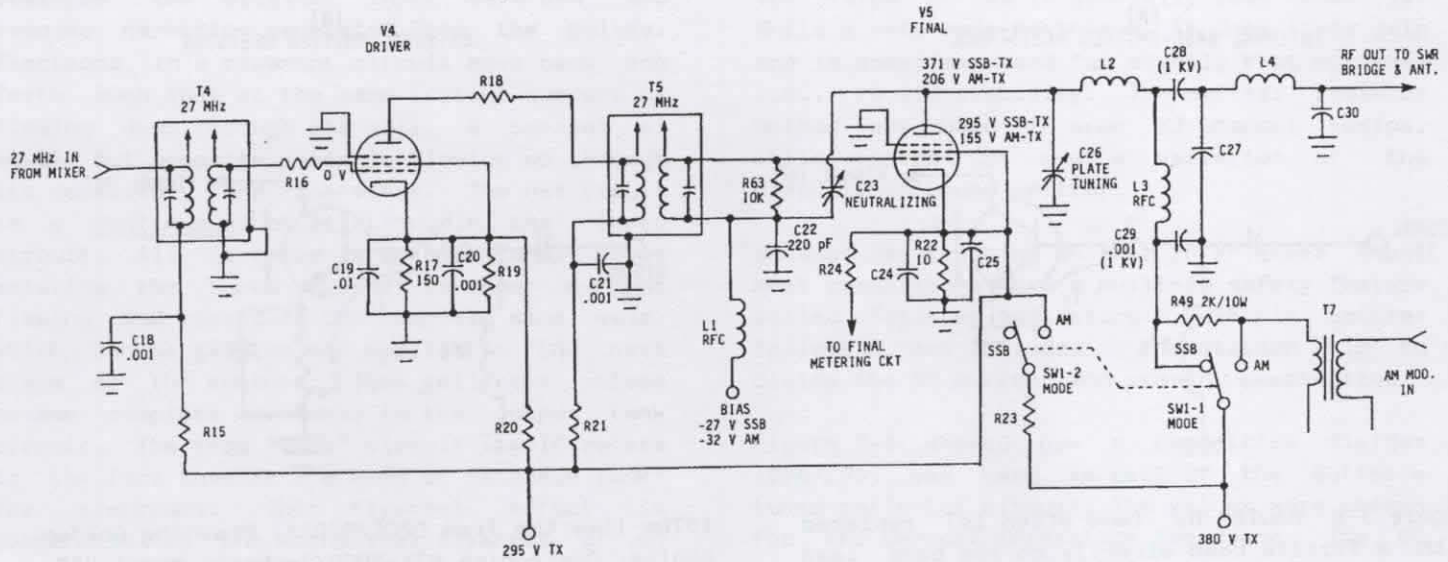
Tube-type CB radios are no longer made, but are still popular enough in the the U.S. to justify some discussion. Among these types are original 3- and 6-channel models from the 1960s, and the synthesized 23-channel radios from the 1970s like the Tram D201/D201A, Browning Golden Eagles, Gemtronics GTX-5000/Teaberry Model "T", etc. Also some hybrids like the DAK Mark X that were basically solid-state except for the RF and audio power stages.

The only real differences between tubes and transistors as RF power amplifiers are the operating voltages, and the fact that tubes are voltage devices (which implies high-impedance) while transistors are current operated devices (i.e., low-impedance). These factors account for the differences in the values of many passive components as well as the circuit complexity. For example, you rarely have to neutralize a transistor RF amplifier because interelectrode capacitances aren't usually significant at 27 MHz. Tubes at RF are operated Class B, AB, and C. Drivers are Class AB or B, since linearity is important. Only the Final is switched between Class AB (SSB) and Class C (AM), or constant Class C in AM-only radios.

Pentode tubes are universally chosen for CB RF amplifiers. They have very high amplification factors and high plate resistance, on the order of 30KΩ. Voltage gains are typically 50-200. They rarely need neutralizing. Their high power sensitivity compared to triodes means less driving power and bias voltage is needed. Since CB power levels are relatively low, receiving type tubes and the smaller TV sweep tubes are often used. Biasing is by fixed grid-leak resistance, cathode bias, a separate DC supply, or a combination of these.

Figure 5-9 shows a typical example. (Filaments left out for simplicity.) The 27 MHz signal is coupled by T4 to the control grid of V4, the

FIGURE 5-9
VACUUM TUBE RF AMPLIFIER CHAIN
(Browning Mark III)



Driver. Bias is developed by R16 and cathode resistor R17. Because of the direction of normal plate current flow, the end of R17 closest to the cathode is more positive. The voltage drop across R17 thus causes the grid to be more negative than the cathode. But once RF is applied the negative half cycle would cause the gain to degenerate, since it could greatly decrease or cut off normal plate current. To prevent this a cathode bypass capacitor, C19, is always used. It's chosen for low reactance at the operating frequency. Whenever you note a large loss of gain, one of the first suspects is an open or leaky cathode bypass capacitor. (This also applies to tube audio amplifiers.)

Cathode resistance (R17) is a method of self-biasing, since an increase in plate current produces a larger voltage drop, and decreased current a smaller drop. Thus the plate current tends to remain constant. Grid-leak biasing is also commonly used and is identified by a large value resistor directly from grid to ground.

Note that V4 has no grid bias (0.0 V), typical for a 12BY7 RF amplifier. This tube has very high amplification and its plate current is small with no signal input. With no fixed bias, the grid starts drawing current immediately when a signal is applied. Thus grid current flow is continuous throughout the driving cycle, which results in a more constant load on its driving stage. This is a Class B linear amplifier. The power output is proportional to the square of the RF driving voltage and will amplify an RF signal without distortion. Its efficiency is much higher than a Class A amplifier, which has plate current flowing 100% of the time.

V4's screen voltage comes via R20 from the same supply that provides the plate voltage. This is a common safety practice; if separate supplies were used and there was screen voltage without simultaneous plate voltage, the screen would draw excess current and quickly be destroyed. The resistor allows the screen voltage to drop as its current increases. To smooth the extremes of voltage drop a resistive divider is often used, which is the purpose of adding R19. Note the screen bypass, C20, and plate bypass, C21, are smaller than C19. Since harmonics are generated in RF amps, these capacitors need a lower reactance to frequencies above 27 MHz for better harmonic reduction.

The signal couples across T5 to the grid of V5, the Final. R63 across T5 lowers its Q to help prevent self-oscillation. C22 provides DC blocking, RF coupling, and impedance matching. R22 provides some cathode bias for safety. If only grid-leak bias is used and the driving signal is lost, the high plate voltage on V5 would draw excessive plate and screen current; R22 limits this to a safe value.

The DC supply voltages are always heavily filtered for RF, which is the purpose of L1, L3, C22, and C29. Besides keeping RF out of the power supply, the various capacitor values are intended to react to different frequency ranges as required.

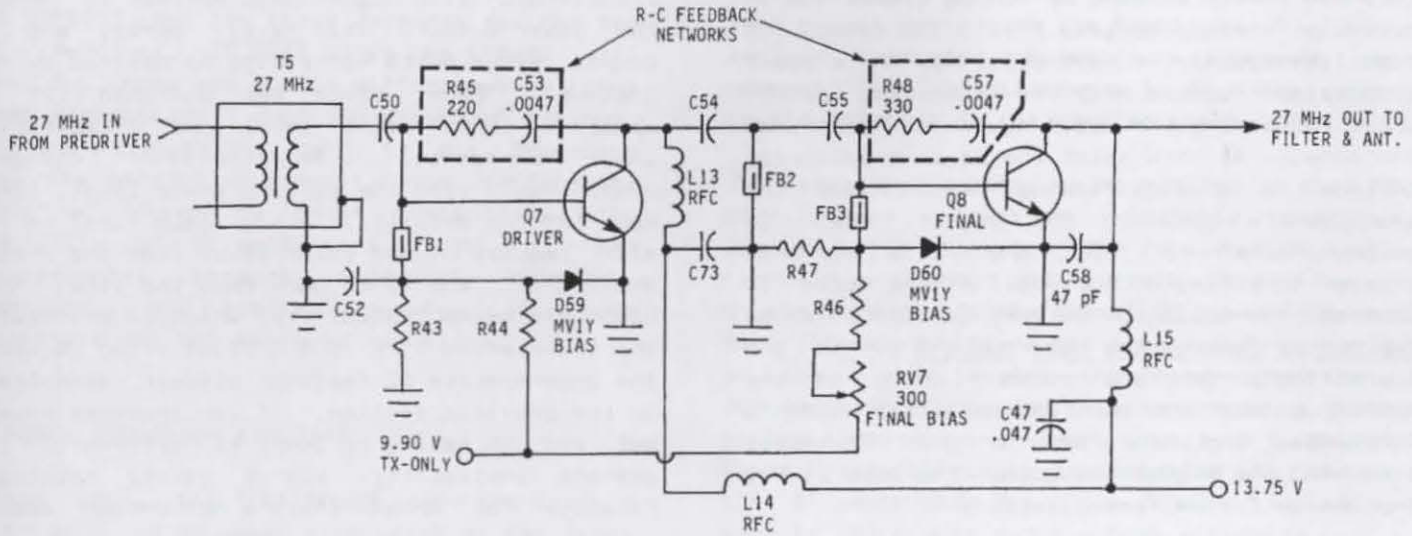
C23 is the neutralizing adjustment; it provides some negative feedback from plate to grid, producing an equal but opposite-phase signal which cancels the effects of the tube's interelectrode capacitances. This is needed to prevent self-oscillation. Self-oscillation exists whenever there's RF output even with the drive removed. Due to minor electrical differences between tubes, neutralization should always be rechecked when replacing V5.

Neutralization is a simple process: connect a wattmeter to the antenna or use the radio's S/RF or SWR meter in the "FORWARD" or "CAL" position. Disconnect plate and screen voltages, leaving all other normal operating voltages. Adjust the neutralizing device for minimum power output indication. A second method is to leave the operating voltages intact but disconnect the RF drive instead, such as by removing a crystal. If there's any indication of RF output with no driving signal, adjust the neutralizing element until it disappears. Most tube radios purposely have a neutralizing link or jumper for easy disconnection of plate and screen voltages. If not, use the second method.

Cathode biasing (R22) is also used on V5. But its smaller value compared to R17 puts the hot end of the cathode much closer to ground, increasing gain. Like the emitter resistor in a transistor RF amp, it does lower the gain when compared to direct grounding, but aids stability. The tube is biased to Class C by virtue of the large negative grid voltage which is only partly overcome by the RF drive cycle, causing plate current to flow in pulses. The grid bias and the plate voltage are switched between AM and SSB. The bias is larger for AM (-32 V), since the tube is cut off longer than for SSB. Again, that's the difference between Class C and Class AB operation. The amplified 27 MHz signal is coupled from the plate of V5 and applied to an impedance matching and filter network, C26/L2/L4/C30/C27. C28 provides DC blocking to keep the dangerous high plate voltage out of the antenna circuit.

CAUTION! You tend to forget tube basics when spending most of your time around solid-state equipment. This leads to carelessness and could be fatal! DC blocking and RF bypass capacitors such as C28 and C29 in Figure 5-9 are always high-voltage types, conservatively rated at a minimum of 1 KV. If they short, watch out! The DC plate supply could appear across the antenna unless the fuse blows. Never replace them accidentally with low-voltage types from your junk box, which are often the same physical size. Read those markings carefully!

FIGURE 5-10
USING NEGATIVE FEEDBACK TO STABILIZE RF POWER AMPS
(Cybernet PCMA001S export chassis: Lafayette 2400, Nato 2000, etc.)



More Amplifier Stability Tricks

Besides careful biasing, another stability method in CB power stages is "degenerative" or negative feedback, where some of the output signal is fed back to the input out of phase. Since the Common Emitter amplifier has a 180° base-to-collector phase reversal anyway, this takes advantage of it. It's used mostly in radios having SSB, where the higher gain of Class AB stages encourages instability.

Refer to Figure 5-10. The 2SC2166, 2SC1969, and 2SC2312 are especially hard to tame, since they have higher gains than the older (and more common) 2SC1306 Driver and 2SC1307 Final transistors. Driver Q7 has a feedback circuit consisting of R45 and C53. An identical circuit (R48/C57) is used at Q8, the Final RF amp. In both stages some of the collector output will be coupled back out of phase to the bases, lowering their gain. The exact RC values depend upon device characteristics, power levels, and impedances, and are determined experimentally when designed.

Sometimes RF amplifier self-oscillation occurs when substituting a power transistor with something other than the exact replacement. In such cases an RC feedback circuit like that of Figure 5-10 will cure the problem. Try using the same RC parts values shown, since the manufacturer already did all the design work for you. Tack these parts across the b-c foils on the solder side of the PC board, using the shortest possible lead lengths.

You'll often find that customers tried to "peak and tweak" a CB for higher power output, but this can rarely be done by tuning alone. You've probably already noticed this! The reason is stability again. The best stability for a power transistor occurs near its saturation point, where increasing the drive no longer increases the output. At this point the maximum collector current is already flowing, which means the transistor's gain is the lowest. (Gain is called "beta" or "h_{fe}," the ratio of base current to collector current.) As the drive is lowered the collector current is also lowered, but not as fast as the base current due to the transistor's inherent current gain. So the spread between the base and collector currents increases, and therefore the gain increases too. And the higher the gain, the more likely the chance for self-oscillation.

Power Doubling Circuits

Many export CBs offer double the RF power output of the standard models, about 10 W AM/FM and roughly 25 W PEP on SSB. Examples include the President Jackson, Franklin, Grant, Ranger AR3300, and Super Galaxy. It's easily done using two Final transistors with identical base input and bias circuits connected to a common Driver, and the collectors tied together in parallel. This results in twice the collector current, and therefore twice the RF power.

The transistors are factory-matched for equal characteristics, and don't need any complicated signal-splitting networks. Although the base input impedance of an RF power transistor is no more than a few ohms and the paralled inputs cut this in half, it's such a small change that the impedances can be adjusted with minor RC value changes. The Finals are followed by the usual coupling and filter circuit. The Driver is typically a 2SC2166, which has an extremely high power gain of about 15 dB at 27 MHz. An external finned heatsink is added to the rear of the frame for the extra cooling required.

In the President Jackson, the usual pair of 2SC2312 Finals was replaced by a single Motorola MRF477 power transistor for circuit simplicity. The 2SC2312 specifies a power gain of about 11.5 dB with 1.5 W drive at 27 MHz and 12 V collector voltage. The MRF477 under these same conditions has about 16 dB gain. Since a power doubling is equal to a 3 dB increase, the MRF477 easily does the same job with some power left over for normal circuit losses.

Many people mistakenly think they can replace the original factory Driver and/or Final transistors with higher-gain devices to boost the power output. This rarely works, and a couple extra watts won't even be noticed by a listener. Each stage was designed for a specific input signal level and a specific input impedance; this impedance changes considerably with the driving power level. (See Page 159 for details.) A high-gain Final would also require higher input power from the stage driving it, and so on back down the line. And high gain means instability, which is precisely why transistors like the 2SC2166 often require the degenerative RC feedback circuit described in the previous section. If you increase power but end up having to lower it afterwards to prevent instability, you've gained nothing. Finally, for AM use there's not enough audio

power in a standard model for 100% modulation at the higher carrier power anyway.

For those who insist on trying this, save it for SSB radios only. Try replacing the Driver and Final with Motorola transistors, which have higher power amplification than their Japanese counterparts and are much more rugged. A Driver would be the MRF476 (about $3) which has a gain of about 18 dB at 27 MHz. For a Final, try the MRF475 (13 dB gain, about $3) or MRF479 (15 dB gain, about $10). They're sold by RF Parts Co.; see CHAPTER 1. If the increased power output causes instability, reduce it by retuning; at least you will have installed better devices which won't fail as easily as the originals.

IMPORTANT: The MRF475 and MRF476 have exactly the same lead basing (B, C, E, reading left to right from marked side) as the Japanese TO-220 transistors. But the MRF479 is B, E, C, so you must criss-cross the collector and emitter leads during installation in a standard radio.

Whenever a radio shows signs of instability, self-oscillation, short transistor life, or related power problems, look for "improvement" changes from the original device(s) or circuit components made by some previous "expert."

Summary

One thing I hope you'll learn from this lengthy discussion of RF amplifiers is the importance of using identical component values and transistor replacements when repairing them. The ECG/SK substitutes don't always have exactly the same electrical characteristics as the original device. For example, the ECG236 is specified as a sub for the 2SC1307, 2SC1969, and 2SC2312, but the three Japanese devices are not identical. In most cases the ECG/SK will work, but there are subtle differences in total power dissipation, junction breakdown ratings, junction capacitances, gain, f_T, etc. Depending upon the particular circuit these differences might be enough to cause instability. The complexity of RF amplifiers is due to three requirements: correct impedance matching, stability, and spectral purity. RF power amplifiers are not designed casually!

RF POWER REDUCTION CIRCUITS

Before 1987, the British CB specs required a switchable 10 dB power attenuator at the front panel. (The new FCC-channel UK radios don't.) So older UK-FM equipment is switchable from LOW (0.4 W) to HIGH (4.0 W). Some multimode export radios also have switchable RF outputs working exactly the same way. It's done by reducing the gain in the Driver stage (typically about 10 dB anyway) and sometimes the Final too. The supply voltage is dropped in the "LO" power position, which reduces the transistor(s) current flow and therefore the power output. Figure 5-11 shows several popular methods.

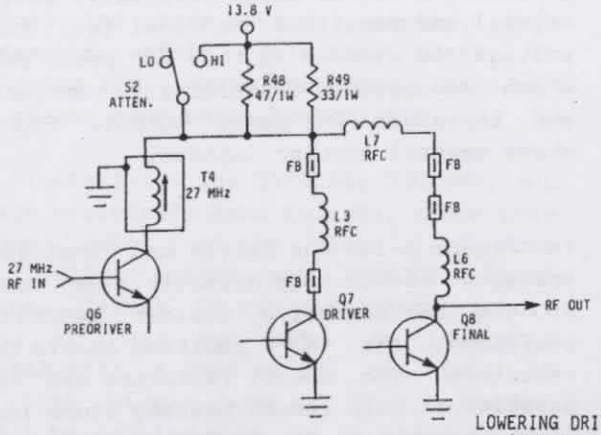
In Figure 5-11A the Driver and Final collector voltages either feed directly ("HI" position) or via the resistive divider R48/R49 ("LO" position); the "HI" position shorts out the resistors. Two 1-watt resistors are used in parallel to help reduce heating since this is a high-current circuit. In Figure 5-11B, just the Driver collector voltage is controlled. In this case VR4 allows a precise 10 dB adjustment; many UK rigs using fixed resistors aren't even close, often dropping a lot more than 10 dB! In Figure 5-11C the Driver emitter is controlled instead, switching between direct grounding and grounding through the voltage divider R119/RV5. R119 across RV5 helps stabilize the circuit and prevent overheating due to the high current flow in Q5. The result is identical, reducing the transistor current flow and therefore its power amplification.

Incidentally, this is exactly the same way power levels are switched in Walkie-Talkies having a HI/LO option. In the "LO" position (often called "BATTERY SAVE"), a resistive divider drops the V_{CC} to the collector of the Driver stage. With less driving power, there's less output power from the Final amp. They also include separate modulation adjustments to account for the difference in AM audio power levels relative to the carrier power.

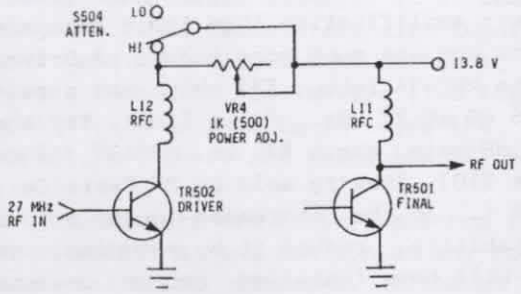
The same principles can be applied to any CB radio where a lower or switchable power is desired. For example, the President Jackson, Franklin, Grant, and certain other export models have double the normal RF power output. Most linear amplifiers can't be driven properly at the higher levels; they're designed for a 50Ω input impedance and this impedance depends on the input driving power, usually 4 W. Any of these circuits could be installed to reduce the RF power when driving a linear, switching back to the higher radio output otherwise.

FIGURE 5-11
POWER REDUCTION METHODS

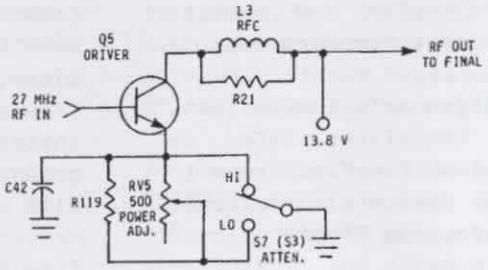
(A)
LOWERING DRIVER & FINAL COLLECTOR VOLTAGES WITH FIXED RESISTANCE
(Cybernet PCMA002F UK chassis: Amstrad CB900, CB901, etc.)



(B)
LOWERING DRIVER COLLECTOR VOLTAGE WITH ADJUSTABLE RESISTANCE
(Uniden PA034/039 UK chassis: Realistic TRC2000, Uniace 100/200, etc.)



(C)
LOWERING DRIVER GAIN WITH ADDITIONAL EMITTER RESISTANCE
(Cybernet PTBM134/135 UK chassis: Beta, Binatone,
Fidelity, Harrier, Rotel, York, etc.)



OUTPUT COUPLING & FILTERING

Once the 27 MHz signal is amplified to the 4 W level, it must be coupled to the antenna as efficiently as possible. The signal is also dirty with harmonics which must be removed or they'll cause interference to other services, especially TV sets. The last circuit in the transmitter chain is a tuned LC network which serves both these purposes simultaneously. The output impedance of all CB radios is by definition 50 ohms unbalanced, which allows for inexpensive coax cables and connecting hardware. Being unbalanced (i.e., one side grounded), the shielded coax also provides extra protection against stray RF radiation.

Transistors are low-impedance devices, while tubes are high-impedance. Neither is anywhere close to 50 ohms, so their output impedances must be transformed to 50 ohms. Otherwise the mismatch causes a power loss. It's exactly the same situation as a mismatched antenna. Think of the output coupling circuit as a way to get a 1:1 SWR match between the Final power stage and the input to the antenna.

Tuned coupling networks just happen to be great filters too, in this case low-pass filters since they pass the desired frequency while rejecting higher frequencies. A low-pass filter uses series inductance and shunt capacitance; the increasing reactance of the inductor at higher frequencies blocks these from passing through, while the decreasing capacitive reactance shunts them to ground. When more filtering is needed, an extra "L" section consisting of a series coil and shunt capacitor is added. That's why you sometimes see three or four coil/capacitor output sections.

To give you an idea of just how low an output impedance you're dealing with in solid-state RF power amplifiers, the impedance of the Final transistor can be approximated by the following formula:

$$Z_{collector} = [V_{ce}]^2 \div 2P_o$$

where Z = collector impedance
V_{ce} = collector supply voltage
P_o = power output in watts

For example, in a typical AM/SSB solid-state radio having a regulated AM collector supply voltage of 6 VDC and 4 W carrier power output, the impedance of the Final collector is roughly $[6]^2 \div (2 \times 4 \text{ watts}) = 36 \div 8 = 4.5\Omega$. That's not much! And if you overpeak the power output by tuning to say, 6 watts, the impedance drops to 3Ω, a 33% change! This partly explains why CBs used with linear amplifiers have so many problems with blown RF transistors in both the radio and the amp; the amp is designed for a specific input impedance, which obviously changes with changing radio power output.

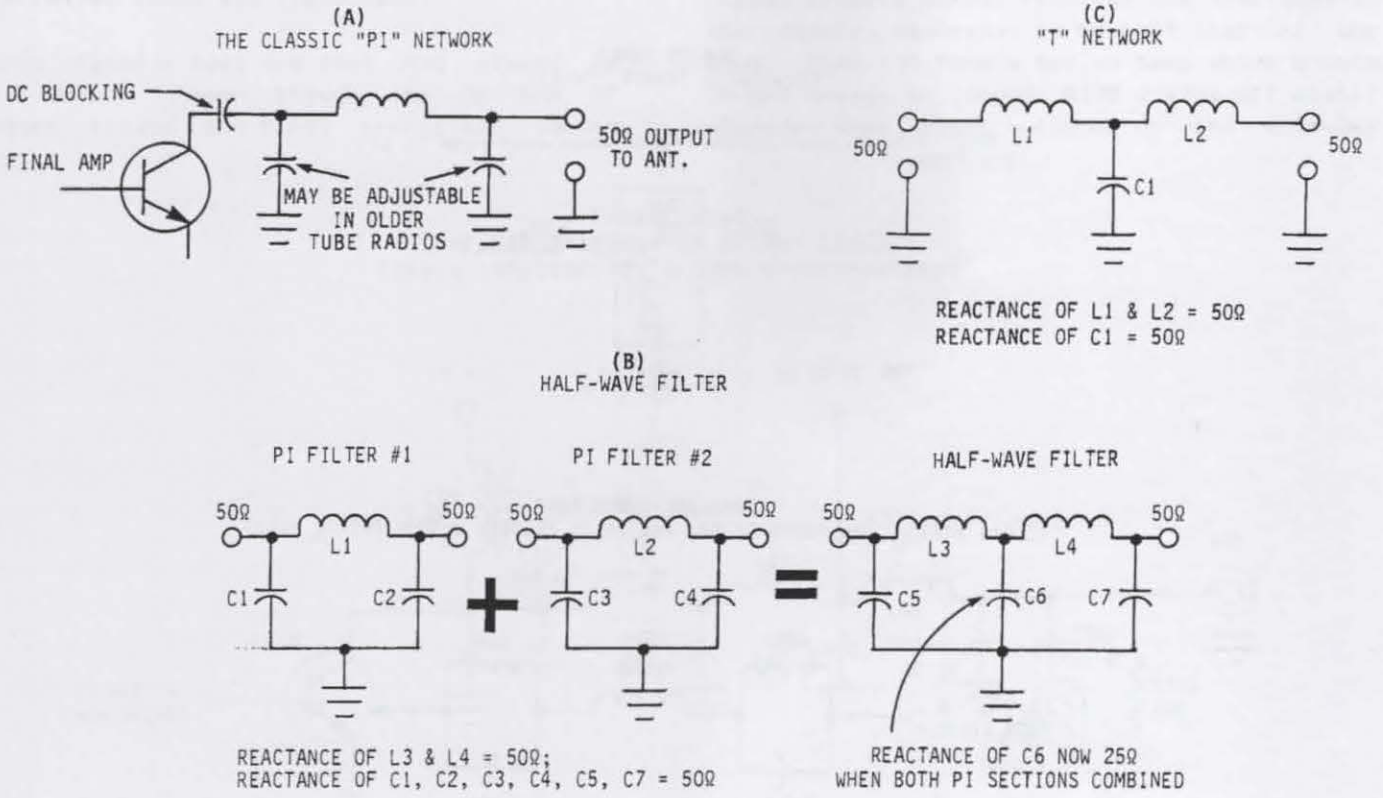
The Pi Network

Most technicians think of CBs as having the traditional "Pi" output network, which is only partly true. (It got the name from its similarity to that Greek letter.) The low-pass version consists of an inductance shunted by two capacitors at the input and output terminals, as shown in Figure 5-12A. In tube circuits where these capacitors are adjustable, they're called "TUNE" and "LOAD" respectively. The problem with this circuit is in matching a low input impedance to a 50Ω output; the required parts values aren't physically practical for transistor power stages. But they're perfectly practical with tube amplifiers, since plate impedances are always much higher than 50 ohms. The simple Pi network can match a wide range of impedances and is often found in tube transmitters, but not in solid-state output stages.

Half-Wave Filter

One way to match the lower impedances of transistors is to combine two Pi networks in series, Figure 5-12B. At 27 MHz this makes the parts values much more practical. The two center capacitors are combined into a single capacitor with the appropriate reactance so the

FIGURE 5-12
MATCHING AND LOW-PASS COUPLING NETWORKS



final configuration becomes two inductors and three capacitors. This double-Pi circuit is also called a "half-wave" filter. Like the half-wave transmission line, it's an impedance repeater since whatever impedance (like 50Ω) exists at the load end (the antenna) is also seen by the source (transmitter) end.

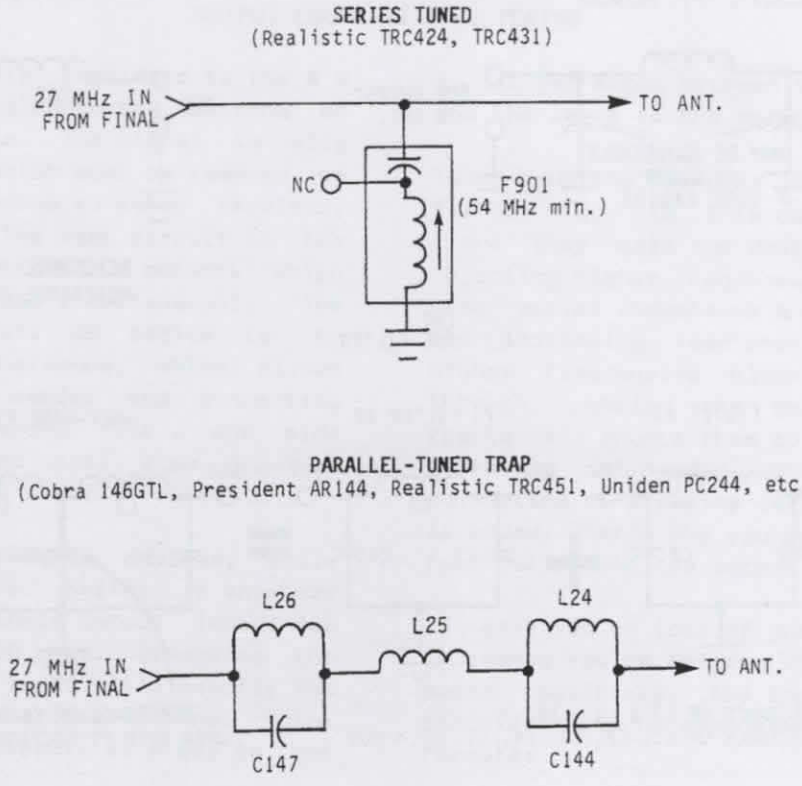
There's no signal loss through a half-wave filter since it has only pure reactances, and power can only be consumed in a resistive load. When the load is reactive, some power will be reflected back towards the transistor. The filter normally has an impedance mismatch between its input and the transistor's output, which as shown earlier is usually much less than 50 ohms. By adding an LC network before the input to the half-wave filter, losses are minimized. CBs always include an adjustable "L" section between the Final amp collector and the input to the half-wave filter.

It's important to understand the subtle meaning of this idea. If a load (like the antenna) has any reactance, this effects the performance of any accessory items that may be in series between it and the radio. Add-ons like external low-pass filters or SWR meters will not work right and will actually increase the total signal losses, since they're designed for pure 50Ω terminations. More on this in CHAPTER 8.

Occasionally you'll see a "T" network used, Figure 5-12C. It looks like the letter "T". The main difference is in reversing the positions of the inductors and capacitors compared to the Pi network. Since coils cost more than ceramic disc capacitors, the "T" isn't as common. "T" networks can be strung in series for added filtering with no effect on input/output impedances. Combining two of them results in three coils and two capacitors, the usual configuration for CB circuits. The CPI radios in particular used "T" coupling networks.

Because filter inductors require small values, they're air-wound; using magnetic cores would increase the inductance. Low-permeability tuning slugs are sometimes included though to optimize impedances and power transfer. Whether or not a coil is adjustable really depends upon its loaded Q, which when low will be broadbanded enough so no adjustment is needed. This is the trend in current CB designs; older

FIGURE 5-13
TVI FILTER CIRCUITS



radios used more tuned coils, but fixed inductors are cheaper. Comparing schematics over the years, you'll find fewer and fewer adjustments in the modern transmitter output stages. The Motorola CB line in particular used untuned, totally broadbanded RF output stages.

Additional Harmonic Filtering

The half-wave output filter is now used almost universally for CB transmitters. Harmonic suppression of a single section is about -35 dB to -40 dB at 54 MHz, and about -55 dB at the third harmonic of 81 MHz. Current FCC specs are -60 dB for the second harmonic, which means more suppression than a single half-wave filter can provide. To increase harmonic suppression, a 54 MHz trap is added just before the antenna.

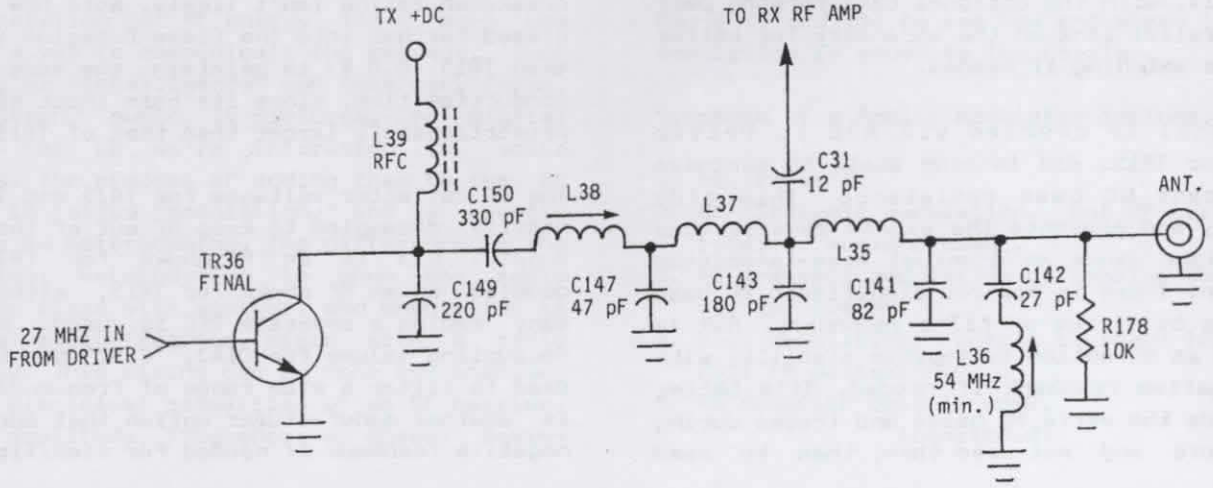
As shown in Figure 5-13, the trap may be either a series or parallel type. A series circuit presents a very low impedance at resonance and a parallel circuit a very high impedance. The series circuit will therefore shunt the 54 MHz energy to ground, while the parallel circuit blocks it from passing to the antenna. At least two parallel traps must be used for the -60 dB spec, which makes this method less popular than the series type with its fewer parts. The series trap circuit is tunable for maximum suppression on a spectrum analyzer or TV set; the parallel traps are fix-tuned.

I once fixed a real dog that had almost no power output, even though the DC and RF voltages around the Final transistor looked normal. Turns out somebody replaced the capacitor in the series-tuned TVI trap with one having double the correct value. Guess what happened? Yep, doubling this value cut its resonant frequency in half, shunting the 27 MHz RF energy straight to ground!

Figure 5-14 summarizes this discussion about transmitter output circuits. (Metering circuits left out for simplicity.) The RF couples from the collector of TR36 through C150 to L38. C150 blocks DC from the antenna circuit, and with L38 forms the main LC network for 50Ω impedance transformation. C150 is purposely kept small to minimize the coupling and help maintain a relatively high Q for harmonic rejection. C149 also has a dual function: it filters some harmonics, and with C150 forms a capacitive divider to further control the loading and impedance transformation to the filter input. In most transistor output circuits these capacitors will range from about 100-560 pF. Due to the minor electrical variations in all transistors and associated passive components, the filter input coil (like L38) is normally adjustable for maximum RF power transfer.

C147/L37/C143/L35/C141 form a half-wave filter. Note how the value of the middle capacitor C143 is much higher than C147 and C141, since combining two Pi filters to form a half-wave filter (Figure 5-12B) requires the reactance of the middle capacitor to be half that of the ends. C142/L36 form a series trap which shunts 54 MHz energy to ground. R178 drains off static charges that might build up on the antenna;

FIGURE 5-14
COMPLETE TRANSMITTER OUTPUT CIRCUIT
(Cobra 148/2000GTL, Uniden Grant/Madison)



it's so large relative to the antenna impedance that there's no loading on the output stage.

It's important to note there's a critical L/C ratio that must be maintained in all output circuits such as C149/L38/C150 of Figure 5-14. While it's possible to change the capacitor values and increase the RF power output, this will also affect the bandwidth and harmonic content. If you should find RF power problems in radios that have had previous work in the Driver and/or Final circuitry, suspect possible changes in the original parts values.

In radios like this which use electronic T/R switching, the output filter circuit is also shared by the receiver input. This reduces the overall spectrum of RF energy entering the receiver, which helps to control front-end overloading. With relay T/R control, one set of relay poles routes the signal from the coax socket to the appropriate Transmit or Receive circuit; the filter network is usually just in the Transmit path.

Note with electronic T/R switching the full RF output power is present at the receiver input via C31, a situation which would immediately blow the front-end amp transistor unless precautions are taken. Such precautions include turning off many or all receiver operating voltages on Transmit. The method's very crude, since in theory there could still be enough rectified RF around to turn on a silicon junction. The back-to-back overload diodes discussed in CHAPTER 4 are especially important in these radios. The input coupling capacitor between the coax socket and receiver input is always small (under 33 pF), both to minimize RF coupling from the transmitter, and to prevent loading down the receiver front end stage.

A PRACTICAL TRANSMITTER EXAMPLE

Figure 5-15 shows a typical transmitter chain which summarizes everything discussed so far. (SWR and RF metering circuits not shown for simplicity.) The 27 MHz PLL signal is coupled to the base of TR16, the Buffer. TR16 operates Class A since positive bias (0.71 V) is present all the time. This bias results from its emitter being somewhat above ground via R60, and from the constant DC voltage supplied by the normally-HIGH PLL Lock Detector pin. R62 and R61 form a voltage divider for bias stabilization. There's only DC bias when the PLL is locked; if unlocked the PLL's LD pin goes LOW, removing the bias from TR16. Note the optional supply voltage location to L17's primary; either the coil's end or the tap may be used to control the impedance match to the collector of TR16. The signal is coupled across L17, with the optional C244 forming part of a parallel tank on the secondary for better impedance matching if needed.

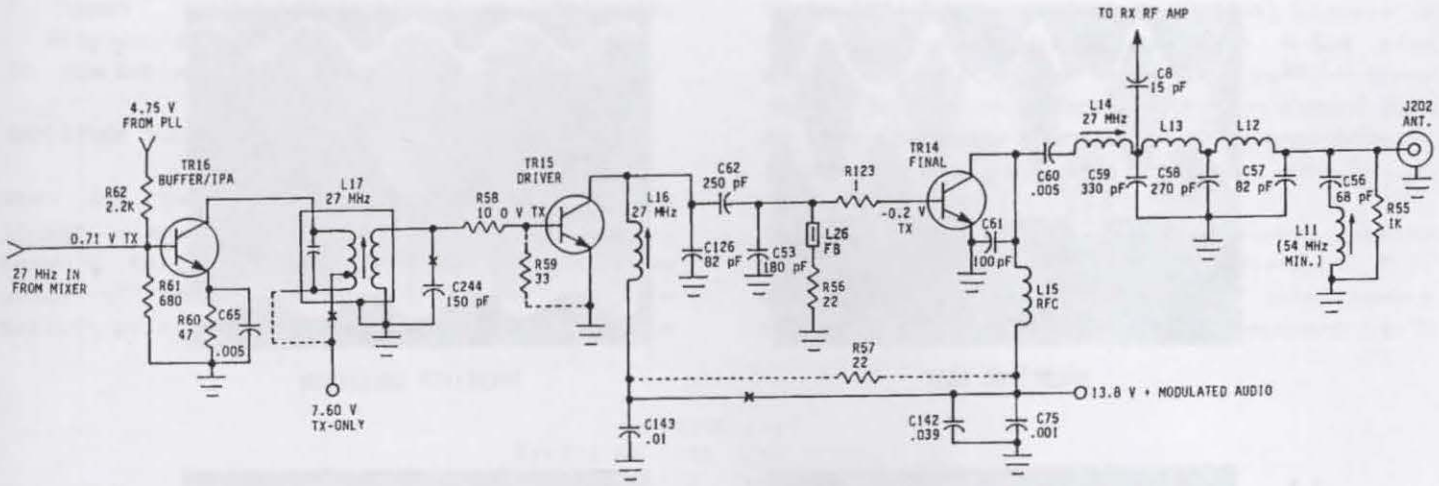
The signal is coupled via R58 to Driver transistor TR15. R58 is made small to minimize significant DC base resistance. This aids stability and prevents the excess reverse bias that might cause an eventual base-to-emitter breakdown. There is however significant RF base impedance by virtue of L17's secondary. R59 is included as an option to improve stability with some negative feedback if needed. It's better to include the extra PC holes and traces during manufacture and not need them, than to need them and have to solder R59 later by hand, an additional labor cost. Note its low value too.

TR15 is a Class C amplifier, since no DC bias exists. Only the positive peaks of the RF drive cycle will make TR15 conduct. The emitter is directly grounded for maximum power gain. The collector output is tuned by the parallel tank circuit of L16/C126. The capacitive divider C62/C53 forms part of the load for TR15 as well as the tuned base input for TR14.

TR14 is the Final power amp, another Class C stage. Biasing is similar to TR15 using a ferrite bead (L26) as a low-Q base impedance. R56 adds base-leak bias. R123 also develops bias, but its value is small enough so that the problem of exceeding the base-to-emitter breakdown rating isn't likely. Note how TR14 is biased further into the Class C region (-.20 V) than TR15 (0.0 V) to maintain the same Class C conduction time, since its base input signal is proportionately larger than that of TR15.

The DC collector voltages for TR15 and TR14 are heavily decoupled to keep RF out of the power supply. L15 is an RF choke for TR14. L16 doubles as an RF choke for TR15, although in many radios a separate RFC is used. Multiple decoupling values for C143, C75, and C142 are used to filter a wide range of frequencies. R22 is another manufacturer option that adds some negative feedback if needed for stability.

FIGURE 5-15
COMPLETE 27 MHz RF CHAIN
(Cobra 29GTL, 29LTD)



The 4-watt signal couples from the collector of TR14 to the output matching and filtering circuits. C60 blocks DC, and along with C61 and L14 forms part of a tunable "L" impedance matching network for the filter input. C61 also helps shunt some high-frequency harmonics to ground. The output of L14 is now 50 ohms. C59/L13/C58/L12/C57 form a half-wave harmonic filter. A half-wave filter has the same impedance at both ends. Since the antenna must be 50 ohms, the filter input is also 50 ohms and maximum RF power can now be transferred. R55 drains static charges that might appear on the antenna. L11/C56 form a 54 MHz series-tuned trap which further reduces the harmonics by shunting them to ground.

Typical RF Waveforms

Figure 5-16 shows 'scope waveforms for various transmitter stages. These indicate the approximate RF voltage levels at each stage for troubleshooting; the absolute values among different radios may vary by perhaps 10-30% from those shown. What's important is to see substantial voltage gain from base to collector of each transistor in the chain. Note the large harmonic content at each stage before removal by the output filter. These photos were taken using 50% modulation, and the envelopes are obvious. An unmodulated AM (or FM) carrier looks similar, minus the modulation peaks and valleys. RF voltage levels at the Driver and Final stages would be proportionately lower for an unmodulated AM transmitter.

MODULATION METHODS

The generation of RF energy isn't much use without a way to communicate the message. Such messages or "intelligence" can take many forms, like speech, music, TV pictures, or digital data. For CB we're interested in voice messages. The process of adding them to the RF signal is called "modulation," and is exactly the same as heterodyning. The difference is the definition: heterodyning is when one radio frequency mixes with another, and modulation is when an audio frequency mixes with a radio frequency. This mixing can be done by changing several electrical properties of an RF carrier, such as amplitude, frequency, or phase. Review Pages 27 and 146 to see how and where the AM/FM modulation is added to the carrier.

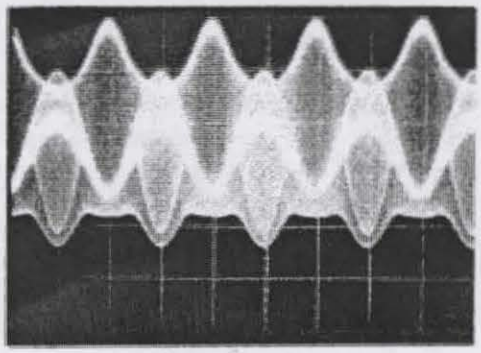
Symptoms of a faulty modulator include:

1. No Transmit.
2. No Transmit modulation, but RF carrier and receiver audio present.
3. No Transmit modulation or Receive audio, RF carrier present.
4. Weak modulation; unable to reach 100% AM or full FM deviation.
5. PA function doesn't work.

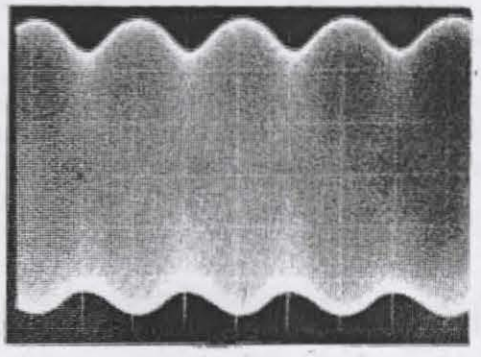
(continued)

FIGURE 5-16
TRANSMITTER WAVEFORMS SHOWING TYPICAL RF VOLTAGE STAGE GAIN
(SHOWN AT 50% MODULATION)

0.2 V
0.5 mS



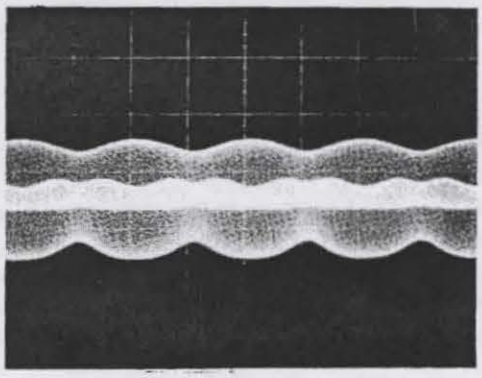
PREDRIVER BASE



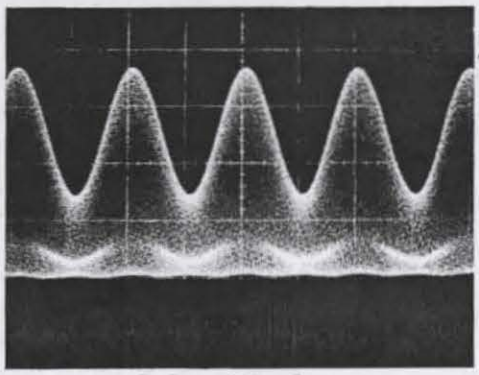
2 V
0.5 mS

PREDRIVER COLLECTOR

2 V
0.5 mS



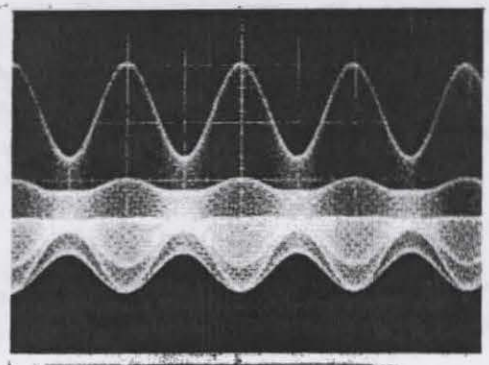
DRIVER BASE



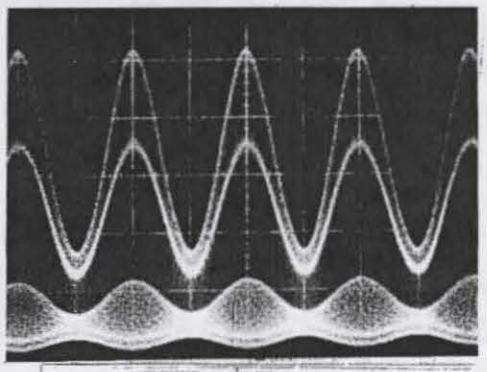
5 V
0.5 mS

DRIVER COLLECTOR

2 V
0.5 mS



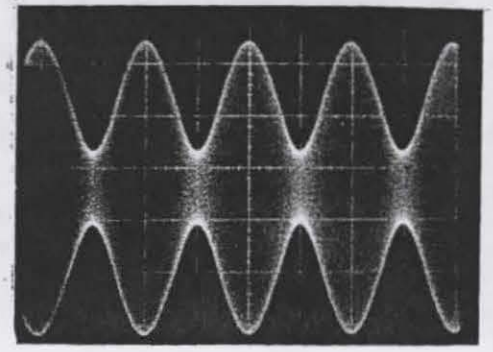
FINAL BASE



10 V
0.5 mS

FINAL COLLECTOR

10 V
0.5 mS



ANTENNA COAX SOCKET

6. Downward modulation. (I.e., negative carrier shift.)
7. Low RF output power.
8. Blows main radio fuse.
9. Severe audio distortion on Transmit, Receive, or both.
10. Hum on transmitted signal.

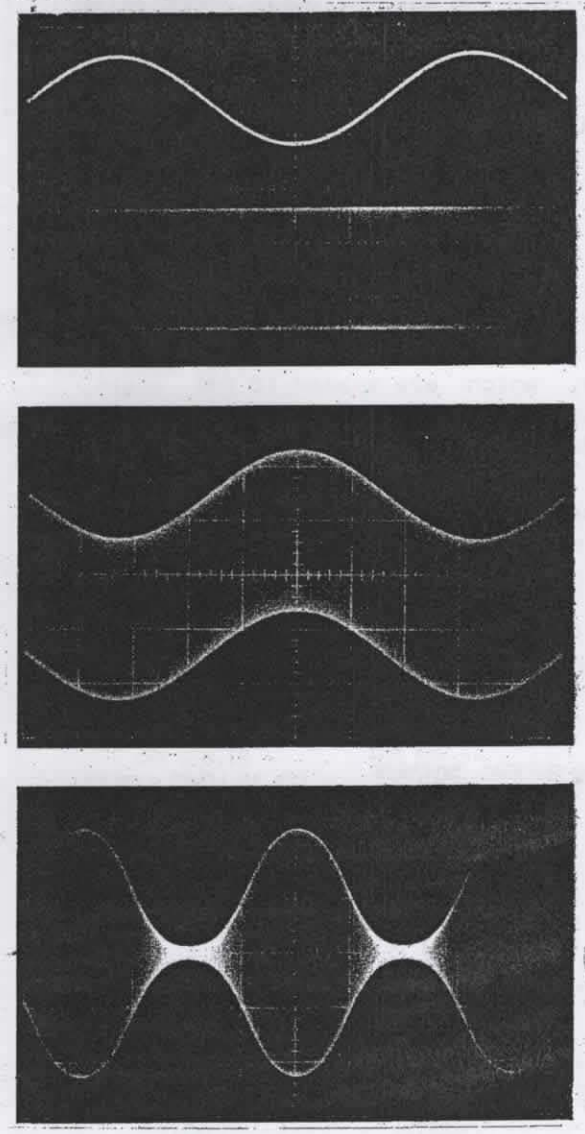
AMPLITUDE MODULATION

When any two frequencies are combined in a linear circuit, each acts as if the other weren't there. Since there can be only one value of voltage or current at any specific circuit point at any given instant, that value must be the algebraic sum of the two frequencies. This is illustrated in the 'scope photos of Figure 5-17.

Photo "A" shows the two individual signals to be mixed. The top waveform is an audio sine wave, and the bottom an RF sine wave. (Since the horizontal sweep speed has been slowed down to show the audio signal, the RF signal appears as a solid band, but is also a sine wave.)

Photo "B" shows both signals combined. Notice how each retains its individual waveform. This signal can't carry any useful intelligence because the low-frequency audio component can't

FIGURE 5-17
EFFECT OF COMBINING SIGNALS IN LINEAR & NON-LINEAR CIRCUITS



(A)
INDIVIDUAL AUDIO & RF SIGNALS

(B)
LINEAR COMBINATION

(C)
NON-LINEAR COMBINATION

Courtesy ARRL RADIO AMATEUR'S HANDBOOK

be propagated efficiently as a radio wave. Note its similarity to 60 Hz signal hum caused by things like poor 'scope probe grounding.

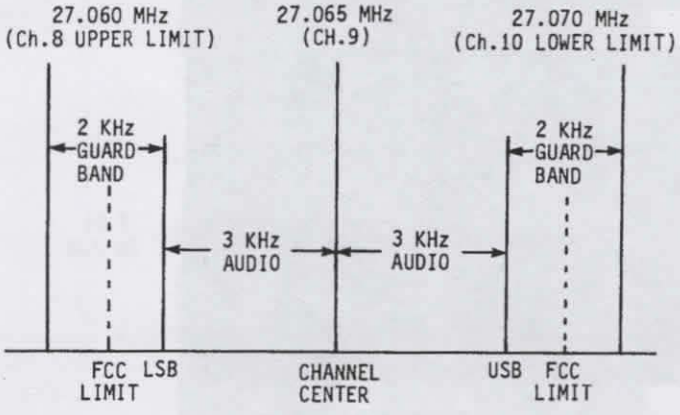
By mixing these two signals in a non-linear device like a Class C amplifier instead, the result is Photo "C." This is the familiar AM modulation envelope. The signal is now entirely at radio frequencies, but its strength or amplitude is changing at an audio rate. When an audio frequency controls the amplitude of a radio frequency, it's called Amplitude Modulation, or simply AM.

While this example uses a single pure audio modulating tone, a band of frequencies could also be used. Such bands appear slightly above and below the RF carrier frequency and are called the Upper Sideband and Lower Sideband, respectively. The extent of these sidebands will depend upon the highest audio modulating frequency; the higher the audio frequency being used, the wider the sideband.

AM Bandwidth

The human voice can be transmitted very effectively by limiting it to a frequency range of 300 Hz-3 KHz. With such limits the resulting bandwidth will be 3 KHz x 2 sidebands, or 6 KHz total. (The maximum FCC spec is 8 KHz for AM and 4 KHz for SSB.) Figure 5-18 shows how the CB channels, which are spaced 10 KHz apart, have a small guard band of 4 KHz total (2 KHz on each side, assuming a 3 KHz maximum audio frequency) to prevent interference to the adjacent channel. Obviously if the audio frequencies went far enough beyond 3 KHz, some would appear in the next channel and cause interference. Harmonics of the modulating signal are also generated, which further broaden its bandwidth. This must be prevented when CB modulation circuits are designed.

FIGURE 5-18
SPECTRUM DISTRIBUTION OF AM CB SIGNAL



Summing up, the mixing of any two sine waves in a non-linear device results in the following:

1. A DC component.
2. The two original frequencies.
3. Components which are the sum and difference frequencies of the two original frequencies.
4. Harmonics of the two original frequencies.
5. A total bandwidth determined by the highest transmitted audio frequency.

Modulation Percentage

Referring again to Photo "C" in Figure 5-17, when the modulating voltage is positive the envelope amplitude is increased beyond its unmodulated value (Photo "A"), and vice-versa when the modulating voltage is negative. Thus the envelope gets larger and smaller, depending on the strength and polarity of the modulating voltage. At the receiving end, the AM detector output follows this changing envelope. The stronger the modulation, the greater the usable receiver output. So it's desirable to make the modulation as strong as possible, but only within certain limits which are often ignored!

In Figure 5-19, you can see that modulation strength is the amount of power increase ("A") relative to the unmodulated carrier level ("B"), expressed as a percentage. This formula assumes equal positive and negative changes, which they would be in a properly operating CB audio system. Both the "envelope" and "trapezoidal" 'scope patterns can be measured this way. Methods for generating both displays are described later in this chapter.

It's possible to increase the current flow indefinitely, up to the limit of the circuits to handle this extra power. But you can never decrease it to less than zero. Thus the modulated RF signal can be increased beyond 100% positive modulation, but negative modulation of more than 100% is impossible.

Overmodulation

Using the formula shown in Figure 5-19, if the "B" value falls to exactly zero, the modulation percentage is 100%. At this point the carrier

envelope swings between zero and twice its unmodulated value. Any further increase in the modulating audio signal results in a finite time period where the RF is completely cut off, since it's impossible to have less than zero RF power. This means the modulated carrier rises to more than twice its unmodulated value, but the minimum is still only zero.

The result is a very serious form of distortion called "overmodulation." This condition must be avoided because it generates additional sidebands extending far beyond the normal 6 KHz CB bandwidth, causing the kind of interference to adjacent channels known as "splatter" or "bleedover." Overmodulation causes more splatter than most other forms of distortion in an AM transmitter. It's a major CB problem, as users trying to get more "talk power" and range are usually going about it the wrong way! Much of your repair work will involve restoring AM circuits to their proper operation.

FIGURE 5-19
MEASURING MODULATION PERCENTAGE
(Courtesy McGraw-Hill Book Co.)

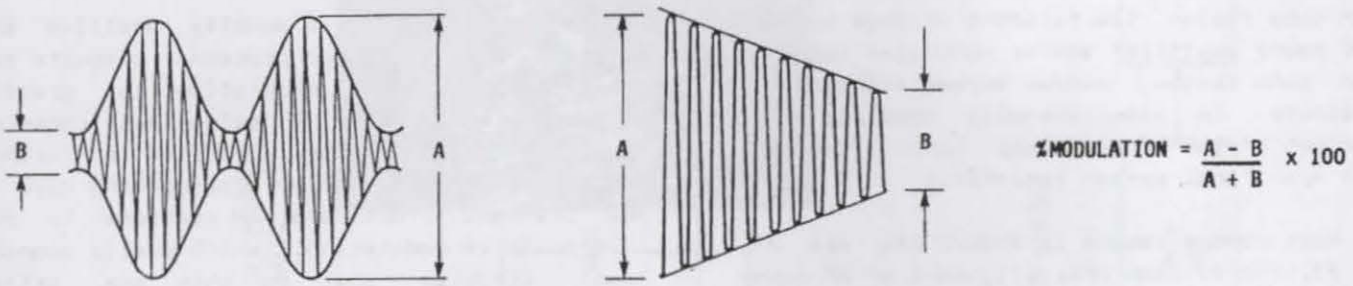
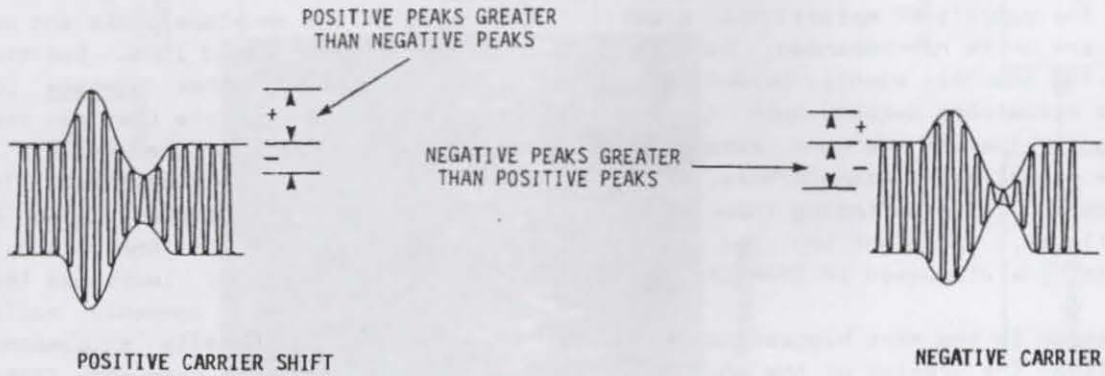


FIGURE 5-20
CARRIER SHIFT
(Courtesy McGraw-Hill Book Co.)



Positive & Negative Carrier Shift

If the positive modulating voltage causes the carrier to increase more than the negative half is decreasing it, a condition called "positive carrier shift" results. If the negative half cycle is larger than the positive half, it's called "negative carrier shift" or more commonly, "downward modulation." These are shown in Figure 5-20. In either case distortion results, since the envelope is no longer symmetrical. Some positive carrier shift isn't bad, and may even be done purposely to increase the talk power. But negative carrier shift is very undesirable and results in audio that sounds weak or choked, because the modulation is not increasing the RF power output normally.

Downward modulation is a very common CB problem and may have many possible causes:

1. Low RF drive to the modulated stage, usually the result of incorrect load coupling (i.e., mistuning) between RF stages.
2. Poor power supply regulation to the RF power amplifier collectors. (Or the Final plate and screen, in a tube type circuit.)
3. Distorted audio, like that caused by losing one transistor in a push-pull audio stage.
4. Improper impedance matching between the modulator and the modulated stage, like that resulting from shorted turns in the audio output transformer.
5. Improper output coupling from the Final to the antenna, which reflects an improper impedance. Solution: proper coil alignment.
6. In tube radios, low filament voltage or weak RF power amplifier and/or modulator tube.
7. In tube radios, excess screen voltage, or failure to simultaneously modulate the screen of the RF power amp tube. (Example: an open Final screen resistor.)

The most common causes in modern CBs are #1, #2, #3, and #5. Improper alignment of RF power or mixer stages by amateurs is very common. For example, American versions of certain Uniden SSB chassis (Cobra 146GTL, 140/142GTL, 148/2000GTL, new Grant, new Madison, new Washington, Realistic TRC451, TRC453, TRC490, Sears 663.3810, Uniden PC122, PC244) often show downward modulation at one end of their new operating range when they're expanded for extra channels. (You need a 'scope to see this, not a wattmeter or the radio's RF Meter!) The mixer transformers are quite narrowbanded, handling only about 80-100 channels evenly. Beyond that, the impedance mismatches degrade both AM and SSB performance. There's no cure except to substitute the export model transformers, which have a much lower Q. Since finding these parts is very difficult, you might try the other broadbanding methods discussed in CHAPTER 3.

Poor DC regulation is the next biggest cause. I already mentioned the problem of the Cybernet export radios; they advertise a 7.5 watt "HI" power position, but the modulator and DC supply are hopelessly inadequate for that level. It's a sucker's advertising gimmick! The cure is to keep the RF output down to 4 W maximum, or use a 'scope to peak the modulated RF power only to the point where any further power increase causes "flat-topping" of the envelope peaks. (Interestingly, just about at the 4 W level!) Flat-topping is the most obvious indication of insufficient audio power in an AM transmitter. I've also seen cases where poor grounding of the -DC wire in a mobile CB produced a normal unmodulated 4 W carrier, but the extra current drain at 100% modulation peaks just killed it.

The only way to detect downward modulation is with a 'scope, RF Ammeter, or modulation light type dummy load. Since positive modulation causes the power (and hence the RF current) to increase, any of these indicators will show an output increase. Don't rely on the radio's S/RF or SWR meter (or external SWR meter), since these circuits can't show modulation properly.

Speech Processing

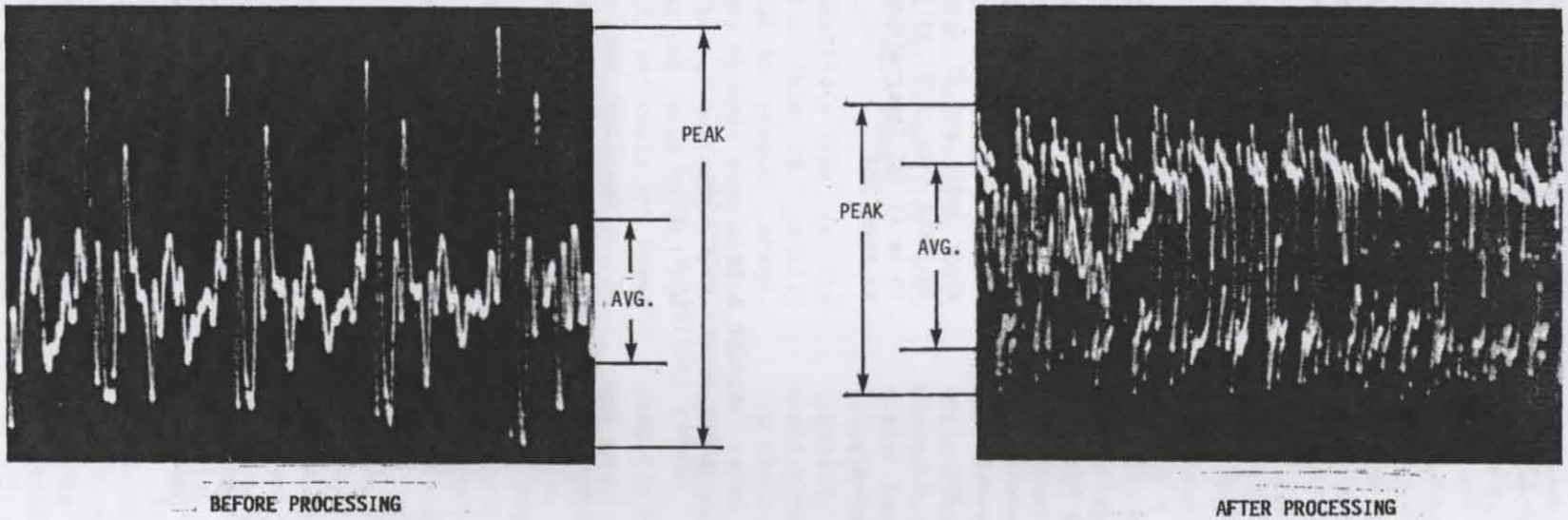
Normal AM signals are equally positive and negative. Special speech processor circuits can produce asymmetrical modulation to greatly increase signal power. By selectively choosing the frequencies to be amplified a further improvement is made. In my broadcasting days it was standard practice at AM stations to run 125% positive modulation, which really sounded loud! Circuits that do this are called "logarithmic" speech processors; they're quite effective but too sophisticated and expensive for most CB use.

A less expensive but very effective method is speech clipping. Tests have shown that 15-20 dB of clipping, a reasonable amount, will add about 4 dB of improved readability. That's almost one "S" unit. The object is to change the ratio of the envelope peaks and valleys so the peaks never exceed 100%, but the valleys have considerably higher average power. The peaks are clipped before they can exceed 100%, with the result that the valleys become a larger part of the whole envelope. In addition the higher audio frequencies, which have less energy than the lower ones, are purposely reduced. This further increases the average voice energy. What's commonly called speech "processing" is usually a combination of clipping and selective frequency filtering.

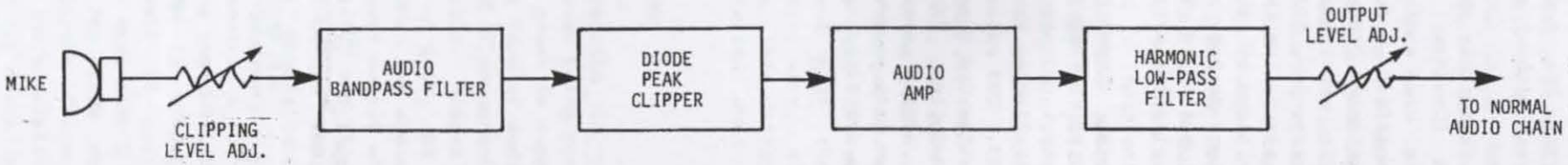
Figure 5-21 is a graphic 'scope demonstration of good speech clipping showing the pronounced increase in average power, along with a block diagram of the circuit principles. (This photo could just as easily represent the difference in peak-to-average power ratios of two different voices with no processing.) Clipping does generate harmonics, which must be removed to prevent excess bandwidth and interference. Regardless of the particular speech processing method, transmitter components must be capable

FIGURE 5-21
SPEECH PROCESSING

(A)
GRAPHIC ILLUSTRATION OF HOW AUDIO (OR RF) CLIPPING
LOWERS AVERAGE-TO-PEAK POWER RATIO



(B)
BLOCK DIAGRAM OF AUDIO CLIPPER CIRCUIT



of handling the increased duty cycle and current drain without overheating.

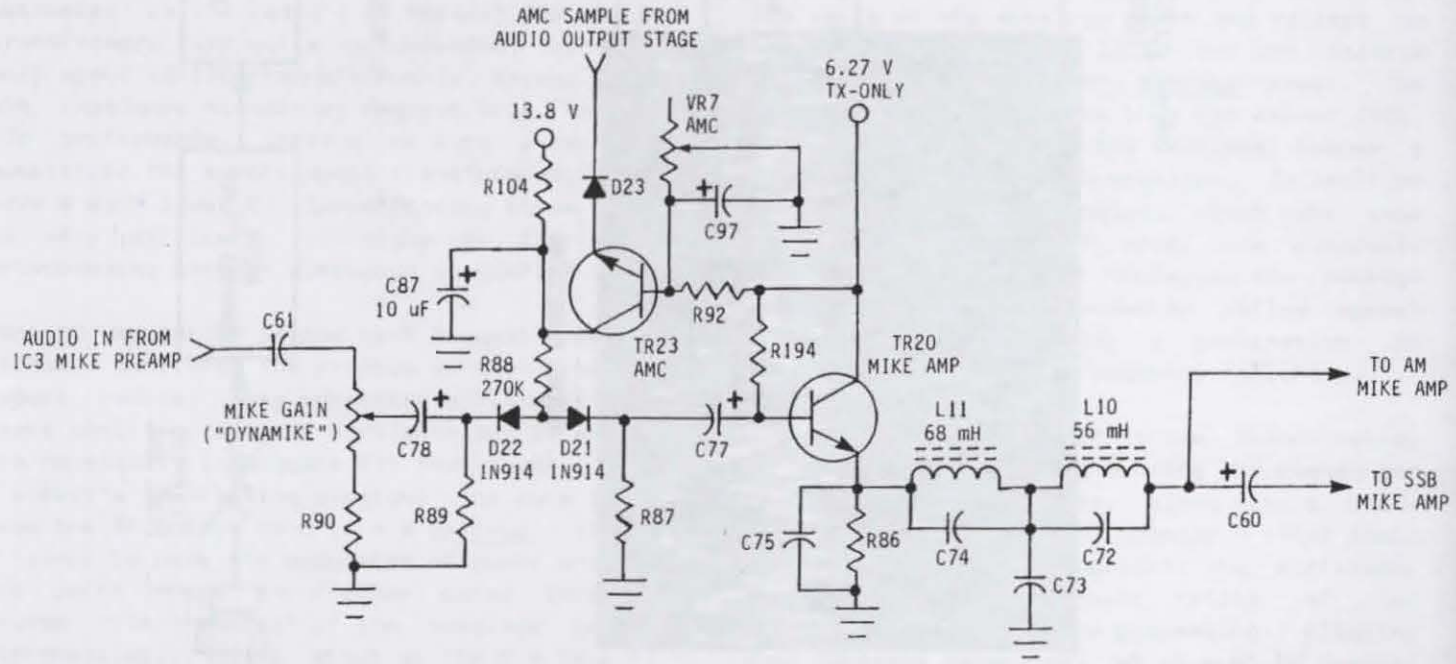
A clipper circuit is shown in Figure 5-22. The MIKE GAIN (DYNAMIKE) sets the input clipping level; the mike audio at this point has been greatly amplified. Audio is applied to a pair of fast switching diodes, D21/D22. D22 conducts on negative modulation peaks, developing a voltage across R89. D21 and R87 do the same on positive peaks, so the whole audio cycle is affected. Since it takes at least 1.3 V P-P to make the back-to-back diodes conduct, the level at this point is made several volts to guarantee clipping action.

The clipping diodes have a constant forward bias applied by R88/R104, which raises the clipper output voltage slightly. This bias is also controlled by the AMC feedback voltage to shunt TR23. D23 raises the AMC threshold for TR23 an extra 0.6 V before it will conduct to reduce modulation. C87 stretches the AMC time constant, adding compression to the clipping for maximum talk power. With heavy input levels the diodes are clipping almost continuously.

The signal is further amplified by TR20 and coupled to a low-pass filter consisting of L10/L11/C72/C73/C74. L11 and L10 will present increasing reactance to the higher frequencies, while C74 and C72 present decreasing reactance and pass such frequencies to ground via C73. The combined effect is to roll off the higher audio frequencies and clipping harmonics, resulting in a processed signal of much higher average audio voltage. Note the processing occurs before the audio branches off to the separate AM and SSB audio paths, so it works in both modes for maximum effectiveness. Since the radio has a MIKE GAIN control, this allows a convenient way to control the clipping when not needed. This circuit was popular in one early Uniden SSB chassis, before the serious cost cutting started; almost none of the current CBs have internal speech processing these days!

NOTE: For a reprint of my article, "ALL ABOUT SPEECH PROCESSING" which describes and compares the four major audio and RF systems, send $3 plus a large business size (#10) self-addressed stamped envelope to me at **CBC International**, P.O. Box 30655, Tucson, AZ 85751 USA.

FIGURE 5-22
AUDIO SPEECH PROCESSOR
(Cobra 138/139XLR, etc.)



Power Mikes

A common CB accessory is the so-called "power mike." This is a mike element and active amplifier in the same physical case. The output is adjusted with a thumbwheel control on the case. Because the amplifier has no clipping and boosts all voice frequencies equally, it's practically useless except in cases of weak audio in the radio itself. It's not a speech processor and has none of those benefits. Since limiting circuits prevent the overmodulation anyway, there's no advantage except in the operator's mind. A large part of your job will be to convince customers they don't need one!

Compression-type power mikes, like those from Turner, K-40, and Sadelta, do offer some audio improvement. These circuits compress the spread between the peaks and lows slightly to raise the average modulation, but not nearly as effectively as clipping. Many tests over the years have proven that audio compression will improve the actual receiver readability only about 1 dB, a barely detectable amount.

Another after-market substitute mike is the "noise cancelling" type. This is usually combined with the built-in preamp stage. Basically it's an ordinary dynamic mike with a high-pass filter. Since background noise like that inside an 18-wheeler cab tends to be low frequency in nature, the filter rolls off those frequencies to make them less noticeable. In noisy locations like this, they may be more useful than the radio's stock mike.

Power Relationships In The AM Signal

An unmodulated 4-watt carrier when modulated 100% by a sine wave will add 2 extra watts of power to the carrier, 1 watt in each sideband for a total of 4 + 1 + 1 = 6 watts. This is because each sideband has half the voltage (or current) amplitude of the carrier. From Ohm's Law, power is proportional to the square of the voltage (or current), which means each sideband therefore has $(1/2)^2$, or 1/4 of the carrier power. To say it another way, the instantaneous peak envelope power (PEP) is four times more than the unmodulated carrier power.

If the modulation were reduced from 100% to 50%, there would only be 1/4 as much power in the sidebands. That's because the modulation was cut in half (50%), but we have two sidebands: 1/2 x 1/2 = 1/4. In this example it means only 1/4 of the 2 watts or 0.5 watt added by the sidebands, 0.25 watt in each. Since only the sidebands contain the voice information, the importance of maintaining 100% modulation levels becomes obvious.

So far we've talked about peak power. However it's much more convenient and practical to talk instead about average power. Since we just saw that a 4-watt unmodulated carrier increased to 6 watts with 100% modulation, this represents a 50% power increase. (Since 2 watts of sideband power is 50% of 4 watts.) Saying this another way, the average power at full modulation is 1.5 times the unmodulated power. (4 watts x 1.5 or 150% = 6 watts.) This is important because any system that increases the average power output by 50% automatically fulfills our need for 100% modulation. Finding ways to do this in CB radios is the subject of much argument!

In all the preceeding examples the modulating signal was a pure sine wave, but as a practical matter we're dealing with the human voice. The voice is a complex waveform and has much less average power than a sine wave. In fact a voice typically has only about half the average modulating voltage of a sine wave, even though the peaks may be the same. This difference must be taken into consideration when designing modulation circuits.

CIRCUITS FOR AM GENERATION

Amplitude modulation results in a power increase, this extra power being contained in the sidebands. The extra power is supplied from a separate source in the form of audio power. We've seen that audio and RF components must be mixed in a non-linear device. Diodes are non-linear devices but have no gain, so tubes and transistors are needed. When the audio power is used to modulate the power output of a non-linear Class C RF amplifier, and it's added at the last possible point before the antenna, it's known as "high-level" modulation.

High-level modulation requires a lot of audio power; in fact 50% of the unmodulated carrier power, plus a bit more to compensate for circuit losses. A 4-watt CB carrier will therefore need slightly more than 2 watts of additional audio power for 100% modulation. This allows the most efficient (Class C) use of the RF power amplifiers. The modulating voltage is added to the collector (or plate) of the RF power amplifier. Most CBs use this method.

Low-level Modulation

Low-level modulation is also possible, but rare in CB radios. This method injects the audio before the last RF amplifier stage, typically at the mixer, since mixers are non-linear circuits. The result is that much less audio power is needed, but RF power amplification must now be done only with the less efficient Class A, AB or B linear amplifier to prevent distortion. AM designs are always a compromise between cost, complexity, and performance.

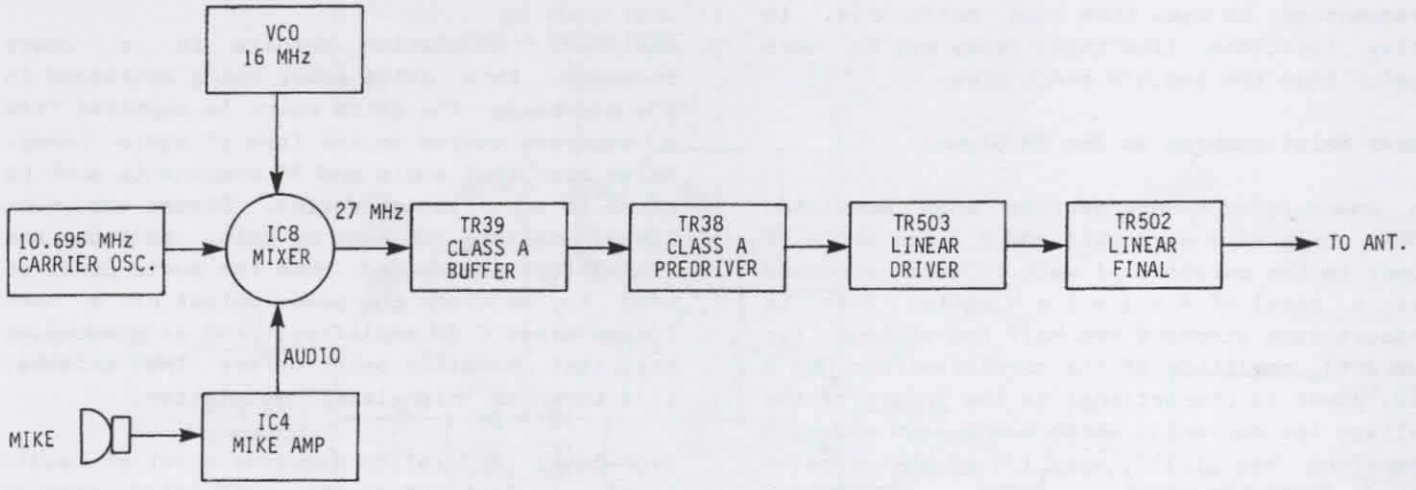
About the only CBs using this method are the CPI types (CP2000, CP300/400) and the Uniden President Jackson. The CPI chassis were designed from the ground up. They used very sophisticated audio circuits, for which they charged a premium price and put themselves right out of business. However Uniden found in the Jackson chassis a way to produce double the AM RF power (10 watts, a great selling feature) without the expense of a 5-watt high-level modulator. Figure 5-23 shows its block diagram.

The low-level audio output from IC4 is coupled to mixer IC8 along with the 10.695 MHz carrier and 16 MHz VCO signals. The result is low-level AM. The RF Driver and Final are not operated Class C; the bases are biased at about +0.55 V for AM and FM. They're linear amplifiers, a requirement of all low-level modulators to reproduce audio without distortion.

There's another catch, since you never get something for nothing. The lower efficiency of linear RF amplifiers means the maximum possible AM output is only about 1/3 of what you'd get using the same transistors with high-level modulation! In a low-level system the RF amp's collector voltage remains constant, and the power increase with modulation results instead from varying the transistor's collector current and efficiency. The result? Less "punch" or talk power than a comparable high-level system.

The Jackson buyer thinks he got a good deal, and maybe so if he's using it on FM or SSB. But not on AM. Compare the Jackson to the Grant export chassis which preceeded it and you'll understand the reason for the change. The Grant also has double the RF power output and the high-level AM circuit. But the Grant required physically larger (i.e., expensive!) modulator transistors (2SB754, 2SA473) to handle all the extra collector current and audio power.

FIGURE 5-23
CB TRANSMITTER USING LOW-LEVEL AM
(Uniden President Jackson)



High-level Modulation

Most solid-state and tube CBs use high-level AM. In this system the audio voltage is added directly in series with the DC supply voltage to the RF power stage or stages. The result is a plate or collector voltage that varies at an audio rate, causing the power output to change too. When the audio voltage is positive with respect to the supply voltage, the power increases beyond the unmodulated carrier level. When the audio voltage swings negative, the net

positive supply voltage becomes less than the unmodulated carrier, so power output decreases.

Figure 5-24 shows a typical example. The main 13.8 VDC supply voltage passes through the secondary of T10 and D10 to the collectors of Q22 and Q23, the RF Driver and Final. The amplified mike voltage from IC2 is also coupled to the same bus, where its fluctuations will change the RF power output at an audio rate.

D10 is very important, and is found in all high-level systems. It's usually called an "isolation" or "limiter" diode. In older circuits like this using transformer audio output coupling, it protects T10 when the mike is unkeyed; otherwise the sudden inductive collapse could produce a high-voltage spike big enough to break down the winding insulation. (Just like using a shunt diode across a relay coil.) D10 also isolates RF from the DC supply, and has a third function as a modulation limiter, since strong negative audio peaks cause it to reverse-bias and clamp at an acceptable level. Since D10 passes the full RF amplifier supply current, it should only be replaced with a heavy silicon rectifier of the 1N4000 (1 A) or 1N5400 (3 A) rated types, not the fast-switching 1N914 type.

FIGURE 5-24
STANDARD HIGH-LEVEL AM
(Realistic TRC433)

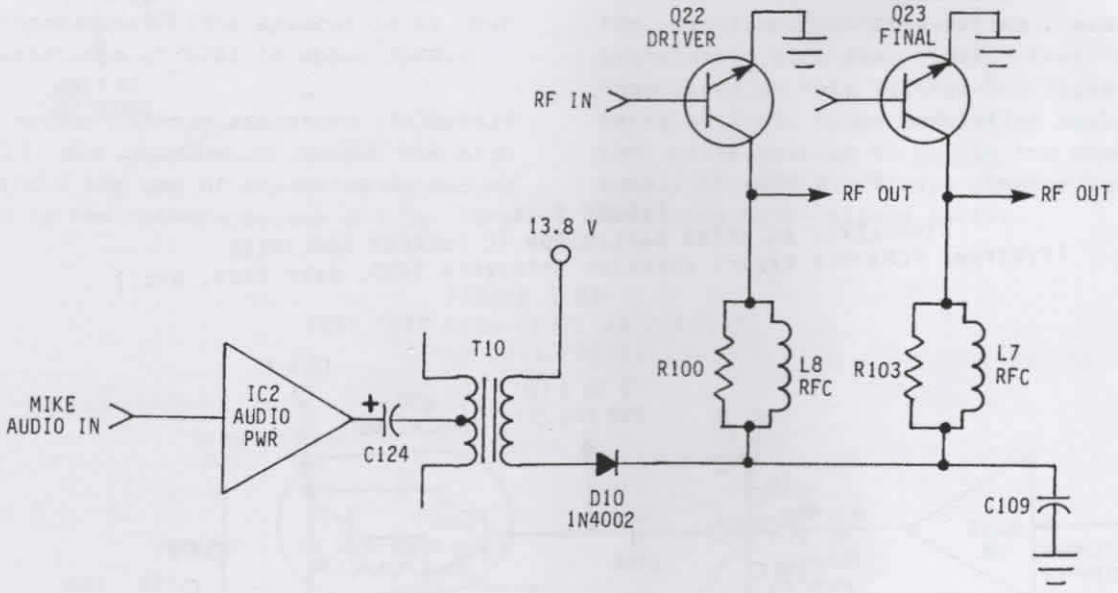


Figure 5-25 shows another common AM modulator circuit in which the output transformer has been completely eliminated. Amplified audio from IC6 is coupled through C174 and used to control the conduction of Darlington amp TR42/TR41. Thus the DC voltage to the RF stages will change at the audio rate. In addition a separate adjustable bias circuit sets the unmodulated conduction level and therefore the AM carrier power. (Details in CHAPTER 6.)

Figure 5-26 is the equivalent Cybernet circuit. Instead of two discrete transistors, the Darlington is now a single plastic power IC working exactly the same way to provide modulation and to adjust the unmodulated carrier power. IC6 audio is coupled through C162, a section of the MODE switch, and C164 to Q30, controlling conduction at an audio rate. Its output goes through another switch section.

Notice that both the Driver and Final stages are modulated in all solid-state transmitters. It's not possible for 100% modulation from the Final amplifier alone, since the audio signal can drive it into non-linear operation. But limiting to only its linear operating region also limits the positive peaks to less than 100%. This limitation is offset by significant RF being coupled through from the Driver stage,

which adds the extra base drive needed to reach 100% peaks. For these reasons, the Driver stage must also be modulated to maintain good linearity. This requirement doesn't generally apply to tube type circuits.

FIGURE 5-25
HIGH-LEVEL AM USING DISCRETE CURRENT AMPLIFIERS
(Cobra 148/2000GTL, Uniden Grant/Madison)

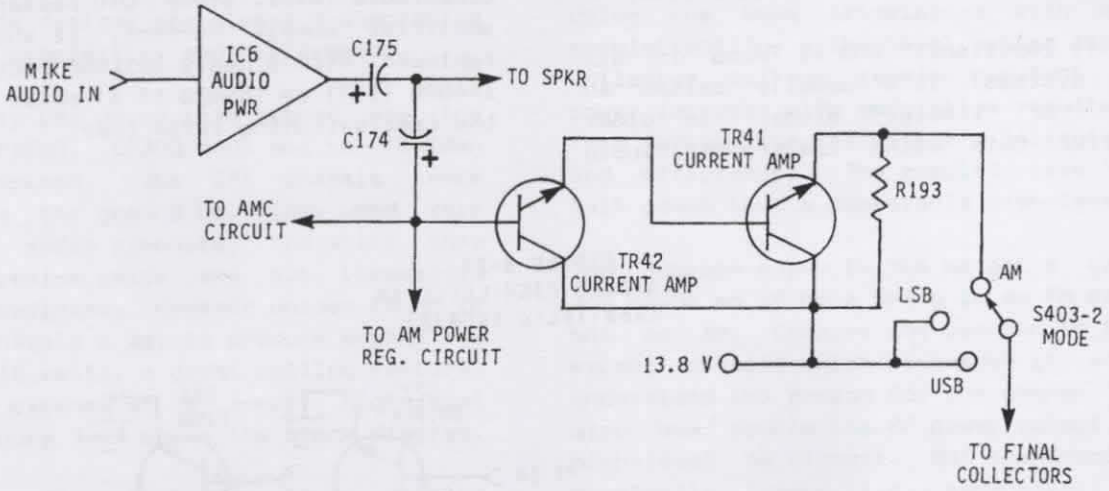
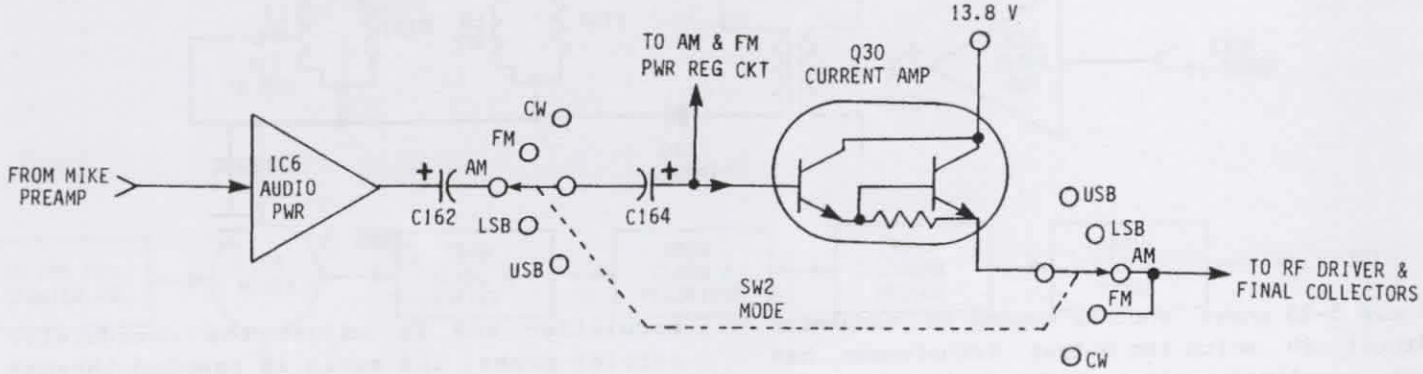


FIGURE 5-26
HIGH-LEVEL AM USING DARLINGTON IC CURRENT AMPLIFIER
(Cybernet PCMA001S export chassis: Lafayette 2400, Nato 2000, etc.)



Tube Modulators

The object of plate modulation in tube circuits is essentially the same as in transistors; i.e., to change the RF power at an audio rate. The big difference is we're now changing the total voltage rather than current. The audio voltage is applied to the plate of the modulated amplifier stage, causing its net plate voltage to swing from zero to twice the unmodulated DC supply voltage at 100% modulation. Since the plate voltage doubles, this implies that the plate current must also double. So like transistors, a modulator capable of delivering 50% of the unmodulated DC input power is still needed. (Since P = E x I.)

Unlike transistor RF amps, in tube circuits the net plate current of the modulated stage appears to be constant. That's because each increase in plate current is cancelled out by an equal decrease on the negative half of the audio cycle. The net result is a steady plate current which can't be seen on an ordinary DC

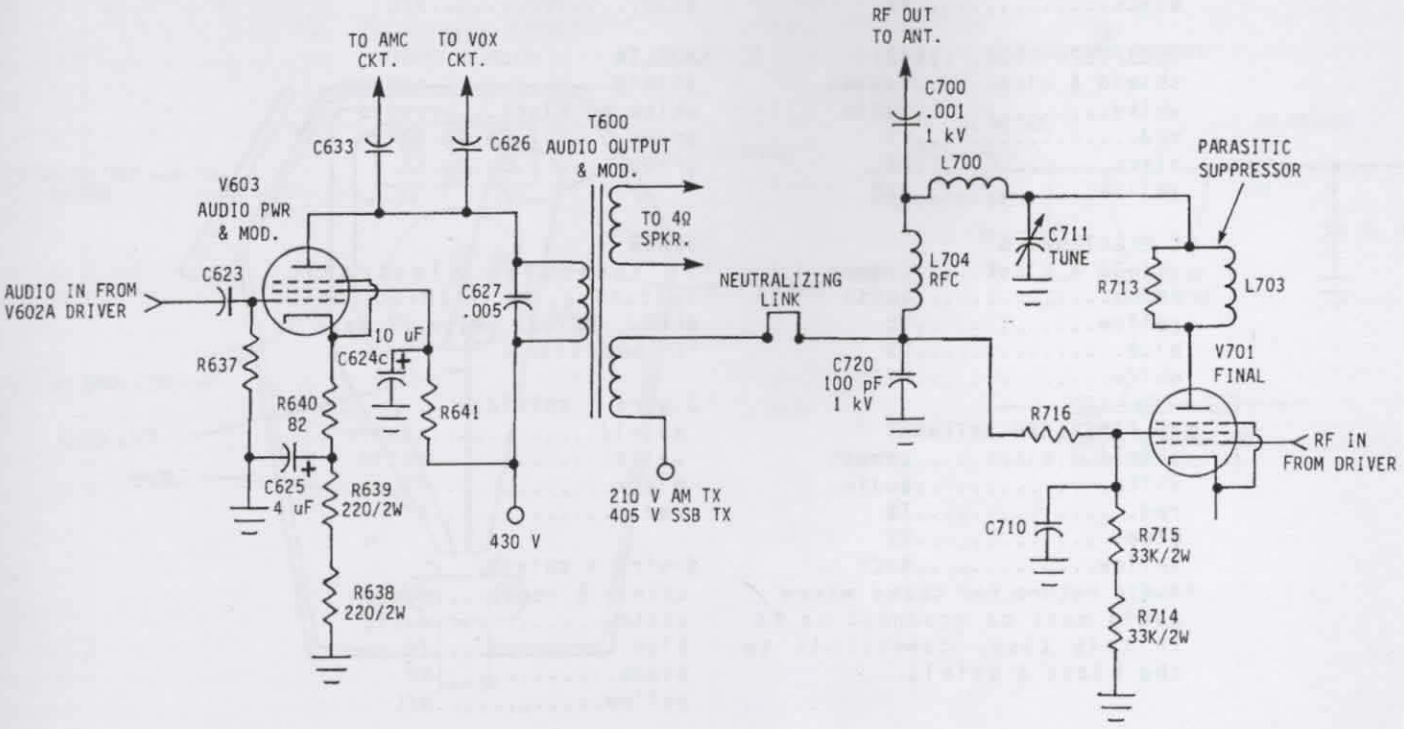
ammeter. (The changing power can be seen on an RF ammeter though.) If the DC meter current does change with modulation, it indicates non-linearity. Non-linearity is caused by low grid drive and improper bias, factors which in turn are caused by improper alignment, weak tubes, or passive component values changing with age.

Because of the higher power possible using tubes, a single modulator tube is more than enough to drive a Class C RF amp up to 100% modulation. Figure 5-27 is one popular example. The mike audio is amplified by several preceeding stages and coupled to the control grid of modulator V603. Since V603 is a single-ended amplifier, it's operated in Class A for maximum linearity. The amplified audio voltage from the plate is coupled to T600, the audio output transformer. C627 provides some high-frequency rolloff to limit bandwidth. T600 has separate windings for the speaker output and the RF amp, since each must be matched to very different impedances. (The speaker is 4Ω but the plate resistance of V701 is about 30KΩ.)

Carbon type series cathode resistors (R638/R639 and R714/R715) are cascaded to handle the high currents without the use of expensive wirewound types. C625 is the cathode bypass and is very important. Without it, the audio voltage would also be developed across R638/R639 as the plate current changes with modulation. This voltage is 180° out of phase with the grid voltage and would reduce it. Bypassing always increases AC gain, and also lowers the input impedance. The cathode bypass is always an electrolytic and is therefore one of the first things to check with a "Low Speaker VOLUME/Weak Modulation" symptom. In this circuit, the cathode is purposely left partly unbypassed via R640 as a means of negative feedback to improve stabilty and audio quality. This technique is also commonly used in many transistor CB audio amps.

The modulated audio and DC plate voltages are applied to the plate and screen grid of V701, the RF Final amp. Modulation of both elements is necessary because the screen voltage has a much greater effect on plate current than the plate voltage. Modulating just the plate causes non-linearity. This is comparable to the need for simultaneous Driver/Final modulation in transistor circuits. Note that all bypass capacitors on this voltage bus (like C720) are rated at 1 KV, since modulation peaks will push the plate voltage to double the unmodulated DC supply of +405 V. Always observe ratings when replacing high-voltage parts!

FIGURE 5-27
TUBE TYPE HIGH-LEVEL AM CIRCUIT
(Tram D201/D201A)



MICROPHONES

Now that you understand how audio voltages are used to generate AM, let's back up a bit and see how such voltages are actually produced from the tiny voltages in a microphone.

A microphone changes speech vibrations to electrical impulses at the same rate. There are many materials that do this, but CB radios use one of two mike types. A "crystal" or "ceramic" mike is one that works on exactly the same piezoelectric effect described in CHAPTER 3. A diaphragm is coupled to a bar of Rochelle salt or a man-made ceramic compound. The mechanical stress from speech vibrations causes it to generate an electrical current.

Crystal mikes are vulnerable to humidity and heat, and aren't used much anymore. But ceramic mikes use an artificial crystal and are very rugged. Ceramic mike elements are high-impedance devices, about 50K-100KΩ. They're not found often except in older tube equipment, or the Johnson CB line in particular. The popular Astatic D104 "Lollipop" is a ceramic mike, and is often used with an optional preamp in its base. The D104 element itself, being ceramic, is high-impedance. But the preamp output (about 5KΩ, when used) can be considered low-impedance for matching to solid-state transmitters.

Mike Problems

Microphones are without a doubt the biggest headache and one of the most common failures associated with CB radios. Problems include broken cord wires, broken connectors, dirty PTT switches, and sometimes an open element. CB mikes are made cheaply, and repeated stretching of the cord almost guarantees an eventual break. Sometimes the problem is compounded by poor human engineering, like many UK-FM radios that still use the standard American left-hand mike plug and socket, even though British vehicles have right-hand drive!

While cable and connector breaks are easy to locate, it's often not worth the time to repair them at $25-$40 per hour shop rates. Consider

FIGURE 5-28
COMMON MIKE COLOR CODES

ASTATIC

D104-M, TUG8-D104:
shield.....common
white.....audio
red.....TX
black.....RX

TUG9/TUP9-D104, 1104C:
shield & blue.....common
white.....audio
red.....TX
black.....RX
yellow.....N/C

GC ELECTRONICS
shield & black.....common
red.....audio
yellow.....TX
blue.....RX
white.....N/C

K40 (AMERICAN ANTENNA)
shield & black.....common
white.....audio
red.....TX
blue.....RX
yellow.....N/C*
*Audio return for cases where audio must be grounded on RX. In this case, connect it to the black & shield.

REALISTIC (RADIO SHACK)
shield.....common
white.....audio
red.....TX
black.....RX
blue.....N/C

SADELTA
shield.....common
white or black.....audio
brown.....TX
green.....RX

TURNER
"J" indicates electronic switching, as in JM+2U, JM+3, RK60J, RK70J. (Also +3 Base in "E" position.)

3-wire + shield:
shield.....common
white.....audio
black.....TX
red.....RX

5-wire + shield:
shield & red.....common
white.....audio
blue.....TX
black.....RX
yellow.....N/C

replacement with a new mike instead, since this means working on only a single end (installing a plug) rather than both the plug and the mike end. When the plug and/or radio socket is beyond reasonable repair, wire it straight into the chassis, using some kind of strain relief clamp for security. For dirty switch contacts, clean with Tun-O-Wash degreasing spray.

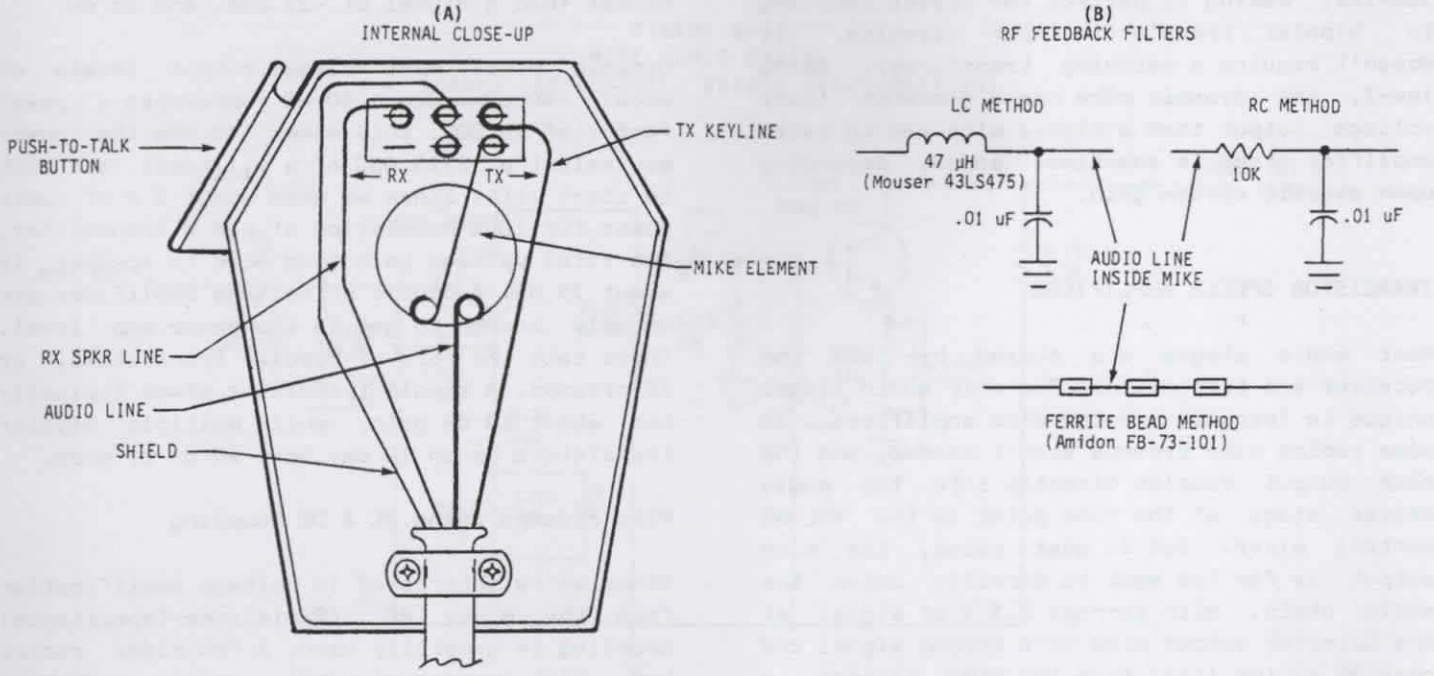
Figure 5-28 shows the functional cable color codes for many common mike brands. By combining the listed functions with the known functions on the radio's mike socket pins, you can wire any repaired or replacement mike to any radio.

Standard replacement type dynamic mikes are available from such suppliers as Dick Smith Electronics (#C-1102), Radio Shack (#21-1172), or GC Electronics (#18-032). GC also sells the mike plugs, a 6-conductor coil cord (#18-054), a 4-conductor cord (#18-052), and a dynamic element (#19-340) which will fit many existing mike cases. Coil cords are also sold by Gold Line (3-conductor, #328, 5-conductor, #330). These companies all offer the various mike plugs and sockets too. (See CHAPTER 1.)

Occasionally the dynamic mike element is bad. First localize the audio loss to the mike itself. Dynamic elements are easily checked for DC continuity with an ohmmeter, and typically show a few hundred ohms if good. In the case of high-impedance elements a 'scope is best, since resistance readings may be meaningless. Dynamic mikes will generate up to 200 mV output on a loud whistle and about 50 mV on average speech. Output voltages tend to be somewhat higher for high-impedance types. Since mike elements come in countless shapes and sizes, you may need to replace the whole mike. If so, check for the possibility of overmodulation afterwards. When overmodulation results that can't be adjusted using the AMC trimmer (or there is no trimmer), add some series resistance of about 1K-10KΩ in the audio wire to reduce the new mike's output.

Another common mike problem is RF feedback squeal, where the transmitted RF isn't being sufficiently decoupled and gets into the mike amps. The most common causes are poor grounding and high antenna SWR, or combining these with an external linear amp. The cures are obvious. If they don't work, try adding a simple RF filter to the mike. You can use an RC network, LC network, or ferrite beads. There's a reason the newer rigs use all those beads! Figure 5-29 shows the inside of a typical mike, and some simple RF filters to cure the feedback problem.

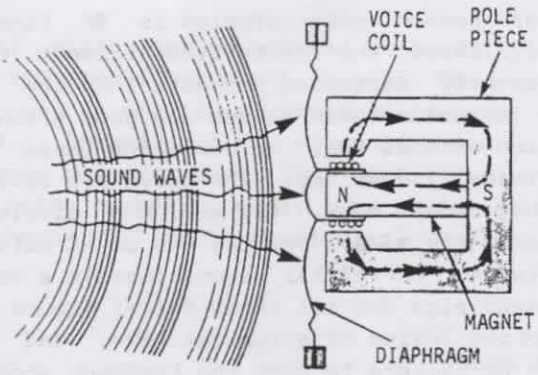
FIGURE 5-29
SOLVING MIKE FEEDBACK



The Dynamic Mike

The mike used in 95% of all CB equipment is the "dynamic" type. This is basically just a loudspeaker in reverse. See Figure 5-30. The diaphragm is attached to a wire coil and suspended in a field of permanent magnets. When sound waves strike it the coil moves back and forth in the field, cutting the magnetic lines of force. This induces an AC voltage in the coil, similar to the operation of a generator.

FIGURE 5-30
DYNAMIC MIKE ELEMENT CONSTRUCTION
(Courtesy Hayden Book Co.)



The dynamic mike is very rugged, inexpensive, and has good frequency response suitable for voice use. The element is low-impedance, about 300-1KΩ, making it perfect for direct coupling to bipolar transistor input circuits. It doesn't require a matching transformer. Being low-Z, the dynamic mike has a somewhat lower voltage output than a high-Z mike and an extra amplifier stage is sometimes added, depending upon overall system gain.

TRANSISTOR SPEECH AMPLIFIERS

Most audio stages are shared by both the receiver and transmitter. The only audio stages unique to Transmit are the mike amplifiers. In some radios mike preamps aren't needed, and the mike output couples directly into the audio driver stage at the same point as the VOLUME control wiper. But in most cases, the mike output is far too weak to directly drive the audio chain. With perhaps 0.5 V of signal at the detector output side on a strong signal and only 50 mV (or less) from the mike element, a lot more voltage gain is needed.

Occasionally you'll find some very exotic and complex mike circuits. For example, CPI and SBE used speech compressors and other forms of processing, which generally added another IC or more transistor stages. The G.E. "Superbase" took the standard Cybernet SSB chassis and added a switchable NE570 type "compandor" processor IC prior to the standard audio amps.

In multimode radios you'll also find control switches routing the mike audio to the various AM, SSB, FM, or PA circuits. These switches may be bipolar transistors or FETs. They control the mike audio either by shunting its signal to ground in a particular mode, or by virtue of being in series with it and opening or closing the audio path. Problems in these associated switching circuits will definitely affect Transmit and/or Receive audio. Regardless of circuit complexity, troubleshooting is easy using a 'scope or signal tracer to check signal continuity from mike element to audio output.

Mike Voltage Gain

The electrical output of a mike is defined as its voltage level for a given sound intensity and across a specified impedance, usually 600Ω. This is often expressed in "dBm," which means "decibels referenced to 1 milliwatt." Thus a specification of "0.0 dBm" means 1 mW of power. Since the actual mike output levels are much smaller than 1 mW, a -dBm figure is specified. For example, a signal of say, -40 dBm is 13 dB weaker than a signal of -27 dBm, and so on.

Dynamic mikes have voltage output levels of about -40 dBm. Since 40 dB represents a power factor of 10,000, this makes -40 dBm the power equivalent of 1/10,000 of a milliwatt. Not much to start with! Since we need about 2 W of audio power for 100% modulation of a 4 W transmitter, the total voltage gain from mike to speaker is about 75 dB. A couple of voltage amplifiers are usually enough to get to the power amp level. These take the form of bipolar transistors, or IC preamps. A single transistor stage typically has about 10 dB gain, while multiple bipolar transistors or an IC may have 40 dB or more.

Mike Preamps Using RC & DC Coupling

Since we're interested in voltage amplification from the mike, RC (Resistance-Capacitance) coupling is generally used. A few older radios had high-impedance mikes using inductive coupling that required an internal step-down

transformer, and then followed by RC coupling. Resistance coupling is cheap, has good frequency response, and is immune to the stray hum pickup often present in high-impedance or transformer-coupled circuits. In tube-type speech amplifiers RC coupling must be used, because tubes have extremely high load impedances which can't be reasonably matched with transformer coupling anyway.

The input impedance of transistor RC stages is about 500-1500Ω, making them a good match for a dynamic mike. Figure 5-31 shows a typical two-stage mike amp. The output impedance is roughly equal to the collector load resistor (R120 for TR23, R116 for TR22), which again makes a good match for driving the succeeding stage. The shunt C105 adds some high-frequency roll-off. Biasing is via the voltage dividers R123/R125 and R118/R119 to insure stability. The input resistors R123 and R119 are generally chosen to present a load about 5-10 times higher than the driving source impedance. Thus R123 is about ten times more than the mike impedance, and R119 about five times more than R120.

Common Emitter audio amps like TR23 and TR22 are always bypassed on the emitters with large electrolytics like C103 and C100. This keeps the bias voltage steady by having a long time constant at audio frequencies. Otherwise gain would be reduced (i.e., degeneration) on the negative half of the signal cycle. This is the same idea as the cathode bypass used in a vacuum tube audio amplifier.

If the bypass capacitor isn't quite large enough, the emitter (or cathode) resistor might discharge it on the lower frequencies without affecting the higher frequencies. The result is a tinny sound typical of low-frequency loss. With a symptom of low-frequency loss or drastic loss of audio gain, suspect an open or leaky bypass capacitor. This is even more true of tube circuits, since the heat eventually dries out the electrolyte and lowers its capacitance. Bridge a good one across it to confirm.

Like the tube modulator back in Figure 5-27, the emitter of TR23 isn't completely bypassed. They've purposely left some (R122) unbypassed. This generates a small negative feedback, which reduces distortion and also raises the input impedance slightly. Since this is a Common Emitter circuit, any portion of the signal voltage developed across the unbypassed resistance will be 180° out of phase with the input. And degenerative feedback lowers stage gain. Any part of the signal fed back to the base out of phase will be greatly reduced when reamplified. The result is a somewhat weaker but less distorted signal, which can then be driven harder at its input. Using feedback also broadens the frequency response, and can change the amplifier impedance when required. Finally, C102 adds high-frequency filtering by feeding them back out of phase too, reducing their gain relative to the lower frequencies.

FIGURE 5-31
MIKE AUDIO CHAIN
(Cobra 148/2000GTL, Uniden Grant/Madison)

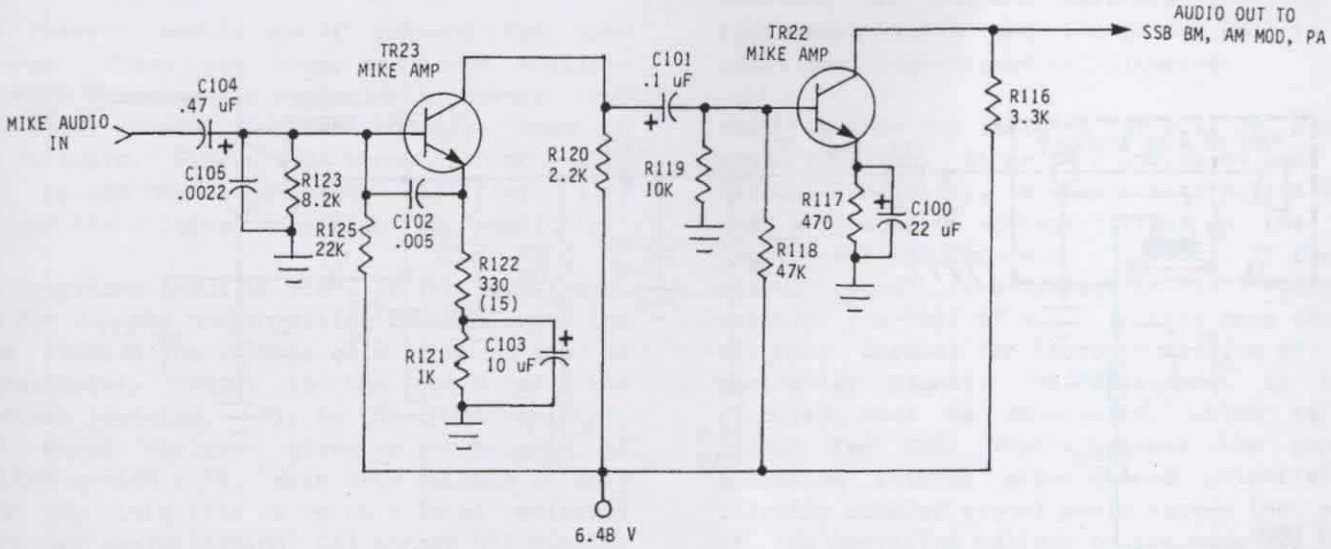


Figure 5-32 shows another common Uniden method. The difference here is the use of direct (DC) coupling between TR29 and TR28. There's no fixed resistor bias on TR29. Since emitter resistor R93 isn't bypassed at all, the voltage drop across it and hence the base bias is not constant; it changes at the audio rate. This causes a corresponding gain change at its collector, which is coupled to TR28. TR28 then amplifies in the normal way. Because TR29 operates more on the principle of changing DC bias than AC signal input, it's called a "DC amplifier." Negative feedback is again used via R92. C85 is for high-frequency attenuation.

FIGURE 5-32
DC-COUPLED MIKE AUDIO CHAIN
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)

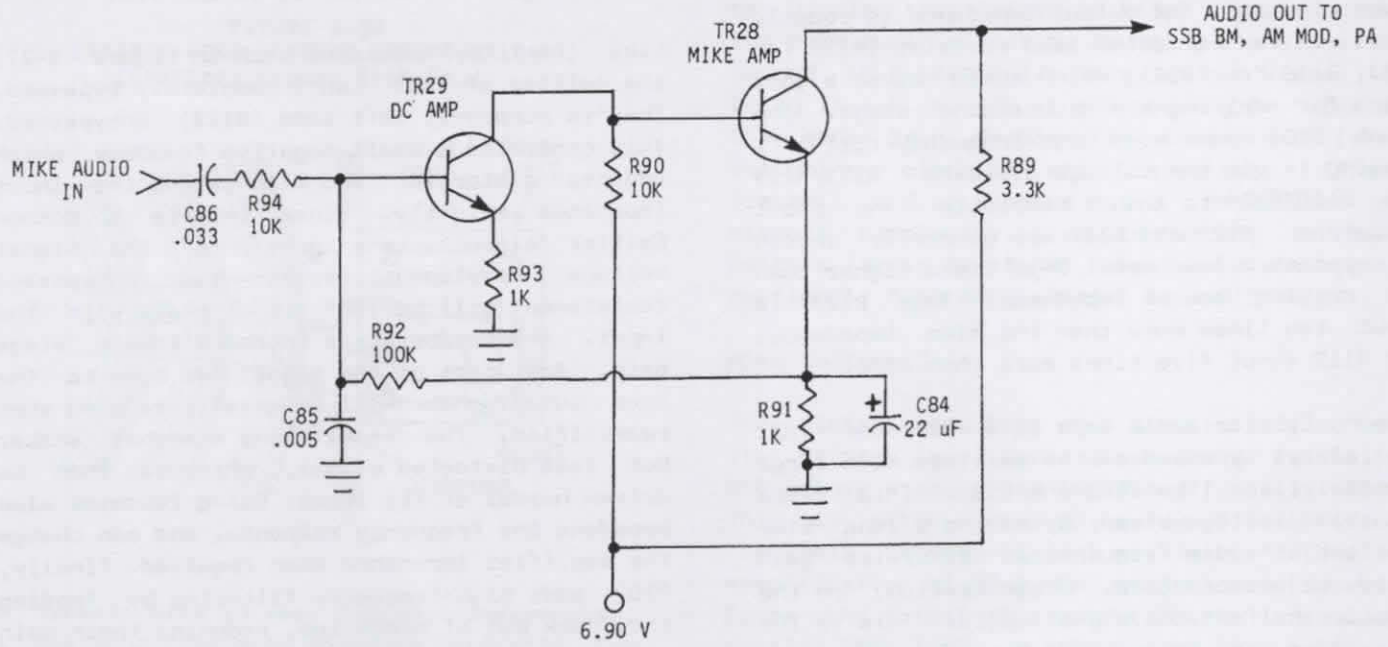


FIGURE 5-33
HIGH-IMPEDANCE MIKE INPUT CIRCUIT
(Johnson Messenger 4120, 4135, 4140, 4145, 4230, 4250)

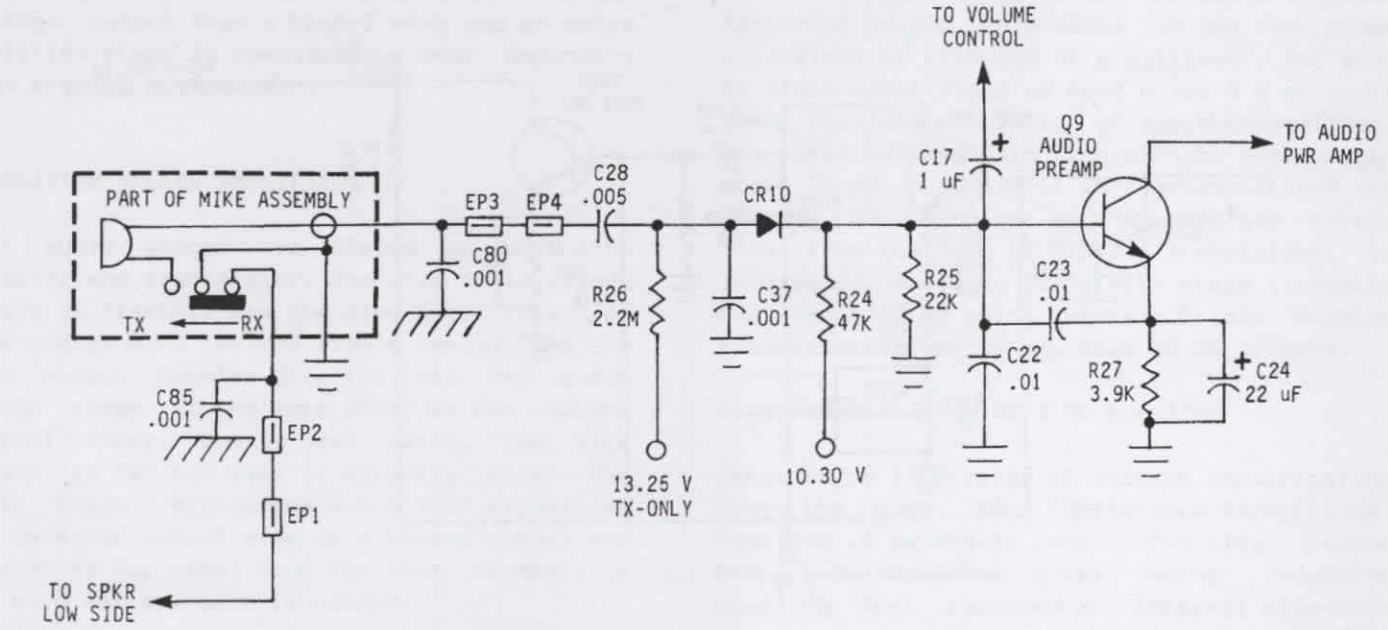
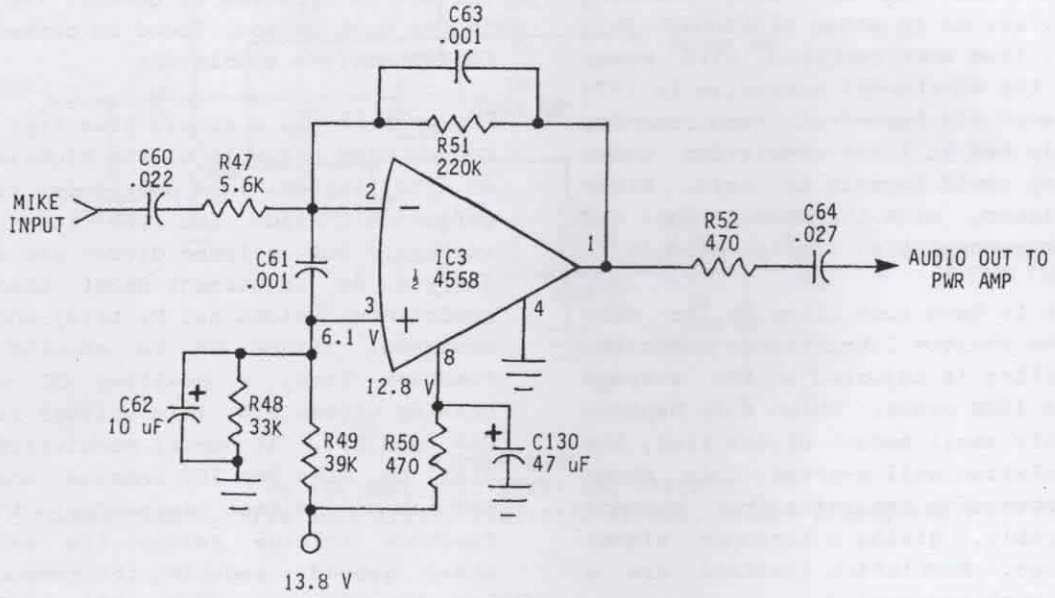


Figure 5-33 is a high-impedance input circuit, typical of Johnson radios with ceramic mikes. The higher output of a high-impedance mike eliminates one extra preamp stage, and less input coupling is needed as seen in the low value of C28. The large value of R26 is another high-Z indicator. Note the generous use of ferrite beads to decouple stray RF; low-Z circuits don't drop the large RF voltages that are troublesome here. Extra decoupling between the chassis and frame is included via C85 and C80 for the same reason. CR10 is a switch to help cut off the mike circuit on Receive and prevent possible feedback; even though the mike element is disconnected anyway, there may be enough stray capacitance in high-Z circuits like this to cause unwanted oscillations. C37 and C22 provide high-frequency filtering. C23 adds some negative feedback to improve audio quality and stability.

FIGURE 5-34
MIKE PREAMP USING IC OP-AMP
(Realistic TRC433)



IC SPEECH AMPLIFIERS

The current models use IC op-amps for mike preamps. These are cheap and since multiple amps are contained in a single IC package, they can serve several functions and save room on the PC board. Figure 5-34 shows half of a 4558 dual op-amp used as a speech amplifier. I've redrawn the original schematic for simplicity.

The inverting input at Pin 2 is the signal pin, and Pin 3, the non-inverting input, sets the bias level. The voltage gain of an op-amp is approximately equal to the ratio of the feedback resistor, R51, to the input resistor, R47. Quick division gives a rough gain of 220,000 ÷ 5600 = 39. With mike outputs of only 20-50 mV, this gets us up to a level suitable for power amplification. C63 across R51 creates a low-pass effect; as the frequency increases the impedance of C63 decreases, effectively shorting out R51 and therefore lowering the resistance ratio and the gain. C61 is for additional high-frequency filtering.

Most op-amps are designed for dual or bipolar power supplies. Since this increases cost and circuit complexity, a simple alternative is to use a resistive voltage divider on the bias input. R48/R49 form such a divider. If they're exactly equal, the voltage at Pin 3 would be exactly one-half of V_{CC}. In this case they're slightly unequal for improved biasing of this particular signal. The mike input in these circuits must be AC-coupled, which is the reason for C60. That's because the amp is operating totally above ground potential; a directly coupled signal could exceed the range of the operating voltage on the negative half of its cycle. C62 is the audio bypass.

A single section of a dual or quad op-amp gives plenty of mike voltage amplification. The other sections are often used for such things as squelch or AGC. The Uniden/Uniden clones in particular use the second section of the 4558 op-amp IC as a DC amplifier to control T/R switching. (Models include the Cobra 148GTL-DX, President Jackson, Franklin, and Grant export, Superstar 360FM, Superstar 3600/3900, Galaxy 2100, Excalubur Samurai/base. See CHAPTER 7.)

MODULATION LIMITERS & COMPRESSORS

Circuits to prevent overmodulation are found in most speech audio chains. There were some radios from the 23-channel era that had absolutely no limiting at all, causing bleedover interference to other stations. This was especially true when combined with power mikes. During the 40-channel expansion in 1976 the FCC tightened its technical requirements, and all models had to limit modulation under 100% before they could legally be sold. Other countries followed, with the result that all radios now have a modulation limiter circuit.

It's desirable to have such circuits for more reasons than the obvious interference problem. If the transmitter is adjusted so the average voice just hits 100% peaks, which only happens over a relatively small amount of the time, the remaining modulation will average only about 30%. Speech processing can raise this average value considerably, giving a stronger signal with more range. Modulation limiters are a simple form of such processing.

The circuit which controls modulation is called the Automatic Modulation Control, or AMC. Often it's incorrectly called ALC (Automatic Load Control), which is a similar circuit for SSB that operates on RF rather than audio stages. In AM/SSB radios the AMC is sometimes referred to or labelled "AF ALC" to distinguish it from the RF ALC used for SSB limiting.

AMC is a means of volume compression working on exactly the same principle as receiver AGC. A feedback loop samples the modulation from the audio power amplifier and applies it to a control circuit at the speech amplifier, where it adjusts gain as required. Most AMC circuits have internal trimmers to set the 100% limit, although a few use fixed component values.

AMC circuits are <u>not</u> true speech processors in the sense that modulation power is increased substantially. They only control peak levels, and can do nothing about low levels that may be caused by a soft voice or a weak mike. Since manufacturers never give anything away, they only do enough to pass the legal requirements. Any extra built-in processing (like that in the CPI rigs) or external add-on accessories (like our own **DYNAMIC SPEECH PROCESSOR**) cost extra.

There are two basic types of AMC. In the "bias" circuit, the sampled feedback voltage is applied to the emitter of the mike amplifier to control its gain. In the "shunt" AMC circuit a transistor, acting like a variable resistance, is shunted directly across the mike input to ground. The more it conducts, the more mike voltage is bypassed to ground. The shunt method is the most common, found in perhaps 80% of all CB transceiver models.

Figure 5-35 is a simple bias type AMC circuit. C50 couples a sample of the high-level audio to D9, the limiter. This particular circuit uses a germanium diode for its lower conduction voltage, but silicon diodes are also common. There's no adjustment other than the fixed resistance values set by trial-and-error when designed. Since D9 is shunted across the feedback loop, a positive DC voltage will develop across R58. This voltage is filtered by C49 and R57. At normal modulation levels the bias on Mike Amp TR9 remains unaffected. As modulation becomes excessive, the rectified feedback voltage raises its emitter higher above ground, reducing the conduction of TR9 and therefore its gain. C41 and C42 roll off the higher undesired audio frequencies.

All AMC circuits are carefully designed with time constants in mind, just like receiver AGC. These are determined by the RC values chosen, like R58/C49/R57 in Figure 5-35. If the time constant is made about one second, the system will follow the average modulation well, giving a fairly constant modulation percentage. If not long enough, the faster attack time results in some overshoot before settling down. This is often noticeable on your 'scope, where a loud whistle into the mike may overshoot the 100% limit momentarily before settling. The AMC is therefore a compromise between effective limiting and high average modulation.

A common Uniden shunt limiter is shown in Figure 5-36. TR27 is the shunt element; the harder it turns on, the more the mike audio is grounded. The conduction of TR27 is controlled

in turn by the conduction of TR28 and TR29. Note the mixed use of NPN and PNP transistors to take advantage of polarity differences. The high-level audio is sampled at TR44, the main AM modulator. VR5 sets the standing bias on TR29, while D43 establishes a minimum forward bias of about 0.6 VDC. As the sample voltage increases, TR29's emitter is raised higher, turning it off more. As it turns off more, its collector voltage rises. This turns off TR28 more, raising its collector voltage. The higher collector voltage is applied to the base

FIGURE 5-35
BIAS TYPE AMC CIRCUIT
(Pearce-Simpson Bobcat 23C)

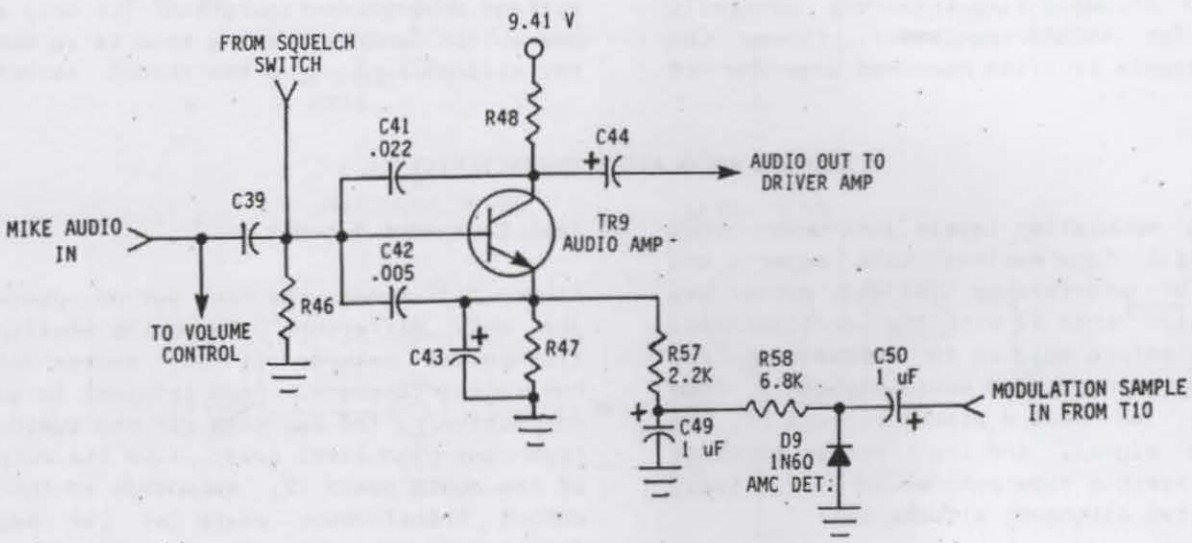
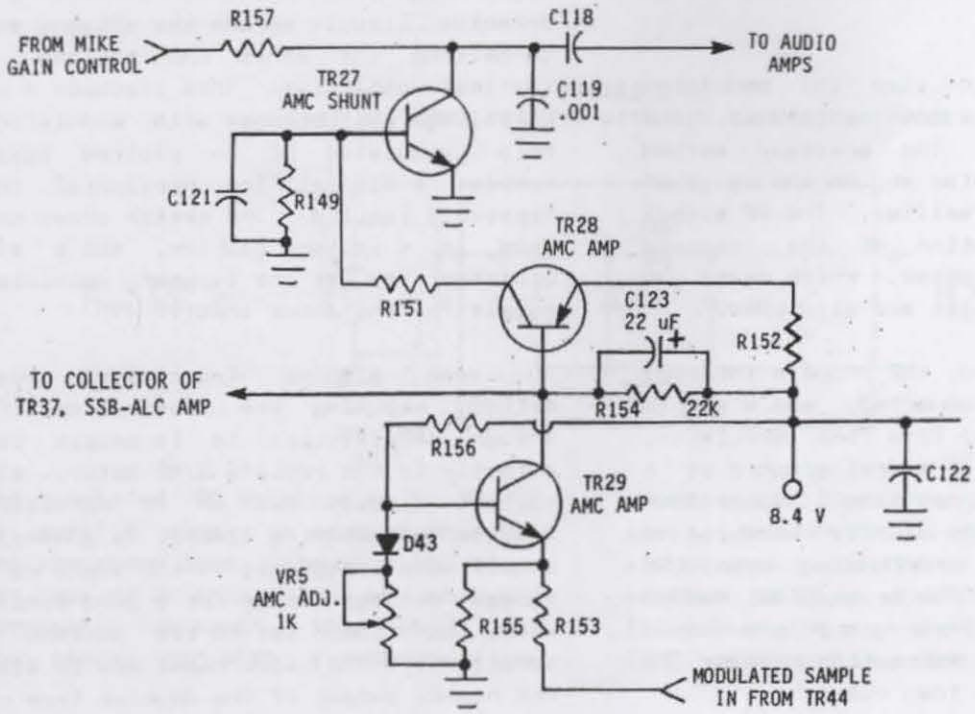


FIGURE 5-36
UNIDEN AMPLIFIED SHUNT AMC CIRCUIT
(Cobra 146GTL, President AX144, Realistic TRC451, Uniden PC244, etc.)



of TR27, which conducts harder to limit the mike audio. C123/R154 sets the appropriate time delay. C119 reduces the higher frequencies.

This circuit is somewhat sophisticated, using three transistors. The extra amplification allows greater sensitivity and control range. It can be done more simply but less effectively using only one or two transistors and a diode detector to control the shunt element. Shunt AMC always requires a transistor to act as the variable resistance element. The more complicated circuits like this are generally reserved for AM/SSB equipment, where the feedback sample is often combined with the ALC for improved SSB modulation control as well. In such radios, additional switching transistors or diodes are used to gate the feedback path to the appropriate AM or SSB circuits.

In tube-type equipment there isn't always an AMC circuit, since most of these were made before the tighter FCC rules. When present, the bias method is used to change the bias on the control grid of the speech amplifier tube and therefore its audio gain. The AMC sample typically comes from a pair of diodes in a voltage doubler configuration. The only special precaution when replacing them is to use high PRV silicon types like the 1N4004, 1N4005, etc.

MEASURING MODULATION CHARACTERISTICS

Maintaining modulation levels just under 100% is essential for maximum talk power and prevention of interference. The only proper way to accomplish this is with the oscilloscope. Modulation meters sold as CB accessories are grossly inaccurate, and obviously can't show distortion. You need a visual picture of the transmitted signal, and the 'scope provides this. No serious repairman would ever attempt AM transmitter alignment without one!

Ideally you'll have a 'scope with a mimimum bandwidth of 30 MHz in the vertical amplifier. This allows you to view the 27 MHz modulation envelope directly. It's also possible to use a less expensive instrument by connecting it as described shortly.

There are two ways to view the modulated transmitter signal: the envelope method, and the trapezoidal method. The envelope method shown in the earlier photos and on the cover of this book is the most familiar. The RF signal is displayed as a function of the 'scope's internal horizontal timebase, which means you can control how many cycles are displayed.

In the trapezoidal method, the scope's internal horizontal sweep is disconnected, and a sample is coupled in externally from the modulator. The display is then an RF signal graphed as a function of the audio signal itself rather than some fixed timebase. The display resembles a triangle or trapezoid, depending upon the modulation percentage. The trapezoidal method is better for catching the more subtle problems such as non-linearity, since it's easier to interpret straight lines than curves.

Test Equipment Set-Ups

Figure 5-37 shows the two set-up procedures. The only difference between the envelope and trapezoidal methods is the source of the horizontal timebase, from internal to external respectively. You can pick off the audio sample from any high-level area, like the output pin of the audio power IC, secondary of the audio output transformer, plate of the modulator tube, etc. Make sure it's capacitively coupled though. A 'scope probe is convenient for this.

Without a 30 MHz 'scope, it's still possible to get the trapezoidal pattern. See Figure 5-38. Basically this involves connecting an RF detector circuit across the antenna socket and connecting the other end to the 'scope's vertical amplifier. This produces a rectified DC voltage that changes with modulation. When this modulated DC is plotted against the sampled audio at the horizontal input, a trapezoid results. The sketch shows two diodes used in a voltage doubler, and a 47KΩ load resistor to get the largest possible signal sample for the'scope input.

An even simpler trapezoidal measurement method, assuming the vertical amplifier has enough sensitivity, is to couple its input directly to the radio's S/RF Meter, since that circuit already has an RF detector handy. However the metering circuit is generally only a half-wave rectifier, which might not produce enough voltage sample for a good display even with the 'scope set to its maximum vertical sensitivity. In such cases you'll still need the higher output of the doubler type circuit.

FIGURE 5-37
MODULATION MEASUREMENT TEST SET-UPS

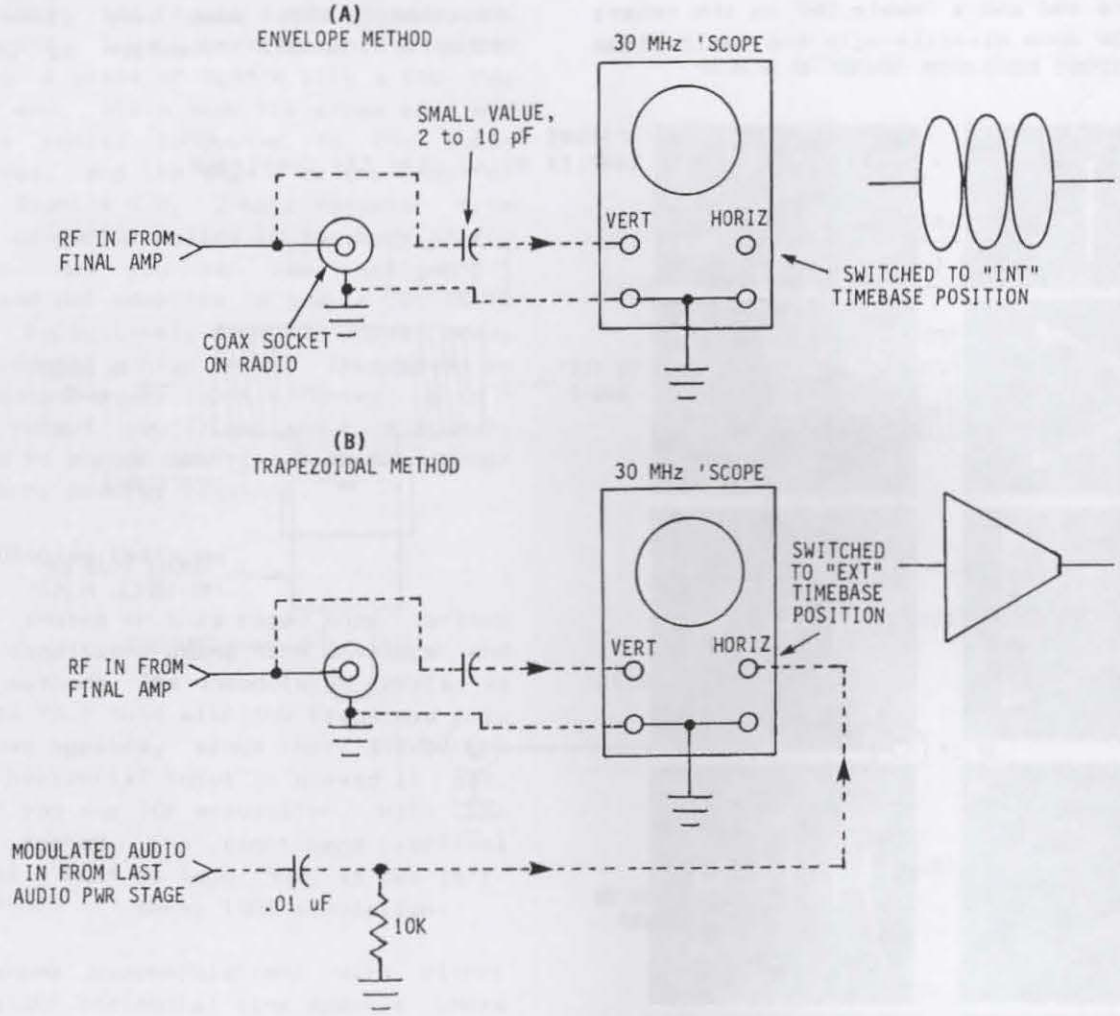
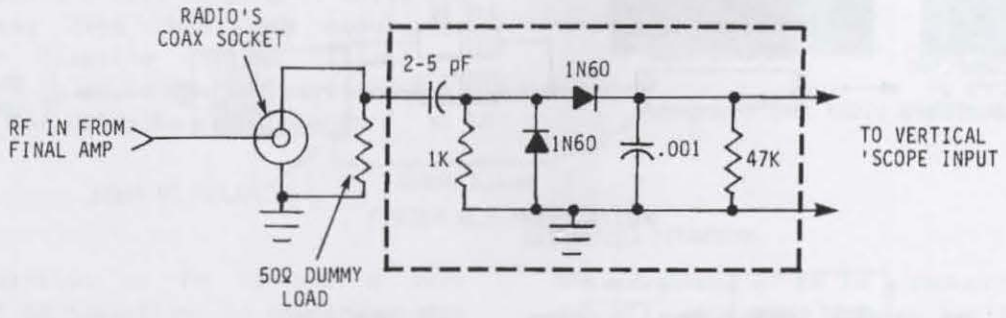


FIGURE 5-38
RF DETECTOR FOR USE WITH LOW BANDWIDTH 'SCOPE



To view the modulated RF envelope on a 30 MHz 'scope, a small RF sample is coupled from the coax socket and dummy load. Figure 5-39 shows one clever way to do this. Take an ordinary coax "T" connector (Amphenol M-358, etc.) and remove its center pin with a nutdriver or needle-nose pliers; the pin is screwed in. (See photo in CHAPTER 1.) Hacksaw off most of the pin so when you rethread it, the remaining pin section is flush with the plastic dielectric. (If you should ruin the pin, a piece of 4/40 or 6/32 machine screw also works.) This formerly

male section now becomes a capacitive pickoff point. The two female ends of the "T" become a series feed-thru from radio to dummy load.

Now make up a piece of RG58/U coax with a BNC plug on one end and a female UHF on the other; this can be done directly with the solderless female Amphenol 83-58FCJ, or indirectly with a PL259 and a double-female (PL258) connector. This makes a coupler having a few picofarads of capacitance between the center of the female connector and the cutoff pin; when screwed together, they come very close but don't actually touch. (Confirm by DC ohmmeter

FIGURE 5-39
CAPACITIVE SIGNAL SAMPLER USING COAX "T" CONNECTOR

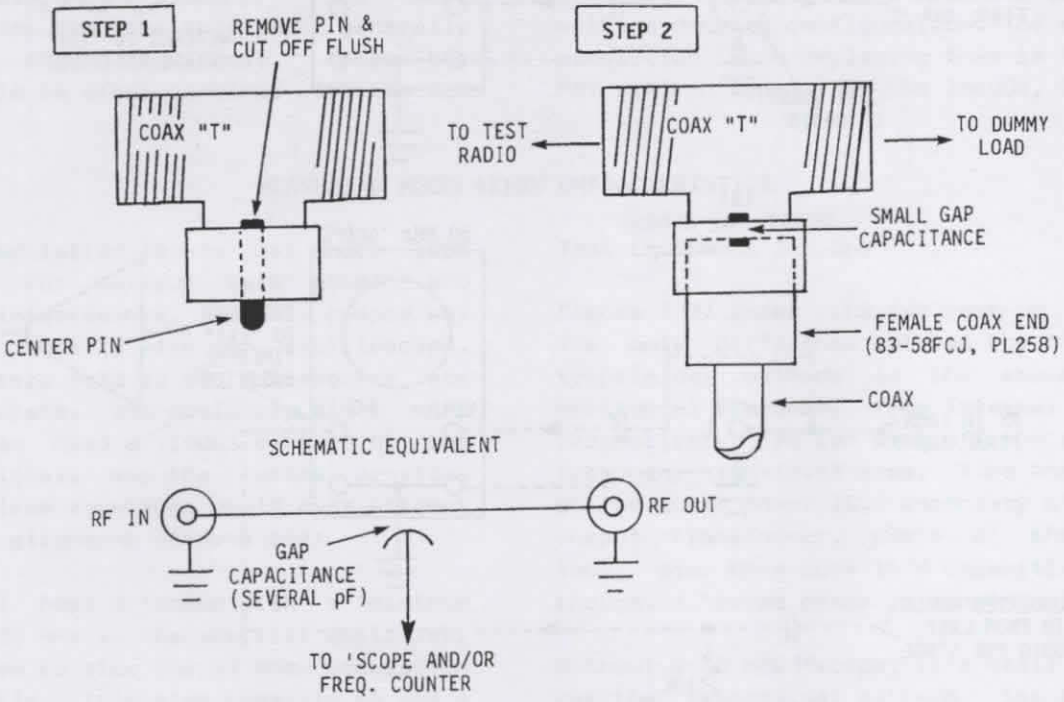
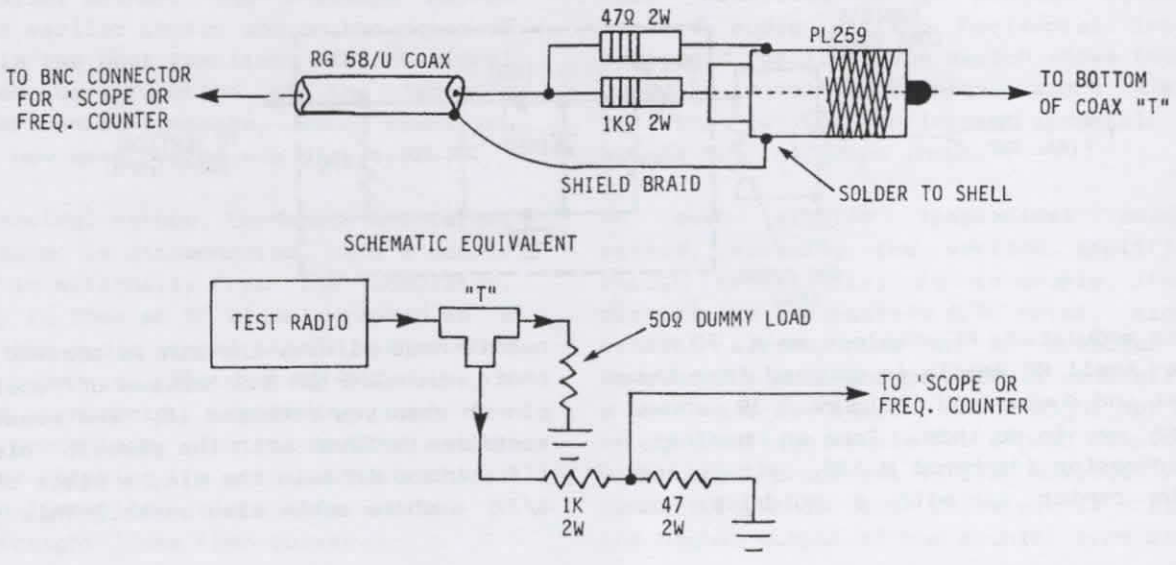


FIGURE 5-40
20:1 VOLTAGE DIVIDER RF SAMPLER



checks.) If your frequency counter is sensitive enough it might read on this too. Another bonus is the fact that it's shielded.

Another sampling method involves making a 20:1 voltage divider. See Figure 5-40. Solder one lead of a 1KΩ, 2-watt resistor into a PL259 plug. Using a piece of RG58/U with a BNC for the 'scope end, strip back the other end and solder the center conductor to the loose resistor lead, and the shield to the body of the PL259. Shunt a 47Ω, 2-watt resistor from the center conductor splice to the body of the PL259 plug. Now you can use various "T" connectors and UHF adapters to sample directly rather than capacitively from the dummy load; the 1KΩ presents a high enough impedance so normal RF output power isn't affected. With a typical 4 W output you'll get about 2 V P-P, which should be enough to drive both the 'scope and a frequency counter together.

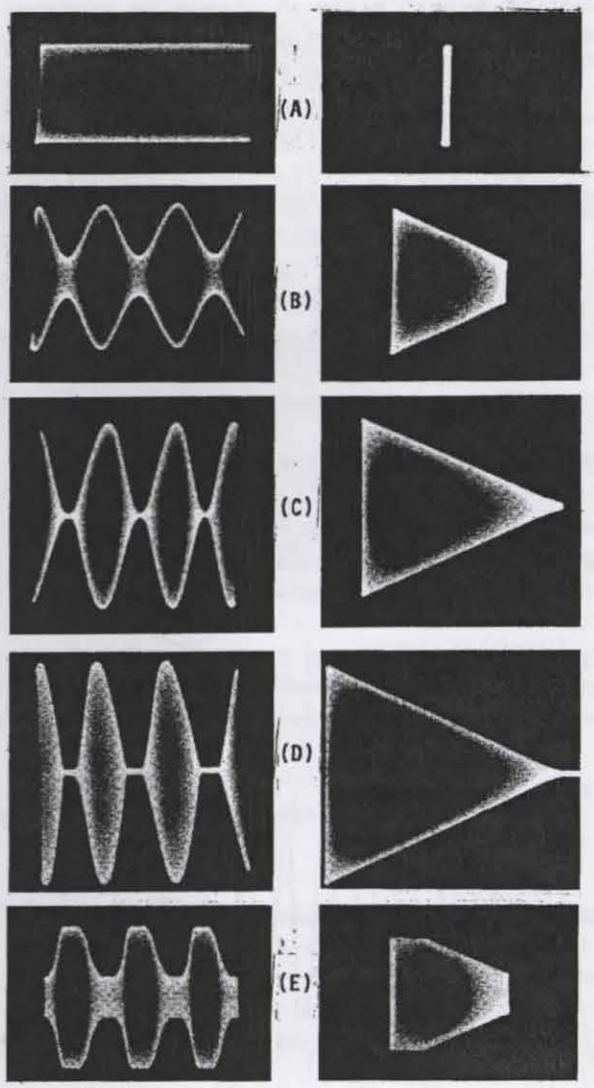
Modulation Display Patterns

The 'scope photos on this page show various modulation conditions using both envelope and trapezoidal methods. The unmodulated carrier is seen in Photo "A." Note with the trapezoid only a vertical bar appears, since there's no audio yet at the horizontal input to spread it out. In Photo "B" you see 50% modulation. With the trapezoidal method, the right-hand vertical edge is exactly half as long (50%) as the left-hand edge. Photo "C" shows 100% modulation.

Photo "D" shows overmodulation; with either method a bright horizontal line appears where the modulation went to zero and stayed there for a finite time. Photo "E" shows the common problem of insufficient audio; the envelope shows peak clipping ("flat-topping"), while the trapezoid shows less than 100% modulation combined with clipping of the triangle's points. The cure is to reduce the carrier power or to increase the drive by realignment.

Problems of non-linearity would easily be seen as a rounding of the straight-line trapezoid edges; proper biasing is the usual cure, unless the modulating waveform itself is distorted.

DISPLAY OF VARIOUS MODULATION CONDITIONS



(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)

FREQUENCY MODULATION

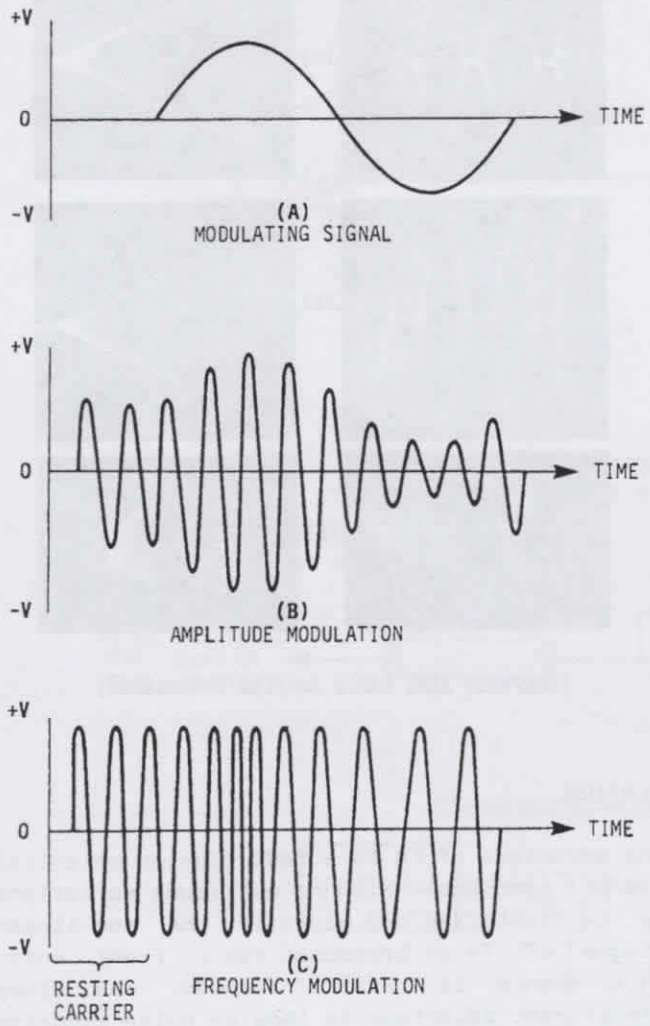
Frequency Modulation or FM is now a very popular form of CB operation. In countries like Britain, Holland, and Germany it's the only legal system. In the U.S. it's not "officially" legal, but is nevertheless widely used due to the popularity of the European type multimode export radios here. Figure 5-41 shows the basic signal difference between AM and FM.

One advantage of FM is a reduction in potential TVI/RFI problems. With no amplitude variations to be rectified and mixed in the non-linear stages of TV or broadcast radio front ends, interference is greatly reduced. The other significant advantage is impulse noise immunity from sources like static thunder crashes and automobile ignitions, problems which often make

AM or SSB communications impossible. Finally, FM modulation occurs in a low-level transmitter stage; this means very little audio power is needed, and the RF power amplifiers can be run with high Class C efficiency.

Disadvantages include a slightly wider receiver bandwidth than AM, and the difficulty in "shooting skip," since shortwave FM propagation results in phase distortion that makes copy difficult. That's why FM is generally limited to the VHF/UHF services which don't have skip. No doubt European politics played the biggest role in creating 27 MHz FM, when CB operators there demanded a shortwave "skip" type band, and Americans have simply been copying them.

FIGURE 5-41
AM & FM SIGNAL CHARACTERISTICS



(Courtesy Prentice-Hall Inc.)

Frequency vs. Phase Modulation

FM and PM (Phase Modulation) are very closely related, since one property can't be modulated without also modulating the other, and vice-versa. Both are sub-categories of a general method called "angle" modulation, a condition where the phase angle of a sine wave carrier is varied from its reference value. PM can't be used directly in communications systems without including special audio shaping circuits, but it helps to generate FM so it's important to understand their subtle differences.

The differences have to do with the amount of "deviation" or frequency shift from the center unmodulated carrier. With FM, deviation is proportional only to the amplitude of the audio signal regardless of its frequency, while in PM the deviation is proporional to both the amplitude and the frequency of the modulating signal. For example, using PM a 20 mV, 2 KHz mike input signal would produce twice the deviation of a 20 mV, 1 KHz input; using true FM there'd be no difference in total deviation.

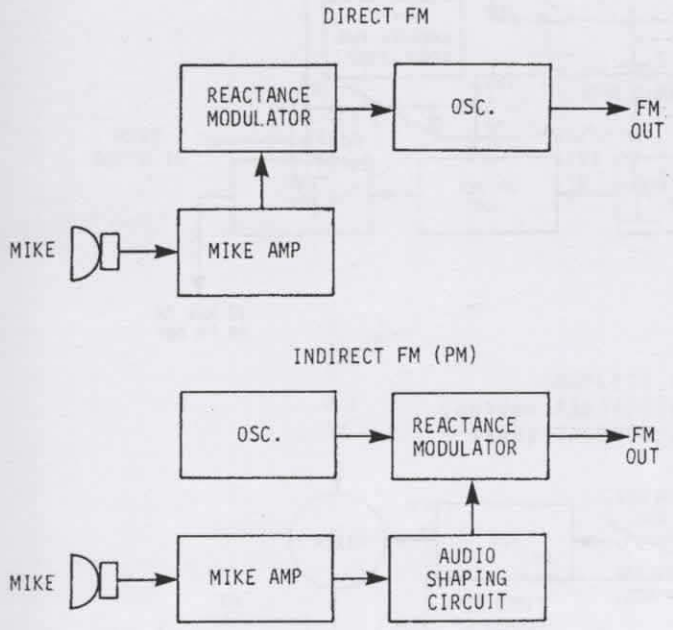
Because of this, PM requires special audio shaping circuits. If there's no limit to the PM modulating frequency, the result would be a tinny sound and very excessive bandwidth. To prevent this pre-emphasis is used, rolling off the higher modulating frequencies at about 6 dB per octave. In practice, this means PM must first be changed to FM before applying the audio signal to the modulated stage.

Another difference is in the stage being modulated. When the frequency-controlling stage like an oscillator is modulated, this is called "direct FM." When modulating a stage following the oscillator, the RF carrier will be phase-modulated instead; this is called "indirect FM." Since 27 MHz FM didn't come along until well after the introduction of the PLL with its sensitive VCO, all FM CB equipment uses direct FM. The audio signal is applied directly to the VCO stage, changing its frequency and therefore the 27 MHz carrier at an audio rate.

PM is generally reserved for crystal-controlled communications, because it's not possible to pull a crystal directly enough for full deviation. A typical crystal deviation is only about 50 parts per million; i.e., 50 Hz for each 1 MHz. In commercial VHF/UHF radios having large oscillator multiplications anyway, it's practical because the deviation will also be

multiplied by the same amount. But CBs don't use frequency multipliers except an occasional doubler or tripler, which explains why FM CB wasn't practical before PLL synthesizers evolved. Nevertheless, many customers will ask about FM conversions for their old 23-channel crystal-synthesized radios, so make sure you understand this and can explain why it's not possible. Figure 5-42 shows FM/PM differences.

FIGURE 5-42
GENERATION OF FM & PM



Multimode vs. FM-only CB Equipment

FM CB equipment can be grouped into two main categories: the multimode export types, and the FM-only types. There's often a big difference in performance. The multimode radios simply added FM to existing AM/SSB chassis, while the FM-only types started from scratch. Most receiver circuits are basically the same, with the main difference in the FM transmitter. Figure 5-43 shows these differences.

Many multimodes use high-level audio (on the order of 2-4 watts) from the power IC, which is filtered and applied to the VCO varactor at the same control point driven by the PLL Phase Detector. The Cybernet AM/FM/SSB models in particular (PCMA0015, PTBM121D4X, PTBM059C0X, PTBM125/131A4X, etc.) use this method. There's no special speech processing like the kind needed for good FM. The MODE switch in the "FM" position breaks the high-level audio path to prevent simultaneous AM, and changes the DC bias for Class C amplification. This is shown in Figure 5-43A by "SW1" (audio path) and "SW2" (DC path). The DC supply for both FM and AM is regulated at a lower collector voltage than the 13.8 VDC used for SSB. (See CHAPTER 6.)

The DC voltage regulation in multimode radios is usually quite poor. Add to this the use of long wire harnesses, an audio power IC drawing high current and pushed to its limit, and the voltage to sensitive oscillators can fluctuate. This results in some unavoidable phase modulation. And phase modulation results in simultaneous amplitude modulation as the shifting phase detunes the modulated stage from resonance. The unwanted AM is often noticeable in these models. It's not the best method, although obviously the cheapest.

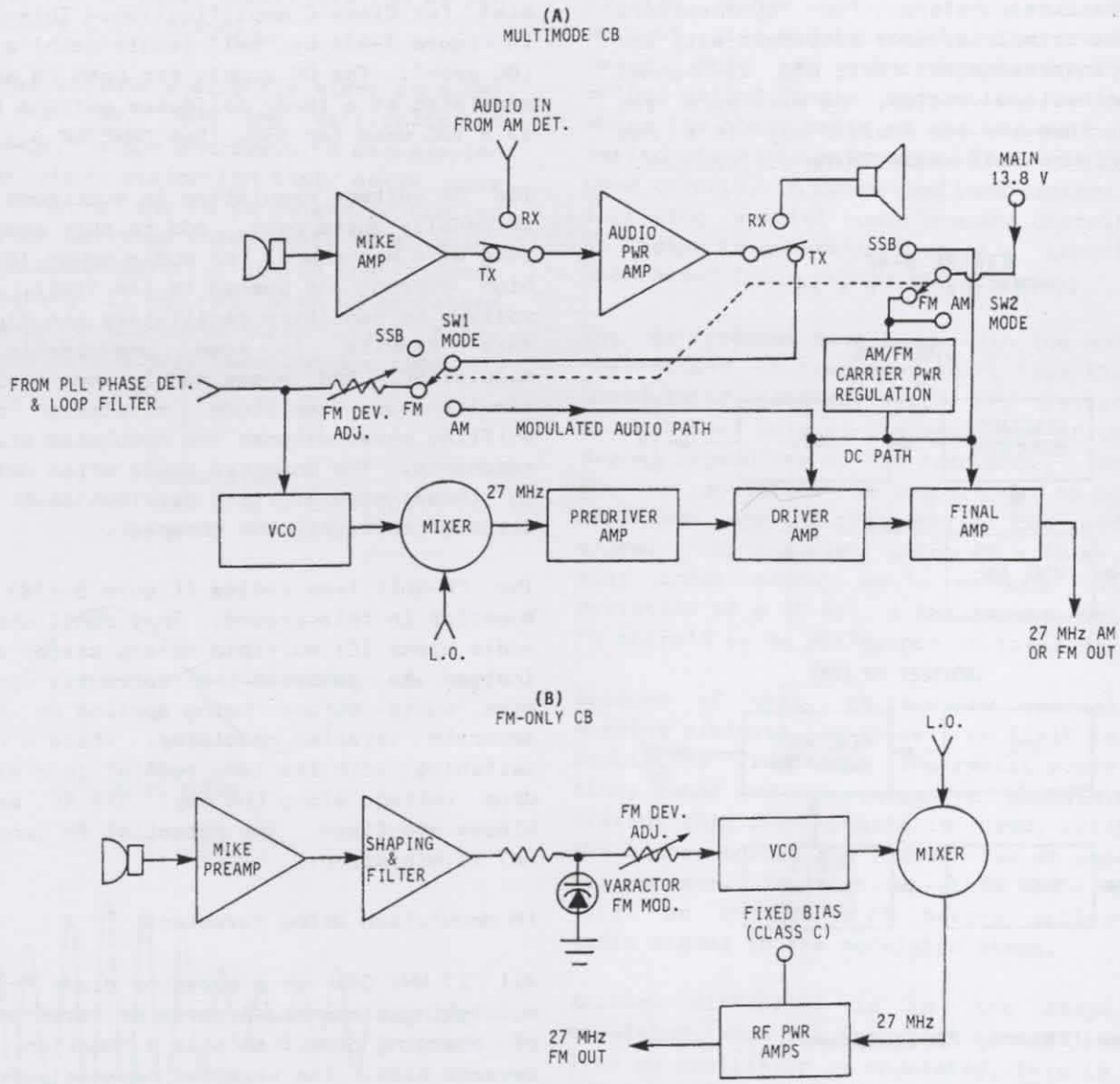
The FM-only type radios (Figure 5-43B) are far superior in this regard. They don't share the audio power IC; multiple op-amp stages are used instead to generate the correctly processed mike audio before being applied to its own separate varactor modulator. There's no mode switching with its long runs of thin wires to drop voltage along the way. The RF amplifier biases are fixed. Any potential PM (and hence AM) is minimized.

FM Modulation Using Varactors

All 27 MHz CBs use a varactor diode for the FM modulating element. A varactor takes advantage of changing capacitance as a function of its reverse bias. The varactor becomes part of the tuned oscillator circuit, and the changing capacitance (actually the reactance) causes a corresponding change in oscillator frequency. This type of circuit is thus known as a "reactance modulator." In practice a small fixed reverse DC bias is also applied to put the diode in the linear part of its operating range, and the modulating voltage is added to this. The circuit may use the existing VCO varactor, or a separate varactor just for FM.

Figure 5-44 illustrates the simple method used in multimode radios. The Uniden types improve on the Cybernet method somewhat by taking mike audio from the lower-level preamp output, but there's still little speech processing other than pre-emphasis. Audio from mike preamp IC4 is coupled via switches D33 and D34 to VR4, the

FIGURE 5-43
FM CB TRANSMISSION METHODS



DEVIATION trimmer. C129 rolls off some higher frequencies. C87/R128 form a pre-emphasis filter. The fluctuating voltage is applied to varactor D31, which is shunted directly across the VCO tank coil to produce FM. R130 supplies the fixed varactor bias to which the modulating voltage is added. Audio limiting is by the same AMC circuit used for AM. One problem here is that AM compression limiters have the wrong time constant for FM use; the AM attack time is generally not fast enough, and results in some instantaneous overdeviation on voice peaks.

Figure 5-45 shows the complete audio circuit used in the British and CEPT FM-only type transceivers. The audio power IC is used only for receiver speaker audio. Instead a 4558 dual op-amp processes the mike audio. The first section of IC4 is a straight voltage amplifier coupled to back-to-back diode peak clippers D11 and D12. This is followed by an RC "T" network low-pass filter (R71/C94/R70) to remove the clipping harmonics. The second IC section is an active low-pass filter which further attenuates harmonics and the higher audio frequencies. Another RC "T" network (R61/C74/R102) follows this for pre-emphasis.

The processed mike audio is applied to VR5, which sets the deviation. Separate varactors are used at the VCO for the PLL (D7) and the FM modulator (D8). A small constant reverse bias

FIGURE 5-44
FM TX IN MULTIMODE TYPE CHASSIS
(Uniden President Jackson)

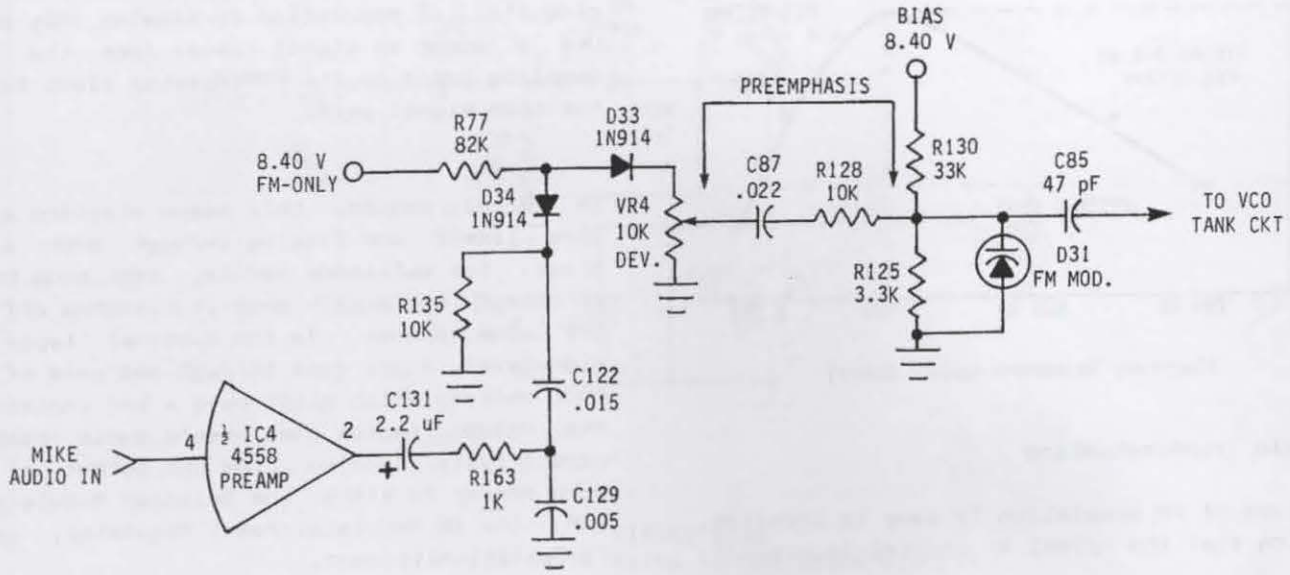
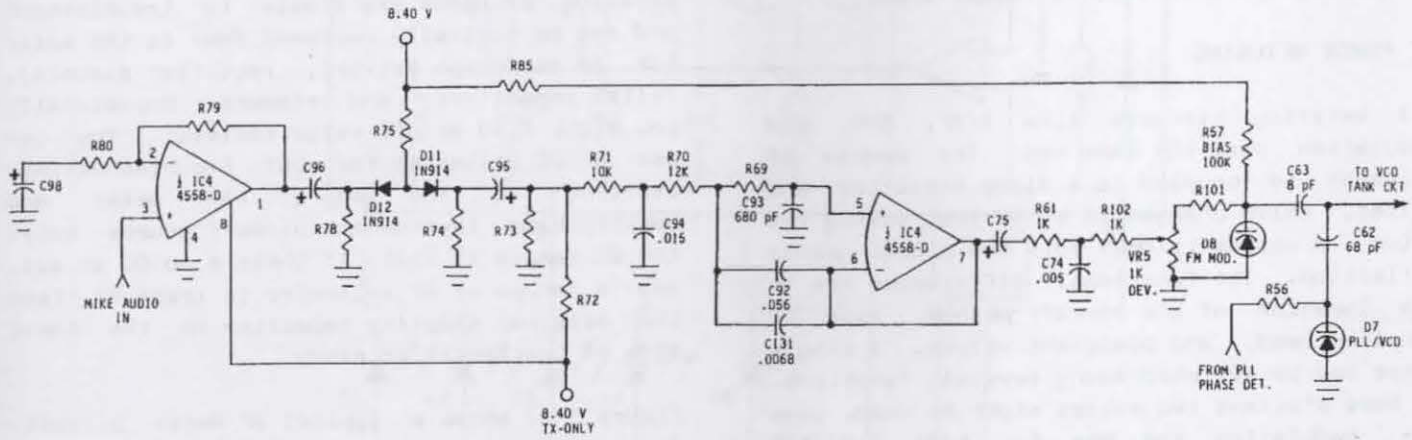


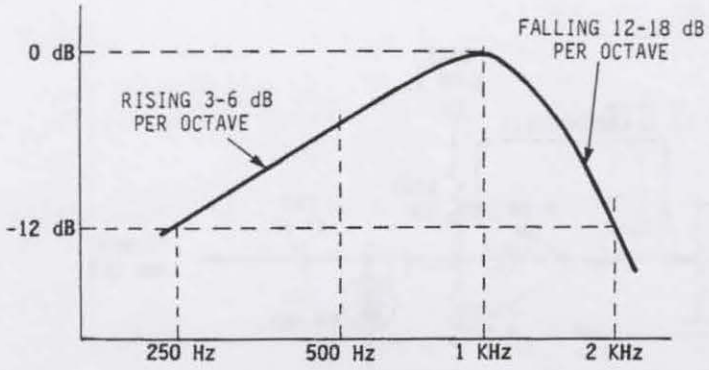
FIGURE 5-45
COMPLETE FM-ONLY TX AUDIO CHAIN
(Uniden PA034/039 chassis: Audioline 340/341,
Tandy TRC2000/2001, Uniace 100/200, etc.)



is applied through R57 to set D8 in its linear range. The series coupling capacitors for each varactor are unequal; C63 is much smaller than C62 because the audio deviation is much less (±2.5 KHz) than the "fixed" 10 KHz deviation needed when changing channels. Divider C62/C63 also stabilizes the VCO by controlling the overall influence of D8 relative to the carrier frequency. This reduces the chance for spurious FM of the resting carrier, and explains why two separate varactors are usually included.

The importance of FM speech processing is summarized graphically in the typical frequency response curve shown in Figure 5-46. Besides increasing the bandwidth, the higher audio frequencies have less energy than the lower ones. Reducing the higher frequencies relative to the lower ones increases the overall audio energy. The average male voice has the most energy concentrated at around 1 KHz. The total attenuation from pre-emphasis and filtering is about 12-18 dB, starting at about 1.5 KHz.

FIGURE 5-46
TYPICAL FREQUENCY RESPONSE OF CB FM MODULATOR



(Courtesy Heinemann-Newnes Books)

FM Audio Troubleshooting

A failure of FM modulation is easy to localize. Assuming that the normal RF carrier is present, determine whether the modulation is missing in all modes, or just the FM mode. If modulation is missing in other modes too, troubleshoot the audio chain and the associated T/R switching circuits. If modulation is missing only on FM, use a 'scope or signal tracer from the audio sampling point to the FM varactor diode to find the open signal path.

In FM-only radios, this means starting at the mike itself and tracing through each active stage. For multimode radios, each mode has a different audio path once it branches off from the mike preamps. In the Cybernet types the high-level audio goes through one pole of the MODE switch, which might have a bad contact. In the Uniden radios each mode's audio path is capacitively coupled from the output of the mike preamp to either the Balanced Modulator on SSB, the AM Modulator/Power Regulator, or the FM Deviation trimmer.

TRANSMITTER ACCESSORY CIRCUITS

This section explains the operation of some common transmitter metering and accessory circuits. Most are quite simple, but they must be thoroughly understood to repair them.

RF POWER METERING

All metering circuits like S/RF, SWR, and Modulation work the same way. The sample of interest is coupled to a diode rectifier and filter, which changes it to DC that drives the meter. A series trimmer sets the proper meter deflection. The functional differences are in the location of the pickoff points, type of coupling used, and component values. A single meter may be switched among several functions. In base stations two meters might be used, one for modulation and one for S/RF and SWR functions. A trend in the newer radios is the use of an LED bar/graph display instead of a meter, but operation is otherwise the same.

The rectifier diodes can be either silicon or germanium. Germanium has a lower conduction voltage and is well suited for RF, having only a few pF of capacitance. The main disadvantage is its low reverse breakdown voltage, less than 100 VDC. This normally isn't a problem in most CB circuits, but with several export models having RF power outputs of 25 watts PEP or more, a mismatched antenna could easily produce enough RF voltage to exceed the safe rating. Silicon diodes are always used in those models.

Metering problems are simple to troubleshoot and can be logically narrowed down to the meter (or IC bar/graph driver), rectifier diode(s), filter capacitors, and trimmers. Occasionally you might find an off-value resistor. You can use a DC voltmeter for most troubleshooting, starting at the [+] of the meter and backtracking towards the pickoff source until the DC sample is lost. If there's no DC at all, use a 'scope or RF voltmeter to trace RF from the original sampling capacitor to the input side of the rectifier diode.

Figure 5-47 shows a typical RF Meter circuit. The meter always has two inputs: one from the last receiver IF for the S-Meter, and one from the transmitter output filter for the RF Meter. The RF sample is coupled from the transmitter by C142. This coupling capacitor is always a small value, under 5 pF, to prevent loading of the output filter. R39 and C39 provide the required RF filtering. D8 is the rectifier.

In this particular circuit D8 is of the silicon fast-switching type. These have a reverse recovery time of typically 4 nS, more than fast enough at 27 MHz. Sometimes two diodes are used in a voltage doubler configuration to increase

FIGURE 5-47
RF POWER METERING CIRCUIT
(Cobra 21/25GTL, 21/25LTD, etc.)

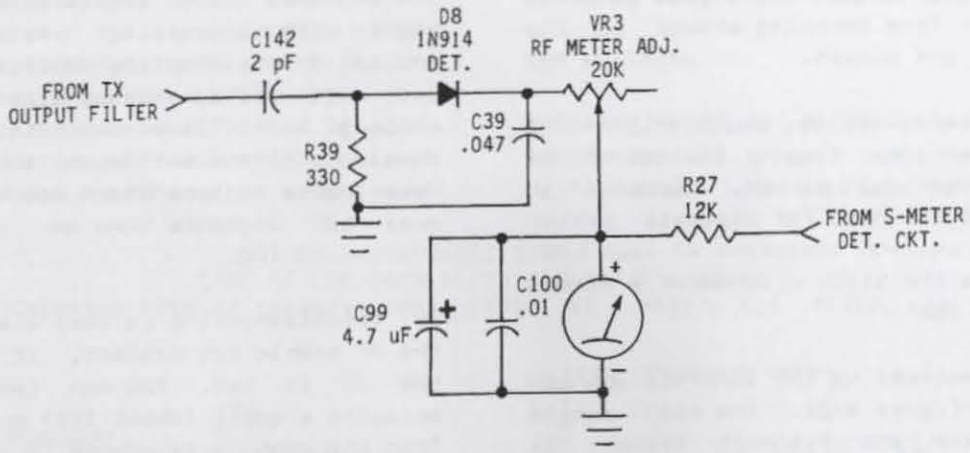
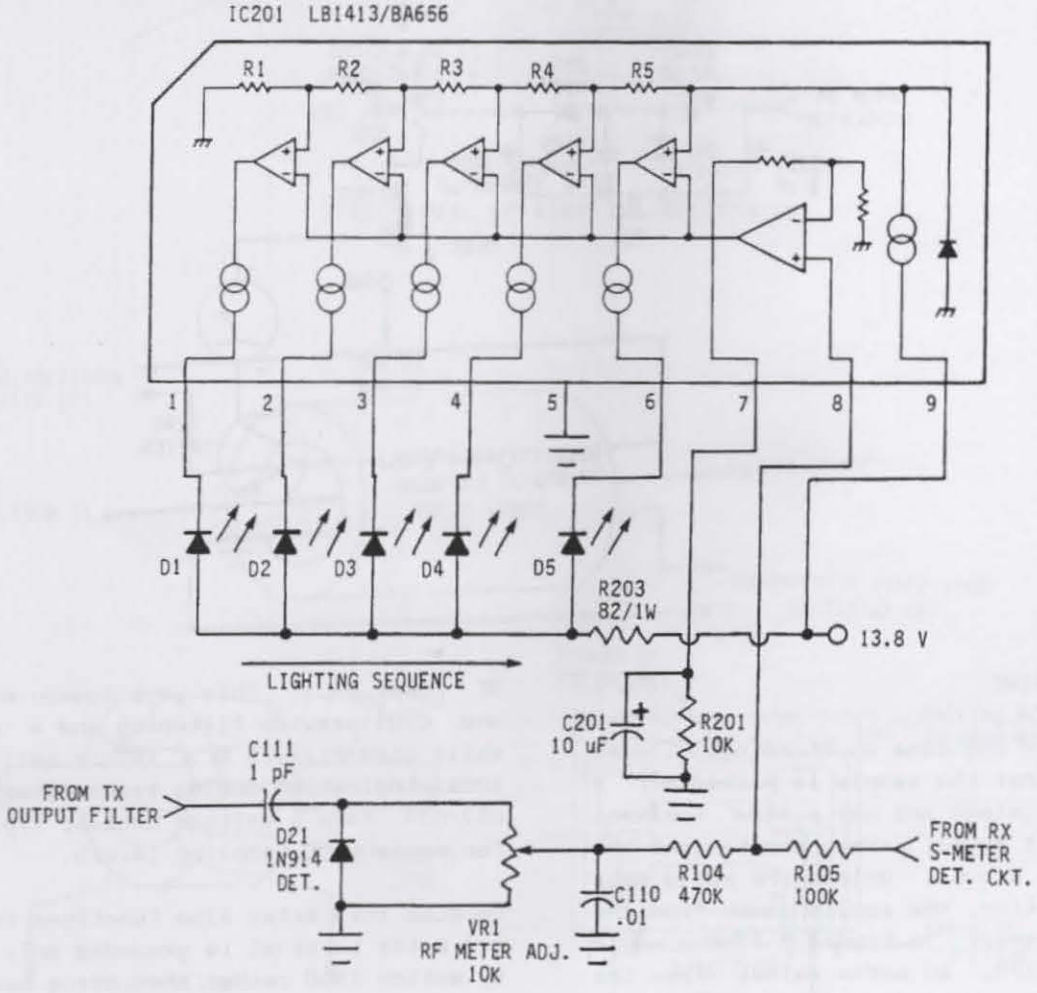


FIGURE 5-48
S/RF INDICATOR USING IC BAR/GRAPH DISPLAY
(Realistic TRC433)



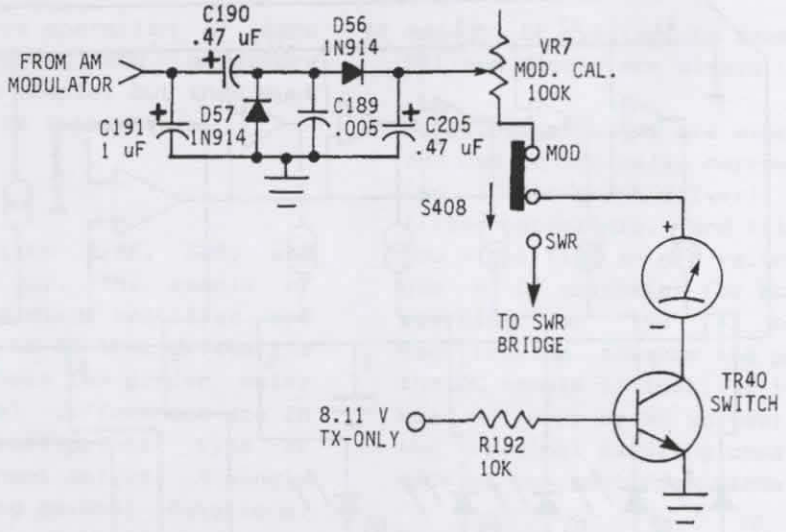
the DC drive to the meter. VR3 sets the desired meter deflection, with C100 for additional RF filtering. C99 is a large value used mainly for the S-Meter part of the input; there's mostly audio at that point, and the long time constant keeps the meter from bouncing around so the movement is slow and smooth.

More and more inexpensive AM- or FM-only radios now use an LED bar/graph display instead of the more costly mechanical meters. Special IC drivers eliminate the need for discrete driver transistors and pull-up resistors at each LED. Figure 5-48 shows the block diagram of a common bar/graph driver IC.

Operation is identical to the discrete Johnson display back in Figure 4-26. The main sample from both Receive and Transmit signals is applied to Pin 8, a DC amplifier that drives five more op-amps, one for each LED. The LED anodes are connected to the V_{CC} bus. As each segment op-amp turns on, current flows through it to ground which makes that segment light up. The segments (D1 to D5) illuminate from left to right with increasing S-Meter or RF Power inputs. As the sampling voltage increases, more and more voltage drops across the resistor chain R1 to R5. Since the total voltage drop is equal to the sum of each individual voltage drop, more op-amps start conducting and hence more LED segments turn on. LEDs conduct at about 1.50 VDC.

IC troubleshooting is very simple. If V_{CC} and the DC sample are present, it's safe to assume the IC is bad. You can test each LED by bridging a small (about 1KΩ) pull-down resistor from its cathode to ground to see if it lights. If so, the driver IC is definitely bad.

FIGURE 5-49
MODULATION METERING CIRCUIT
(Cobra 2000GTL, Uniden Madison)



MODULATION METERING

This is basically the same as RF metering. The difference is that the sample is picked off a modulated audio stage and has a time constant more suitable for audio, since now we want the meter to bounce around. Unless the radio uses low-level modulation, the sample comes from the high-level modulator. In Figure 5-49 the audio is sampled via C190, an audio value, from the same modulator bus that feeds the AMC/ALC and RF power amps. This is a common method. C191 and C205 provide filtering and a small delay while C189 filters RF. VR7 is calibrated for a 100% indication during transmitter alignment. D57/D56 form a voltage doubler type rectifier for maximum DC sampling levels.

Because this meter also functions for SWR, the [-] meter terminal is grounded only on Transmit by switch TR40 rather than being hard-wired to ground. This prevents possible DC rectification

in the "SWR" position from the bridge diodes on strong received signals; otherwise the meter might also deflect during reception.

Many radios use a simple LED or lamp for a modulation indicator. The stronger the audio, the brighter it lights. In Figure 5-50 the modulation LED is in series with high-level audio from output transformer T16 and ground, via Q46. The conduction of Q46 controls current flow through PL3 and therefore its brightness. Q46 is biased just at the turn-on point with no modulation; the additional audio voltage makes it conduct harder. C193/R162 establish a time constant which is slow enough to make the changing brightness easy to see.

SWR METERING

The SWR metering circuit gives the operator an indication of proper antenna matching and performance. It consists of a directional

FIGURE 5-50
LAMP OR LED MODULATION INDICATOR CIRCUIT
(Cybernet PTBM048 chassis: Boman CB950, GE 3-5825A, RCA 14T302, etc.)

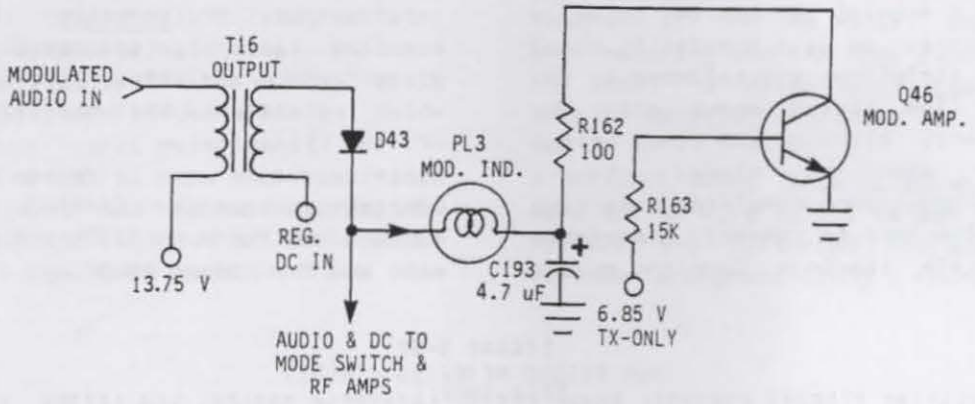
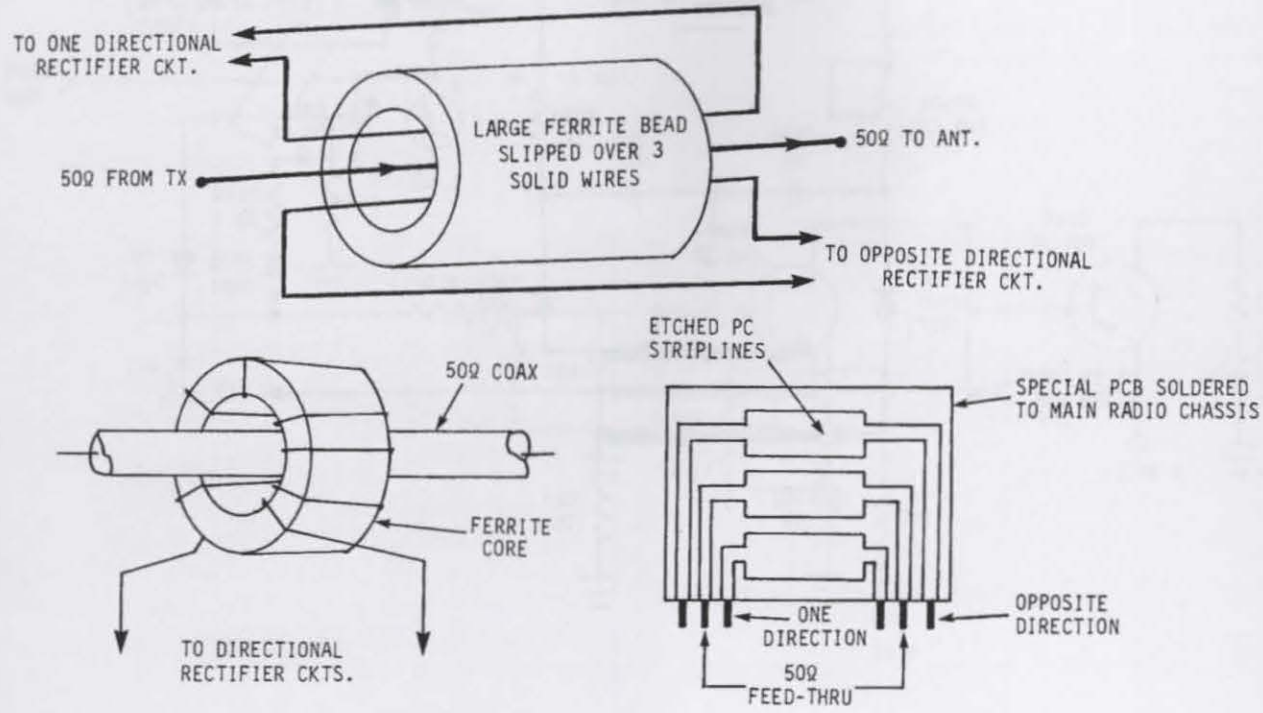


FIGURE 5-51
DIRECTIONAL RF SAMPLING METHODS

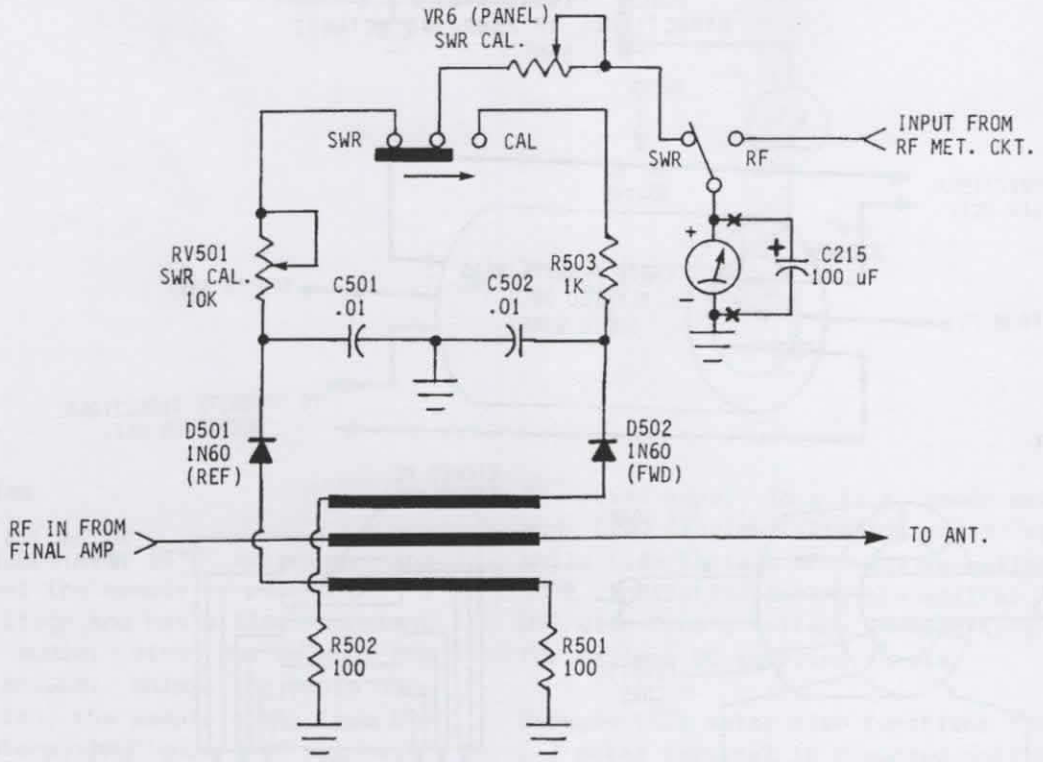


sampling loop that measures the RF input/output power balance (or imbalance) at the antenna socket. This balance is the Standing Wave Ratio or SWR. The RF power moving outward from transmitter to antenna is called the "forward" or "incident" power; that returning from the antenna is called the "reflected" power. The SWR meter is also called a Reflectometer. A calibration control on the front panel lets the operator set the full-scale forward meter reading so that the reflected reading will be correct. CHAPTER 8 discusses SWR in detail.

The forward and reflected RF voltages must be sampled in a particular way. Figure 5-51 shows several methods. The RF is coupled to the meter circuit through a special transformer using a ferrite bead or core, or by a special PC board having parallel striplines and soldered to the main chassis. (The sketch shows only the striplines present, although the other bridge components may also be placed there.) Regardless of method, each simulates a section of 50Ω transmission line to prevent mismatches and their inaccurate readings. Coupling occurs through the mutual inductance and capacitance between the main center conductor and the wires or PC foils placed near it. The PC board is a simplified version of the top bead sketch using three striplines as the wires; it evolved as a labor-saving step. The coax cable method is actually not found in CBs, but is used in some external SWR meters and helps illustrate the directional sampling idea.

Like all transmission lines, the coupler has a characteristic impedance which affects the RF voltages, currents, and phases in both directions, and these can be measured. In CB circuits the SWR meter measures the relative input/output RF voltages, or VSWR. Each sampling input is terminated in a rectifier diode at one end and a resistor at the other which establishes the characteristic impedance of the transmission line. You'll see various resistor values used in CB SWR meters but since complex impedances are involved, all that matters is the eventual 50Ω transformation at each end for proper matching.

FIGURE 5-52
SWR BRIDGE METERING CIRCUIT
(Cybernet PTBM048 chassis: Boman CB950, Lafayette SSB140, RCA 14T302, etc.)



In Figure 5-52, the RF current flowing outward induces a voltage in the top stripline proportional to the forward transmission line voltage. The bottom stripline senses the reflected voltage component. Each stripline is sampled at opposing ends, where voltages and phases are also opposite; the SWR will simply be the net [+] and [-] total. The bridge is normally balanced by C501/C502, R501/R502, and R503/RV501; any reflected voltage will upset this balance and be seen on the meter. Forward voltage is rectified by D502 and reflected voltage by D501, with appropriate RF filtering by C502 and C501. Since CBs are designed for a 50Ω resistive load, RV501 calibrates the reflected voltage using a 100Ω (2:1 SWR) or 150Ω (3:1 SWR) noninductive load resistor during initial transmitter alignment. This is done only after setting VR6 to the full-scale meter mark to establish bridge balance.

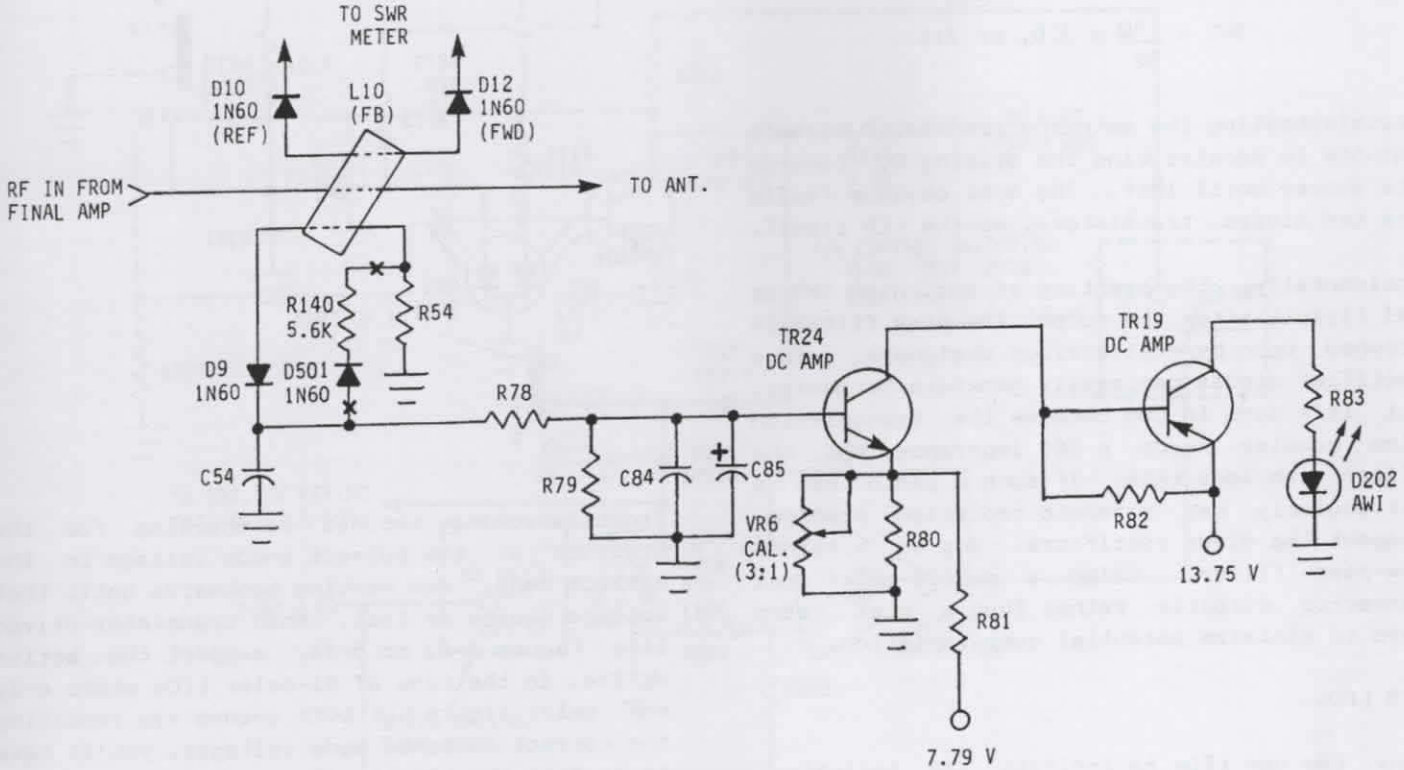
To read the proper ratio, the operator first calibrates the FORWARD voltage reading by adjusting VR6 to the "SET" or "CAL" meter mark. Then switching to the "SWR" position shows how much the bridge is unbalanced. The FORWARD voltage reading changes with reactive loads and small component variations, which is why a calibration control must be included on the radio's front panel. Internal trimmers like RV501 aren't always included though. Initial accuracy is calibrated using several known resistive load values; diode non-linearity and poorly-matched components could affect the true relative voltage readings.

ANTENNA WARNING INDICATOR (AWI)

This is an LED circuit that lights when the VSWR reaches a predetermined level, usually 3:1. Many inexpensive radios use this circuit instead of the SWR Meter, while others have both metering and the LED. Even if just the LED is used, a directional transmission line coupler is still needed to drive it.

A circuit using both is shown in Figure 5-53. Note either wire in the FB can be used for both forward and reflected voltages, since RF voltage and phase along a transmission line is

FIGURE 5-53
ANTENNA WARNING INDICATOR (AWI) CIRCUIT
(Cobra 29GTL, 29LTD, etc.)



always changing; it's not necessary to have a separate wire for each direction. Instead, the bottom wire is used only to drive the AWI LED. The two left-hand wire ends will sense the reflected voltage, and the two right-hand ends will sense the forward voltage.

D9 rectifies RF, with filtering by C54, R79, C84, and C85. D501/R140 is sometimes added to clamp excessive RF voltages from the Final amp to a safe level. TR24 is cut off via R80/R81/VR6 and will only conduct when the SWR reaches 3:1. Increasing reflected voltages develop enough base bias to overcome the cutoff emitter bias on TR24. The more the base voltage, the harder it conducts. As it turns on it pulls the base of TR19 lower, turning TR19 on harder too. As TR19 conducts more, current flows through it to turn on the LED.

NOTE: SAMS #217 and #218 show an FET for TR24, but they actually used a bipolar transistor (2SC945) with its leads crossed to fit the original FET PC holes; it's cheaper!

VR6 is set during alignment. A resistive dummy load of the wrong impedance is purposely used for calibration. SWR is the ratio of voltages, currents, or impedances between source and load. Since the antenna jack is 50Ω by design, a non-inductive resistor of say, 150Ω connected across it gives,

$$SWR = \frac{150}{50} = 3.0, \text{ or } 3{:}1$$

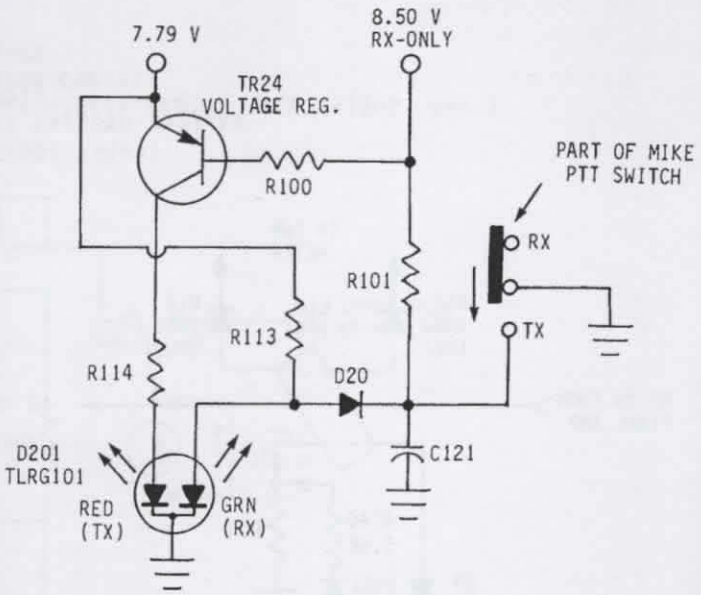
Troubleshooting the metering or AWI/LED circuit amounts to backtracking the driving DC towards its source until lost. The most obvious faults are bad diodes, transistors, or the LED itself.

Incidentally, the practice of adding an SWR or AWI circuit <u>after</u> the output low-pass filter is frowned upon by most serious designers, since rectifier diodes can easily generate harmonics. But it's done in CBs because the transmission line coupler needs a 50Ω impedance and the filter provides this. If such a radio has a particularly bad harmonic radiation problem, suspect the diode rectifiers. Add an external low-pass filter, using a double-male coax connector directly rather than a coax patch cord to minimize potential coax radiation.

T/R LEDs

Many CBs use LEDs to indicate T/R switching. These may be two individual diodes (RED for Transmit, GREEN for Receive), a RED Transmit only, or a two-color LED with GREEN for Receive and RED for Transmit. The dual-color types have two LEDs in a single package with a common cathode. Each anode goes to the appropriate switched voltage source. See Figure 5-54. The GREEN segment is normally conducting via R113 and the 7.79 VDC source. On Receive, switch D20 is cut off by R101, keeping its cathode about 0.7 V higher (8.50 VDC) than its anode. On Transmit, this source and the base of TR24 are simultaneously grounded, allowing D20 and TR24 to conduct. The GREEN diode loses its voltage source and turns off, but TR24 can now supply current to light the RED diode section instead. All such circuits work exactly the same way.

FIGURE 5-54
T/R LED CIRCUIT
(Cobra 29GTL, 29LTD, etc.)



Troubleshooting amounts to checking for the presence of the correct anode voltage in the correct mode, and working backwards until that voltage source is lost. When transistor-driven like Figure 5-53 or 5-54, suspect the active device. In the case of bi-color LEDs where only one color lights but both anodes are receiving the correct switched mode voltages, you'll have to replace the LED itself.

"ROGER BEEP" OSCILLATOR

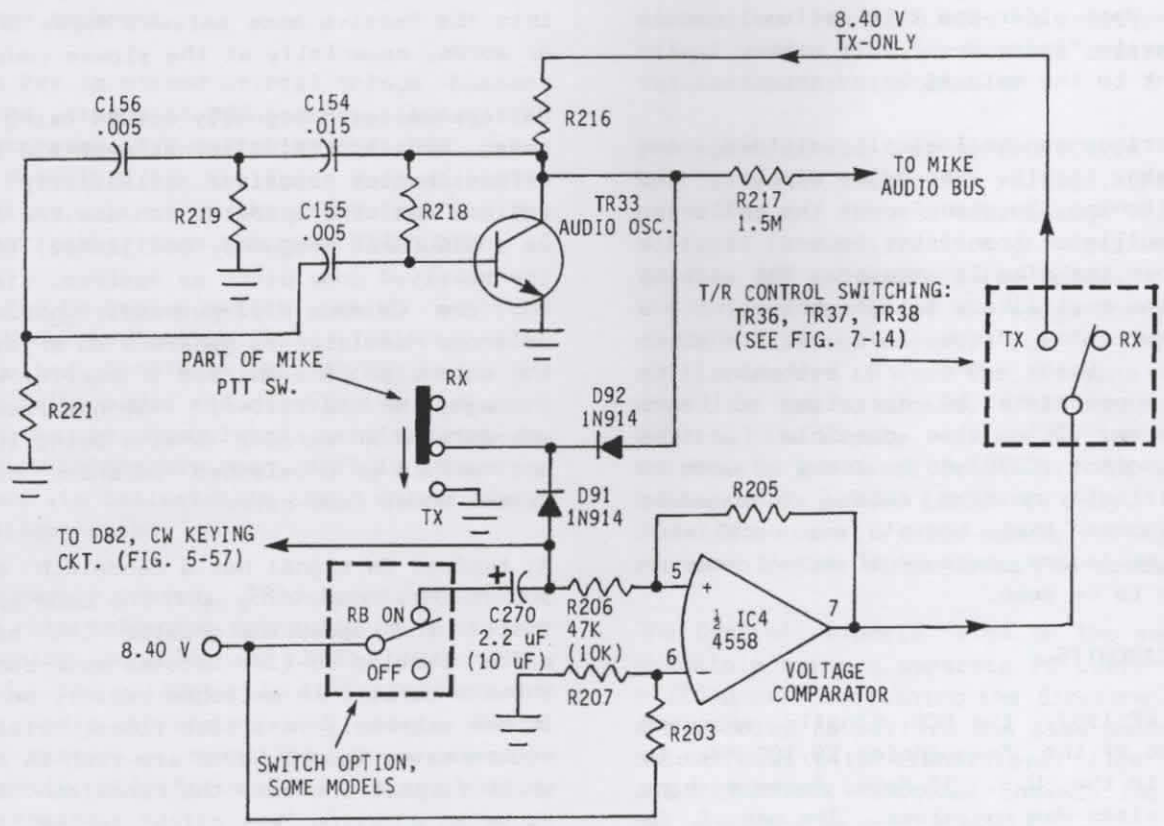
This circuit causes a short audible beep to be transmitted when the mike button is released. A listener knows the transmission is over and he can now transmit, without taking his cue from the traditional "Over" or "Go Ahead" spoken by the other station. With AM and FM this function isn't really needed, since the end of a transmission is obvious when the carrier drops out. However it's quite useful for SSB, which has no carrier and the end of speech isn't so obvious. The radio sometimes has a switch to disable the RB when not desired. Only the export radios have included this feature so far, but there are some add-on RB units sold as accessories to modify standard CBs.

All RB circuits work the same way. A separate audio oscillator is connected across the mike bus and generates a tone of about 1200-2000 Hz. The transmitter remains keyed after release of the mike button for about 150 mS. To accomplish this, several things must happen at once. The oscillator must have operating voltage, but its output must be kept disconnected until the mike PTT button is released. And the T/R switching voltages must be delayed slightly after the button release so the carrier stays on the air just long enough to be modulated by the tone.

Figure 5-55 shows the Uniden circuit, which has a slightly more complicated switching scheme than the Cybernet version. TR33 is a simple audio oscillator using a "T" network RC phase shift for low cost and simplicity. The tone frequency is set by the values of C156 and C154. The output is about 8 V P-P and couples through R217 to the mike audio line. R217 is a very high impedance to minimize loading.

The Transmit keyline of all CB mikes works by the grounding of a voltage when the PTT button is pushed. When the mike is keyed here, D91 and D92 are pulled down near ground and conduct. Grounding D92 kills the oscillator's output, even though the Transmit-only voltage source is still being applied. One section of dual op-amp IC4 is a voltage comparator. It compares two separate voltage inputs, and the output is

FIGURE 5-55
"ROGER BEEP" CIRCUIT
(Uniden PB010 chassis: Cobra 148GTL-DX, Superstar 360FM)



their difference multiplied by the op-amp gain. (The other 4558 IC section is the Mike Preamp.)

IC4 Pin 6 has a fixed bias from voltage divider R203/R207. Pin 5 has a switchable bias, which changes between Receive and Transmit. D91 when grounded on Transmit switches the comparator, which in turn controls the T/R switching voltages of TR36, TR37, and TR38. (Represented here by a simple toggle switch for simplicity; see CHAPTER 7 for a complete discussion of this circuit.) On the PB010 chassis, the CW keyline is also connected to IC4 to control T/R modes.

C270/R206 form an RC time delay. On some models the charging voltage to C270 is switchable (dotted lines) to disable the RB when desired. Note alternate parts values used in some models which still result in the same time constant. After the button release, there's a delay of about 150 mS before the comparator switches, which keeps the radio in the Transmit mode for that amount of time. At the same time D92 turns off, which allows the tone to couple into the mike line and be heard on the air.

The Cybernet circuit works on exactly the same principle, using discrete transistors for T/R switching. The same kind of RC time delay will be found in its switching circuits. The RB is located on a small PC board (PCZS001) in the Nato 2000. Most older Ham International models used a separate "Roger Beep" unit with a 5-wire interconnect to the main PC board chassis.

Troubleshooting can be logically divided among the oscillator itself, the delay circuit, and the T/R switching. You can 'scope the collector of the oscillator transistor to see if it's running when the mike is unkeyed. The active device is the most likely failure point, with a shorted switching diode like D92 another possibility. Check the T/R switching by measuring appropriate DC operating voltages between modes. It's also possible for the timing capacitor (C270) to be leaky or open so there's virtually no time delay. This would make it appear that there's no oscillator output on the 'scope, because it didn't stay on long enough to be seen.

CW KEYING CIRCUITS

In March of 1987, the FCC finally approved limited use of the frequencies 28.100 MHz to 28.500 MHz in the U.S. 10-Meter Amateur band for Novice class Ham operators. The use of CW (Continuous Wave) is now allowed in this entire segment, although courtesy among Hams will limit CW to 28.100-28.300 MHz, leaving the new USB phone privileges for the 28.300-28.500 MHz segment. You can expect a lot more business in the future! Customers will be needing repairs on converted CBs, as well as good techs who can do the actual conversion work. The information in this section can be used to add CW to many standard 23- and 40-channel SSB CB radios.

Many export models include CW. They already have expanded frequencies, and could be used on the 10-Meter Amateur band. Among these are the Cybernet PCMA001S, PTBM121D4X, PTBM125A4X, PTBM131A4X, PTBM133A4X, the Cobra 148GTL-DX, Superstar 360FM, Galaxy 2100, Super Galaxy, Superstar 3600 and 3900, Excalibur Samurai and base, and President Franklin.

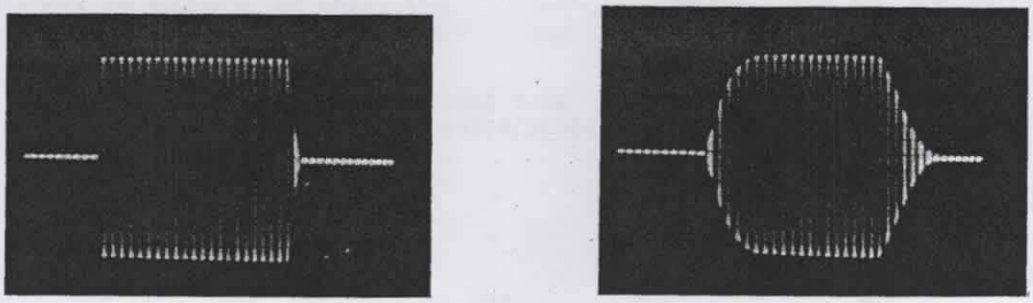
There are some unique circuit requirements for CW. A special Sidetone Oscillator is energized so the sender can monitor his Morse Code in the radio's speaker. The AM and FM modulators must be disconnected, so only the carrier is turned on and off at the Morse Code rate. The carrier frequency must be shifted relative to the SSB filter frequency so it can pass through when the BM is unbalanced. (P. 209.) Finally, some delay timing is included in the keying circuit so the radio isn't constantly switching back into the Receive mode between Morse characters or words, especially at the slower code speeds.

CW transmission actually occurs using the SSB mode, usually LSB. The narrower SSB bandwidth offers better receiver selectivity and S/N ratio. And the operator can use the Clarifier as a BFO (Beat Frequency Oscillator) to adjust the received code pitch as desired. Like AM and FM, the CW mode will purposely unbalance the Balanced Modulator to generate an RF signal. At the same time, the shifted IF carrier will pass through the SSB filter. The net result is an unmodulated RF carrier that's being turned on and off in an unbalanced Balanced Modulator, at the Morse Code rate.

A typical CW signal has a bandwidth of about 300-700 Hz, depending upon the code speed. The faster the speed the greater the bandwidth, since carrier on-time becomes more continuous. When a carrier is switched rapidly on and off it has extremely fast rise times, similar to a square wave. Square waves are rich in harmonics which further increase the bandwidth. They also cause an annoying "key click" to the listener.

For these reasons, RC filtering is added to delay the rise time slightly. Figure 5-56 shows graphic 'scope photos of a typical Morse "dot" with and without adding RC shaping circuits.

FIGURE 5-56
EFFECT OF CW KEYING FILTER



(A)
NO SHAPING

(B)
RC SHAPING TO REMOVE
KEY CLICKS & HARMONICS

(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)

Figure 5-57 shows most of the Uniden multimode type CW circuit. Note that the anode of D82 goes to the same DC T/R switching control used for the Roger Beep of Figure 5-55. The reason will become apparent.

When the key is closed several things happen. First, the cathode of D82 grounds, triggering the exact same T/R switching and PTT delay already described for the Roger Beep circuit. But this time, it holds the T/R delay from the CW key jack rather than the mike PTT button.

TR55 is the CW keying switch, which controls Balanced Modulator switch TR31. TR31 can also be controlled by D74 in the AM/FM modes to kill the mike audio and disable the Balanced Modulator so an unmodulated carrier can be generated. With the key open, TR55 is biased on by R286 and its collector is LOW, which means TR31 is disconnected.

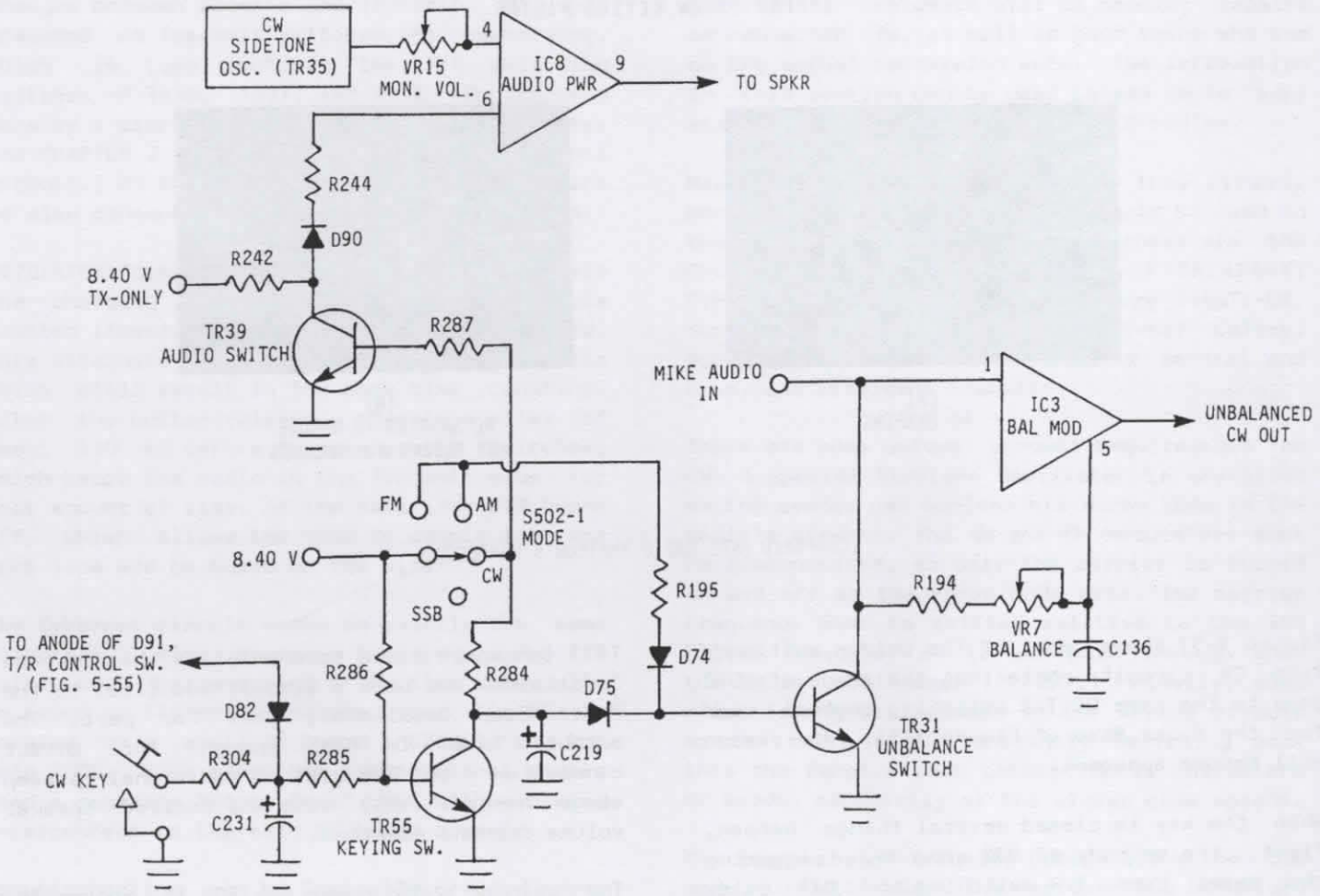
When the key is closed, TR55 loses its base bias and its collector now pulls up HIGH via R284, turning on D75 and TR31. With TR31 conducting, its collector is LOW. This shunts the mike audio to ground and upsets IC3's balancing circuit, resulting in a carrier output signal. C219 filters the voltage spikes caused by keying.

TR35 (shown in block form only) is the Sidetone Oscillator, and uses a circuit identical to the Roger Beep Oscillator, part for part. The output level is high enough for direct connection to IC8 with no additional preamp stage needed. VR15 sets the desired speaker volume for the sidetone.

The gain of audio power amp IC8 is controlled by Pin 6; the higher its voltage, the lower the gain. For AM, FM, and SSB, enough Transmit-only voltage is supplied through R242/D90/R244 to disable IC8 and silence the speaker. (Remember, the Unidens don't use the audio power IC for AM or FM modulation anyway.) But for CW, IC8 must still operate to hear the Sidetone Oscillator when the key is closed. TR39 controls this by holding the supply voltage to IC8 Pin 6 at a relatively low level (about 1.8 VDC), since its collector is pulled LOW on CW only. This pulls down the normally-HIGH supply voltage at R242 required in the other modes for speaker muting.

The Cybernet exports work on the same general principle using a separate PC board (PCCW001S, PTZZ080A0X) containing the Sidetone Oscillator and a relay to perform the same switching that Uniden does with transistors. (The PTBM121D4X and PTBM133A4X Cybernet chassis include these parts on the main PC board.)

FIGURE 5-57
UNIDEN CW KEYING CIRCUIT
(PB010 chassis: Cobra 148GTL-DX, Superstar 360FM)



Troubleshooting such circuits isn't complicated if you understand the functions and switching. If there's no CW keying but USB/LSB is normal, suspect the switching diodes and transistors. If neither SSB or CW work, troubleshoot as if it were an SSB problem. If the Sidetone Oscillator doesn't work, check its transistor and associated audio power IC switching.

SELECTIVE CALLING SYSTEMS (SEL-CALL)

This option attempts to copy the tone-encoded squelch used in commercial VHF/UHF FM radios and Amateur 2-Meter repeaters. When the mike is keyed, a tone burst of a specific frequency and length is used to unsquelch the listener's receiver. This tone burst is generated by an audio oscillator encoder, like a Roger Beep but injected at the beginning of the transmission instead of the end. At the receiver, a decoder circuit detects this signal and opens the squelch. (An example was shown in CHAPTER 4.) There's slightly more communications privacy, since only a transmitter with the proper code can unsilence the receiver. Obviously the same encoder/decoder frequencies and timing must be available in all transceivers using the system. But remember that once the squelch is opened by the correct input tone, any other station that happens to be on the channel can also be heard.

Most commercial tone systems use expensive and sophisticated circuitry. The CTSS method uses a continuous sub-audible tone of 67-193 Hz, which is added to the mike audio to modulate the carrier. This tone is generated by a special vibrating reed, which is also physically large. Commercial radio chassis are much larger than CB radios and have the room inside!

Other systems use sequential tones, or two-tone bursts in the range of 700-1500 Hz, similar to Touch-Tone telephones. This makes listening more difficult for the casual eavesdropper, but once the receiver is selectively unsquelched you can still hear anybody else who happens to be there. Since such tones are in the audible range, they can't be made continuous or they'd irritate the listener. To account for this, the tone burst at the beginning simply starts (or resets) a timer at the repeater. Amateur 2M-FM systems typically use a 3-minute timer.

I've never actually seen a Sel-Call fitted in a CB radio, so I can't say exactly which method they use. Add-on units were especially popular in British CBs a few years ago. Some Uniden and Cybernet export models show interconnections on the schematics, but not the unit itself. You can still get the Cybernet type modules from

FIGURE 5-58
SEL-CALL INTERCONNECTIONS

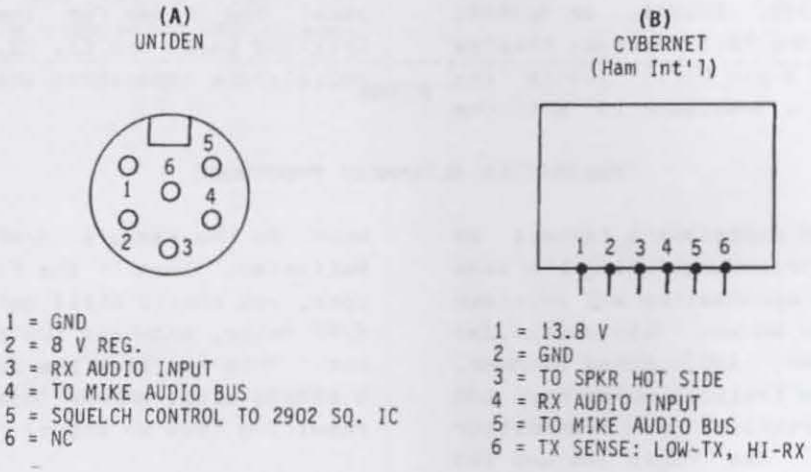
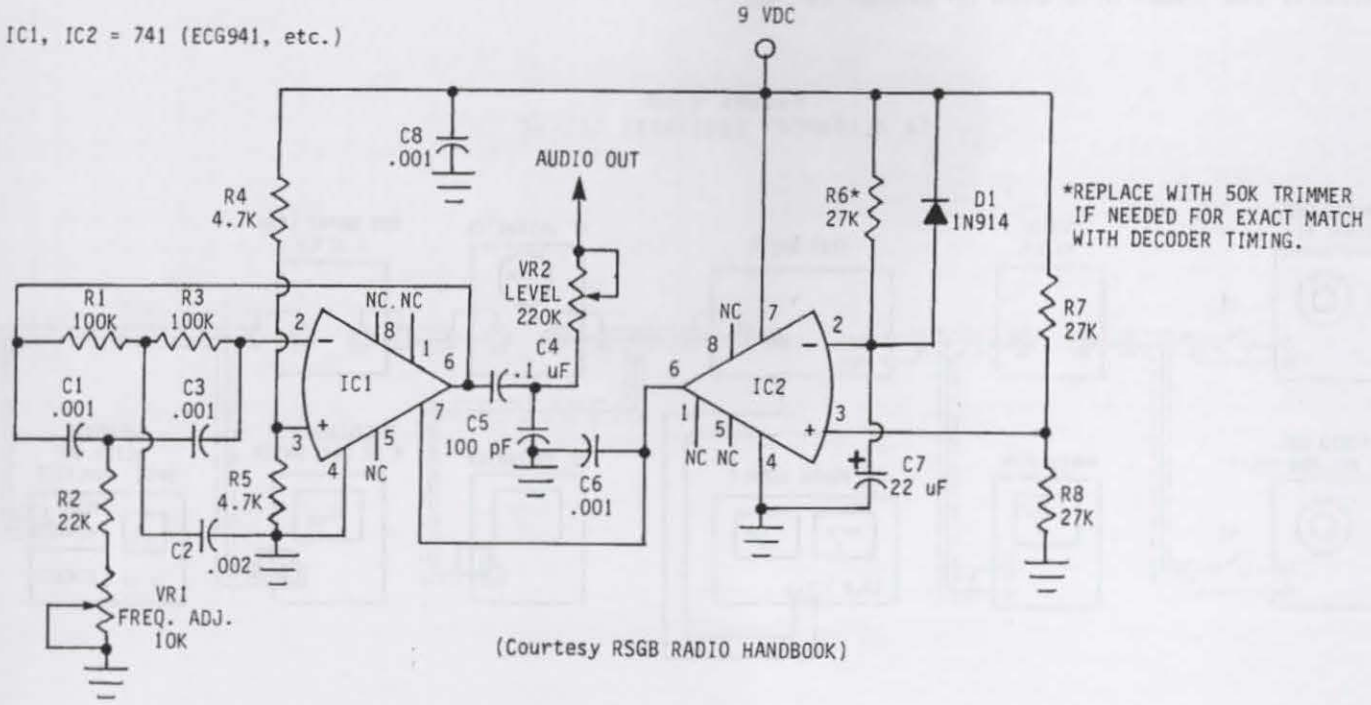


FIGURE 5-59
TONE ENCODER CIRCUIT USING OP-AMPS



(Courtesy RSGB RADIO HANDBOOK)

Ham International in Belgium. (See CHAPTER 1.) Figure 5-58 shows both interconnections. The Uniden version (Stalker 9-FDX, PC893) controls the 2902 squelch IC. The Cybernet module disconnects the speaker itself. Both require a sample of received audio, taken from the audio power output circuit. Uniden combines mike audio and T/R sensing on a single pin, while Cybernet uses one pin for each function. The other connections are for DC operating power.

Figure 5-59 shows an example of a tone encoder that could be applied to CB radios. Any convenient op-amp of the 741 type can be used, like an LM741H, MC1439G, ECG941, or SK3514. (Pin numbers refer to the TO-5 package; they're also available in the 8-pin DIP.) IC1 is the oscillator and uses a T-Network to set the frequency; IC2 is the timer. The oscillator frequency is set by VR1 and the output level by VR2. It can be keyed by switching the V_{cc} line, or to be more consistent with CB keylines, by grounding its negative DC bus.

With voltage applied, the oscillator starts running. C7 charges, raising the voltage on IC2 Pin 2. When it exceeds the voltage divider bias (R7/R8) set at IC2 Pin 3 it switches off, disconnecting the supply voltage to IC1 Pin 7. R6/C7 set the tone burst length, which should match the adjustment of the decoder. When the mike is unkeyed, C7 discharges through D1 to reset the timer for the next transmission. Critical parts are C1, C2, and C3; only mica or polystyrene capacitors should be used there.

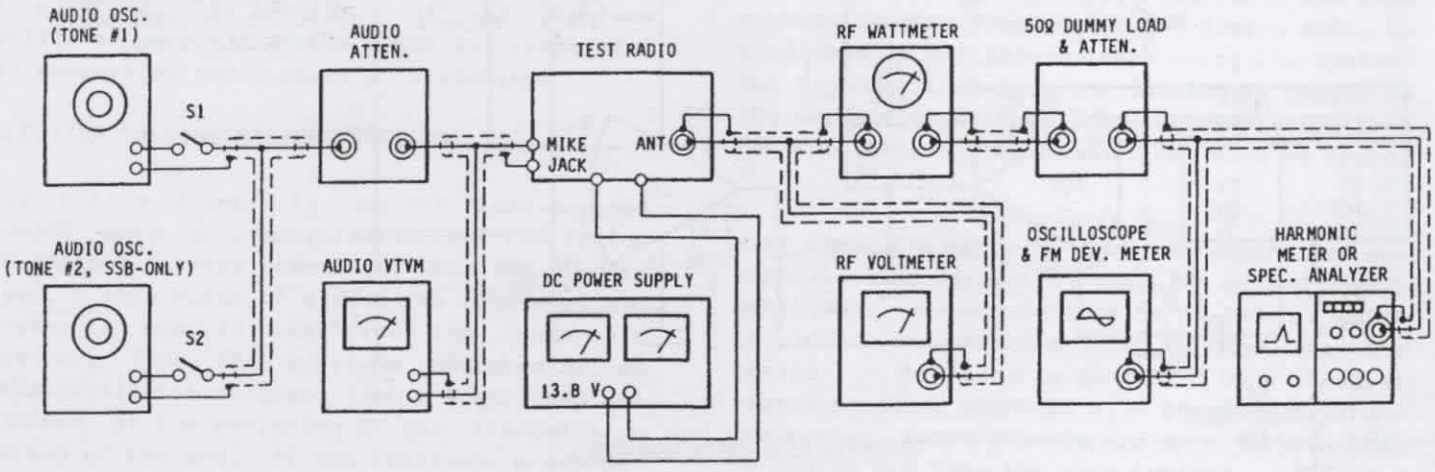
TRANSMITTER ALIGNMENT PROCEDURE

The following section describes a typical AM transmitter alignment procedure, using the same Cybernet chassis whose synthesizer and receiver alignments were already shown. This particular chassis has an SWR meter, AWI, Noise Blanker, and Delta Tune, deluxe features which may add extra steps to the receiver or transmitter alignment when present. See Pages 144 and 145 for the schematic and alignment parts layout.

With an extremely misaligned transmitter where there's no obvious RF output, use a 'scope or voltmeter/RF probe to peak each transformer and coil starting from the synthesizer output. Eventually the power will come up enough to be seen on the radio's S/RF Meter or an external Wattmeter. Even if the Final amp transistor is open, you should still get a small nudge on the S/RF Meter, and hear the carrier in a nearby CB set. This isolates the problem to being either a simple misalignment (common!), or power loss resulting from an actual circuit fault.

Figure 5-60 shows the basic AM test equipment set-up. FM-only radios have virtually identical procedures, except that the modulation and modulation-limiting circuits will be in terms of deviation instead; substitute appropriate FM measuring equipment for those steps.

FIGURE 5-60
TX ALIGNMENT EQUIPMENT SET-UP



1. PRESET CONDITIONS: Ch.19, MIKE GAIN (if present) maximum, radio connected as shown.

2. RF POWER: Adjust L5, T3, T4, L7, L11, and L12 for maximum RF output indication, in that order. Recheck L11 for maximum again.

   Turn L7 clockwise into core until wattmeter reads 4.4 W. Now readjust L12 clockwise for 3.8 W power indication.

3. AMC: Inject a 100 mV, 1 KHz audio signal at MIKE socket. Adjust RV2 for 95% modulation. Use previous photos and formula (Pages 167 and 187) to determine modulation percentage.

4. FM DEVIATION (Option): Switch to FM mode. Inject similar audio signal at MIKE jack. Set DEVIATION trimmer for ±2.5 KHz maximum.

5. RF POWER METER: Adjust RV4 so that panel meter agrees with external wattmeter.

6. ANTENNA WARNING LIGHT (Option): Connect 150Ω resistive dummy load to antenna socket. Adjust RV502 until AWI just lights.

7. SWR METER (Option): Using 150Ω dummy load again, adjust RV501 for 3:1 SWR reading.

NOTES

6 SINGLE-SIDEBAND CIRCUITS

As early as 1914 radio designers knew that if the carrier and one sideband of an AM signal were eliminated, the remaining sideband could still be used to transmit the intelligence. By 1923 a "Single Sideband" system was patented, actually for telephone use, so SSB isn't a new idea! Those early principles are still used, with the SSB CB transceiver a more refined and economical version of the original system.

SSB is the most popular and fastest-growing CB communications mode for the serious hobbyist. Its higher transmitter power and narrower bandwidth are two very practical reasons. The higher initial cost for SSB radios also tends to separate the real CB junkies from the casual users. Their owners are more likely to repair multimode CBs than to replace them. The recent 10-Meter expansion for Novice Amateurs doesn't allow AM for voice work, just SSB; this means converted CBs must be SSB types. For all these reasons, expect to see a lot more SSB radios.

There is no "official" FCC channel assignment for SSB. Over the years tradition (and common courtesy) has resulted in Ch.16 being the SSB calling channel for initial contact, with the use of Ch.35-Ch.40 reserved for SSB only; AM is definitely not welcome here! Radios having the expanded frequencies generally save the space above Ch.40 for SSB and that below Ch.1 for AM. Such operation is illegal, but both modes may still be found around the American FCC band.

Many otherwise good technicians avoid repairing SSB radios because they seem more complicated than AM or FM equipment. They're really not, <u>if</u> you proceed logically when repairing multimode CBs. SSB circuits are a bit more complex, but if you understand the specific differences, troubleshooting becomes very straightforward. There are two main questions when isolating problems between modes: "What is the signal path this particular mode takes?" And, "How is this path controlled electronically?" Since most transceiver circuits are shared by AM (and FM), only those unique to SSB are covered here. Mode switching circuits and methods are also included. Your repair approach is to verify all AM functions <u>first</u> before assuming an SSB-only fault; any problem that affects all modes equally should be treated as an AM problem.

Symptoms associated with SSB problems include:

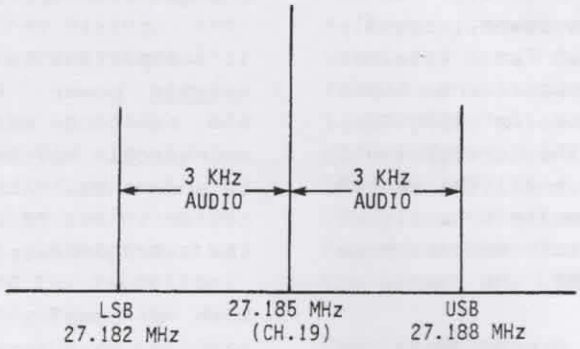
1. No Transmit on either sideband; AM (and FM) works normally.
2. No Receive on either sideband; AM (and FM) works normally.
3. No Transmit and/or Receive on only one sideband; all other functions normal.
4. Distorted or garbled reception on one or both sidebands; AM (and FM) normal.
5. No Clarifier control.
6. Distorted or garbled transmission which the receiving station is unable to clarify.
7. Low RF power output.
8. Poor sideband suppression.
9. Excessive transmitter bleedover interference to adjacent channels.

CHARACTERISTICS OF SSB

An RF carrier amplitude-modulated by a single sine wave contains three different frequencies: the carrier frequency, a frequency equal to the difference between the carrier and modulating frequency, and a frequency equal to the sum of the carrier and modulating frequency. In the case of a complex modulating waveform like a voice, the sum and difference depends upon the highest voice frequency. So these sum and difference frequencies always extend from the center carrier by an amount equal to the <u>highest</u> audio modulating frequency.

The sum is known as the Upper Sideband or USB, and the difference the Lower Sideband or LSB. For example, a Ch.19 carrier signal modulated by a 3 KHz audio tone would have the USB at 27.185 MHz + 0.003 MHz = 27.188 MHz, and LSB at 27.185 MHz - 0.003 MHz = 27.182 MHz. The 3 KHz audio figure is commonly used as a textbook

FIGURE 6-1
FREQUENCY DISTRIBUTION OF TYPICAL DOUBLE-SIDEBAND SIGNAL



example (including here), but the real maximum audio figure is actually closer to 2.4 KHz, or even just 2.1 KHz in some systems. Figure 6-1 shows the spectrum distribution of this signal.

Note that LSB inverts the signal: the higher the modulating frequency, the lower the RF frequency, while USB is directly proportional to the modulating frequency. In the early days of radio that made LSB more difficult to process at higher carrier frequencies. This led to a traditional use of LSB below about 10 MHz, with USB above. There's no longer any technical reason for this, but the tradition is still generally observed today; most HF operation is USB. Interestingly, the FCC certification only requires that the transmitter be capable of USB; LSB is optional for the manufacturer!

SSB Pros & Cons

A major advantage of SSB is its narrower bandwidth, only half that of a comparable AM signal. This means more stations can fit in the available spectrum space. Because of this, CB manufacturers tend to advertise radios as having many more channels than they really do. A typical American 40-channel AM/SSB radio may be advertised as a "120-Channel" radio, meaning 40 AM, 40 USB, and 40 LSB channels. Since only one mode can be used on one channel at a time, it's a very deceptive practice. Make sure your customers know the truth!

SSB also isn't affected by selective fading. This is a form of audio distortion resulting from the fact that slightly different frequencies may not arrive at the receiver at exactly the same instant. No doubt you'd heard such garbling while listening to a rapidly-fading AM shortwave station. If the USB was reflected from the ionosphere at a slightly different angle than the LSB, you'll hear the distortion. When bad enough, the sidebands may completely cancel each other out so the intelligence is lost. But with SSB, there's no definite phase relationship between the sidebands and the carrier, so this can't happen. And with no carrier, there's no annoying heterodyne to interfere with reception like on AM. Finally, the narrower SSB bandwidth greatly improves receiver IF selectivity.

The most important advantage to CB operators is the higher transmitted power. Theoretically SSB has a total advantage of 9 dB over a comparable AM signal: 6 dB resulting from more efficient transmitter use, and 3 dB resulting from the narrower receiver bandwidth with its higher S/N ratio and superior propagation characteristics. A 9 dB improvement is equal to eight times the power of comparable AM! This means greater communications range between SSB stations. A realistic average improvement is closer to 3 dB (2:1 power gain), but even this means a 25-watt SSB signal is equal to a 100-watt AM carrier. (Remember, 100% AM modulation adds 50 watts of extra power to the sidebands, of which only one 25-watt sideband would actually be used.)

Among the SSB disadvantages are its higher cost and circuit complexity. The extra circuitry must generate and detect the SSB signal, and do so with extreme frequency stability. This means much better voltage regulation, more stable oscillators, a special "clarifier" circuit to demodulate the received audio, more complicated electrical and mechanical mode switching, an expensive IF crystal filter, a physically larger chassis and cabinet, etc.

AM & SSB Power Comparison

An AM signal at 100% modulation has 2/3 of its power in the carrier, and only 1/3 of its power in the sidebands. So a 100-watt carrier would add an extra 50 watts of audio power, equally divided between both sidebands, for a total of 150 watts. Since both the upper and lower sidebands have exactly the same intelligence, one of these can be removed. The carrier isn't needed and can also be removed. All the wasted power is eliminated. This results in a signal with half the spectrum bandwidth and a more efficient use of the transmitter.

SSB power output is directly proportional to the power of the modulating audio signal. With no mike input, there's no RF output. An SSB signal is rated in terms of its "peak envelope power" or PEP. This is defined as the maximum transmitter power when the modulating voltage is at its peak. PEP has a direct effect on allowable signal distortion for any particular transmitter. For CB transmitters which allow 4 watts of unmodulated AM carrier output, the allowable SSB power is 12 watts PEP. This is based on the assumption that the typical voice has a peak-to-average audio voltage ratio that doesn't exceed about 3:1, or 4 W x 3 = 12 W PEP equivalent. (Review the photos on Page 169, which show how the peak-to-average power can be different for different voices, or be purposely changed with speech processing.)

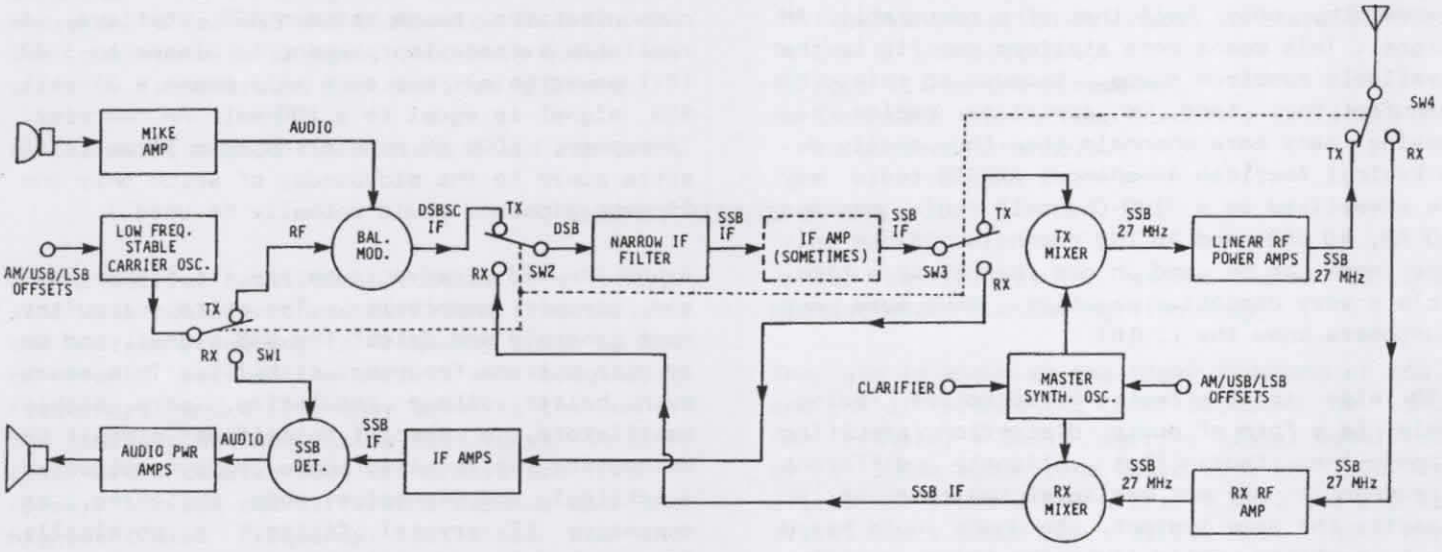
It's important to distinguish between peak and <u>average</u> power. Peaks don't occur very often, and can't be measured on a meter because the mechanical movement can't respond fast enough to show them. And even if it could, your eye couldn't see it anyway. The meter responds to the average power of several RF cycles instead.

With a complex waveform like a voice, the average measurement is the only one that counts. Wattmeters that read peak SSB power use special delay circuits to keep the meter needle in one place long enough to view. When using a single or two-tone sine wave input instead of a voice, the energy is constant and the peak power measurements then make more sense. If your customer happens to watch you tuning his rig, make sure he understands this difference; otherwise he might expect to see the wattmeter hitting the "12 W" power mark all the time when speaking into the mike. Just ain't so!

SSB SIGNAL GENERATION

Figure 6-2 shows the basic SSB CB transceiver. The dotted lines indicate the required T/R mode switching. The SSB signal is produced by first generating a relatively low-frequency, highly stable RF carrier. This signal combines with the mike audio in a special mixer called a "Balanced Modulator" which produces sum and difference frequencies. The carrier and original modulating audio are then removed, leaving only the sidebands which are at RF <u>but</u>

FIGURE 6-2
BLOCK DIAGRAM OF SSB CB TRANSCEIVER



changing at the audio rate. The double-sideband suppressed-carrier (DSBSC) RF signal is then applied to a highly selective crystal filter which removes one sideband. The result is an SSB IF signal which can then be translated up to the required 27 MHz by further mixing, and amplified by Class AB linear RF power stages.

Reception is basically just the opposite of this process, where the 27 MHz SSB signal is converted down to an IF, and mixed with a suitable carrier to demodulate the audio. In CB radios the same carrier that generates the transmitted signal is also used for reception. ("SW1.") The crystal IF filter may also be shared by Receive and Transmit, and sometimes one IF amplifier stage is too. ("SW2," "SW3.")

THE CARRIER OSCILLATOR

A 27 MHz SSB signal is too difficult to process directly and economically. Tuned circuits are critical. A received SSB signal off frequency as little as 40 Hz may be noticeably distorted, and at only 150 Hz away it may be impossible to properly demodulate and will sound like "Donald Duck" to the listener. To avoid this problem the signal is always generated at a lower or intermediate frequency, where tuned circuits aren't as touchy. This carrier frequency is purposely chosen to be near the receiver's IF, for reasons that will soon become apparent.

To further aid stability, all SSB circuits use highly regulated supply voltages. The Carrier Oscillator also functions on Receive to reinsert the missing carrier for proper SSB detection, and runs all the time on AM to provide the proper synthesizer mixing signals.

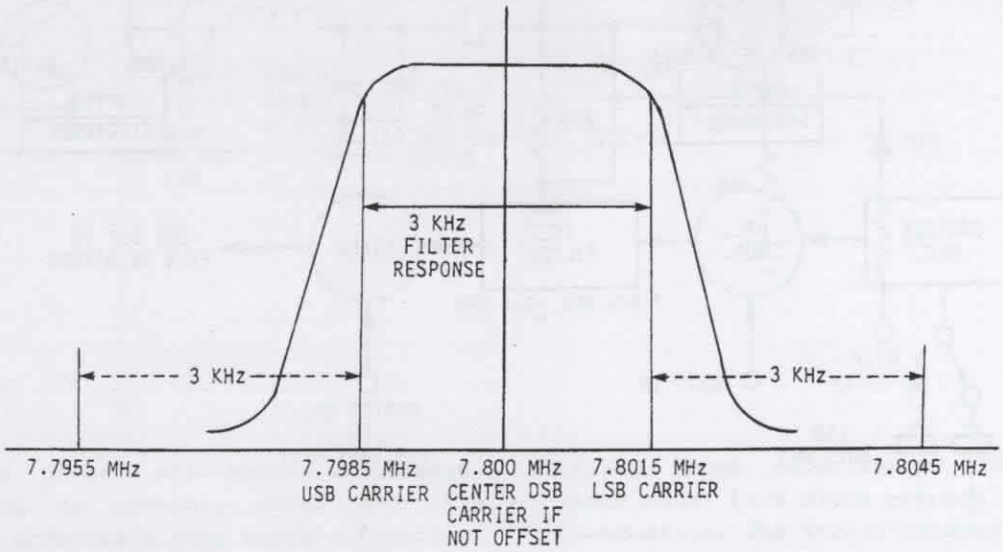
A crystal-controlled Colpitts oscillator is used for the Carrier Oscillator, and its frequency is usually 7.8 MHz, 10.695 MHz, or 11.275 MHz, which is also the 1st AM IF. (A few old radios like the Tram D201, Browning Mark II, III, IV, and the CPIs had their own unique IFs.) Special circuits shift this oscillator a few KHz around its center frequency to generate the proper AM, LSB or USB signal offsets.

Carrier Offsets

Figure 6-2 indicated a single narrow IF filter used to remove one sideband, which is the standard CB method. To do this, the carrier frequency must be placed along one side of the filter passband instead of in the exact center, which means shifting it up or down slightly. Why? Assume that the filter has a flat 3 KHz response, dropping off sharply beyond this. If the DSB RF carrier is at exactly 7.800 MHz, and the highest modulating frequency is 3 KHz, the total bandwidth will be 7.800 MHz ±0.003 MHz, or 7.797-7.803 MHz. The filter passband only has room for 3 KHz of this 6 KHz DSB signal, or 1.5 KHz from each sideband. This means signals from only 7.7985-7.8015 MHz can pass.

Figure 6-3 shows the effect of shifting the carrier frequency slightly. For example, if the

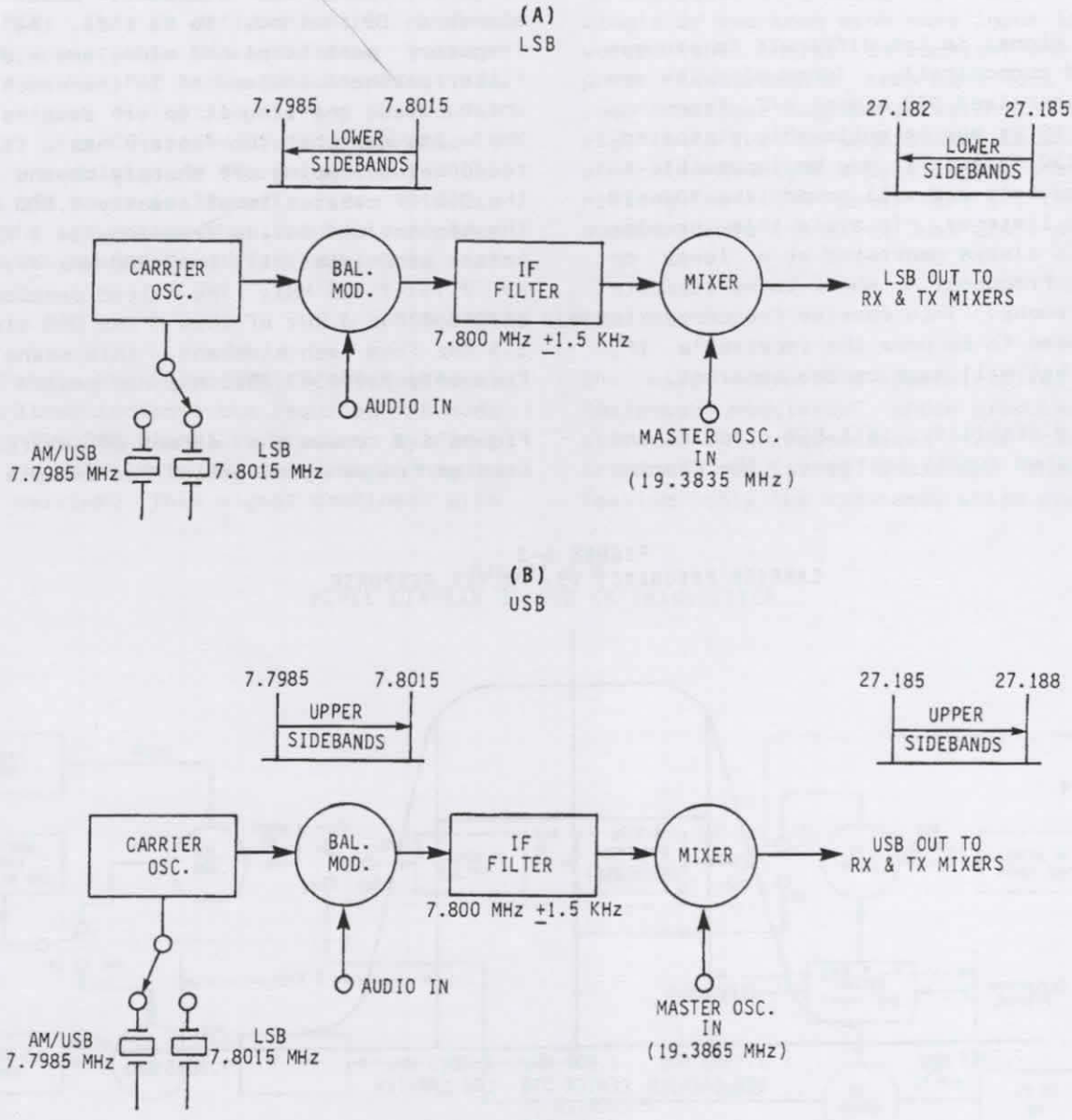
FIGURE 6-3
CARRIER FREQUENCY VS. FILTER RESPONSE



USB carrier frequency is 7.7985 MHz, the 6 KHz of audio then results in 7.7985 MHz ±3 KHz, or 7.7955-7.8015 MHz. Only the 3 KHz wide band of frequencies that's above 7.7985 MHz (the upper sideband) can pass; the lower 3 KHz will fall either on the skirt or completely outside the filter passband and be sharply attenuated. The same is true for LSB, where centering the carrier on 7.8015 MHz allows the lower 3 KHz of audio frequencies from 7.8015-7.7985 MHz to pass, but removes those from 7.8015-7.8045 MHz, which fall outside the filter passband. For correct SSB reception the process is reversed, with the carrier reinserted using the same offset characteristics as the transmission.

The choice of center frequency for the sideband filter depends upon whether or not it's needed for AM reception too. If so, the exact center IF is used and the AM receiver will be single-conversion because only one of the two sidebands is actually detected. And the AM Transmit signal never passes through the sideband filter anyway. But when AM Receive is dual-conversion, the AM and SSB signals take separate IF paths after the 1st mixer. The AM IF path has its own monolithic crystal filter or ceramic filters for selectivity. (Sometimes

FIGURE 6-4
SSB SYSTEM USING SINGLE FILTER AND OSC. OFFSETS (CH. 19)



a monolithic crystal filter is placed right after the 1st mixer, before the AM and SSB signals branch off.) This explains why many radios have sideband filters which are offset slightly (10.6935 MHz or 11.2735 MHz); they're purposely centered between the 10.692 MHz LSB/ 10.695 MHz USB or 11.272 MHz LSB/11.275 MHz USB carriers, which allows the 3 KHz of total audio sidebands to fit within the filter passband.

The use of offsets is shown in Figure 6-4. Each mode's crystal is cut slightly higher or lower than the center carrier frequency. The crystal offsets are 1.5 KHz or 2.5 KHz, depending upon the particular circuit. AM is usually (but not always) associated with USB, so that only two crystals are needed here. One early Uniden PLL type chassis (Cobra 138/139XLR and similar) used three individual crystals, an expensive method. Regardless of mixing scheme, each mode has a slightly different carrier frequency.

The preceeding method was used in most older synthesized radios and is now outdated, but there are still many popular radios using it.

The current trend, even cheaper, uses a single Carrier Oscillator crystal with switchable inductance or capacitance for each mode offset. Three popular methods are described next.

Figure 6-5 shows the capacitance offset method typical of Cybernet and other manufacturers. The sideband filter is 10.6935 MHz for use on SSB only; in these models AM Receive is dual-conversion and the filter's not shared. The crystal is used in its series-resonant mode and has a series RF ground through CT5/C66 for AM/USB. The combination will pull the crystal up in frequency, to 10.695 MHz. This explains why the crystal itself is 10.692 MHz rather than exactly 10.695 MHz. Q11 is a switch which conducts on LSB, adding the capacitance of CT4/C65 and the series inductance of L14 to pull the crystal down to 10.692 MHz. C65 and C66 add stability and temperature compensation, since they divide the RF currents and prevent excess heating of the trimmers. D10/R47 cut off Q12 for AM Receive by raising its emitter to within 0.6 V of the base voltage; the carrier only needs to be reinserted for SSB reception.

FIGURE 6-5
CAPACITANCE METHOD OF CARRIER OSC. OFFSETS
(Cybernet PTBM048 chassis: JC Penney 981-6247, HyGain 2705, Lafayette Telsat SSB140, Midland 79-892, etc.)

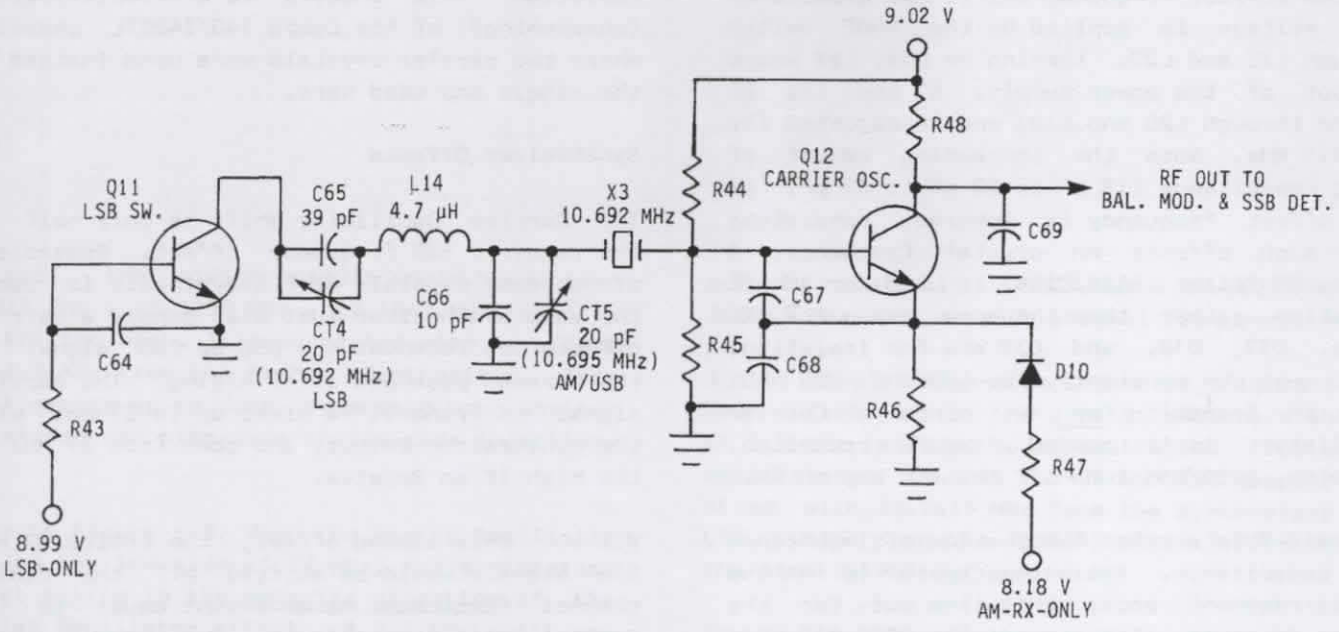
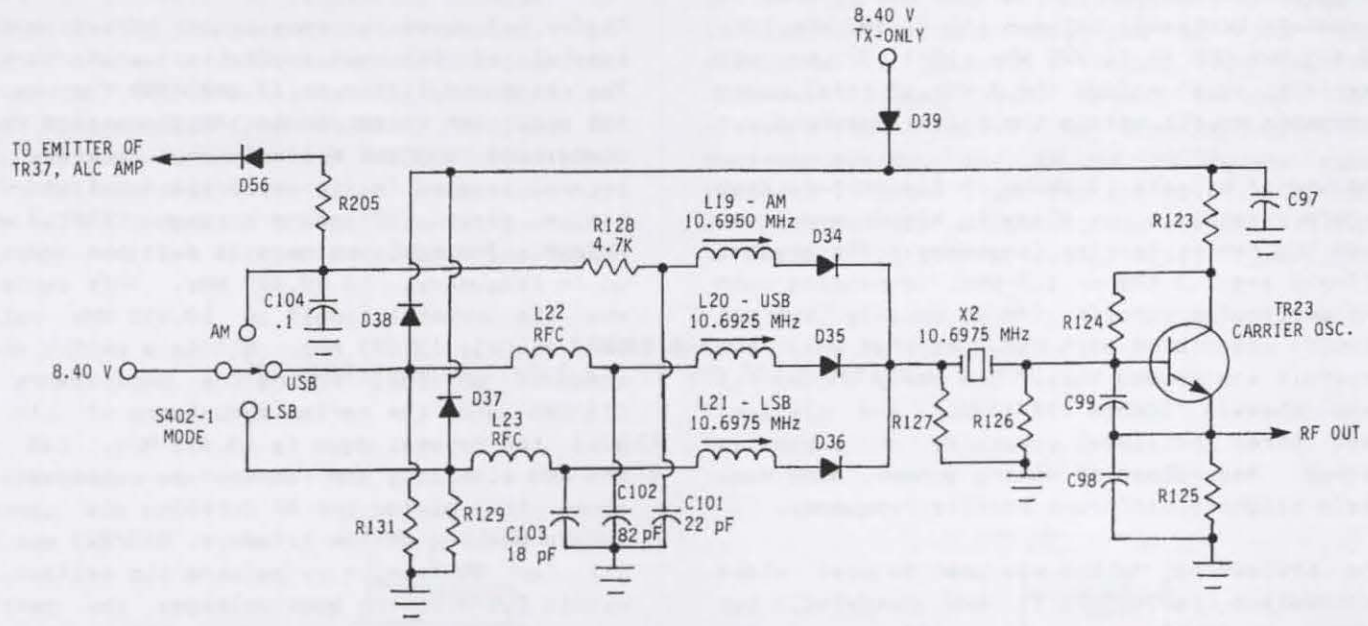


Figure 6-6 has offsets with series inductance. Diode steering is commonly used, and it's important to understand each diode's function. A combination of a tunable series inductor and fixed shunt capacitor is diode-switched for each mode. Each diode grounds through R127 when conducting. The series-resonant crystal mode is used again, which means that series inductance

FIGURE 6-6
INDUCTANCE METHOD OF CARRIER OSC. OFFSETS
(Cobra 146GTL, President AX144, Realistic TRC451, Uniden PC244, etc.)



will lower the crystal frequency. Again, this explains why the actual crystal is 10.6975 MHz rather than exactly 10.695 MHz.

The crystal is grounded for RF by each coil's associated capacitor, which is carefully chosen for the correct frequency shift. For example on USB, voltage is applied by the MODE switch through L22 and L20, turning on D35. L22 keeps RF out of the power supply. X2 has its RF ground through L20 and C102 and is adjusted for 10.6925 MHz. Note the increasing amount of shunt capacitance (18 pF to 22 pF to 82 pF) as the offset frequency is lowered, consistent with such effects on crystal frequency. A simple RC filter (R128/C104) is used for AM RF isolation rather than the more expensive RF choke. D37, D38, and D39 are for isolation; TR23 must run constantly for LSB and USB but only on Transmit for AM, since a Carrier Oscillator isn't needed for AM reception. Likewise, R205/D56 turn off the ALC amp on AM.

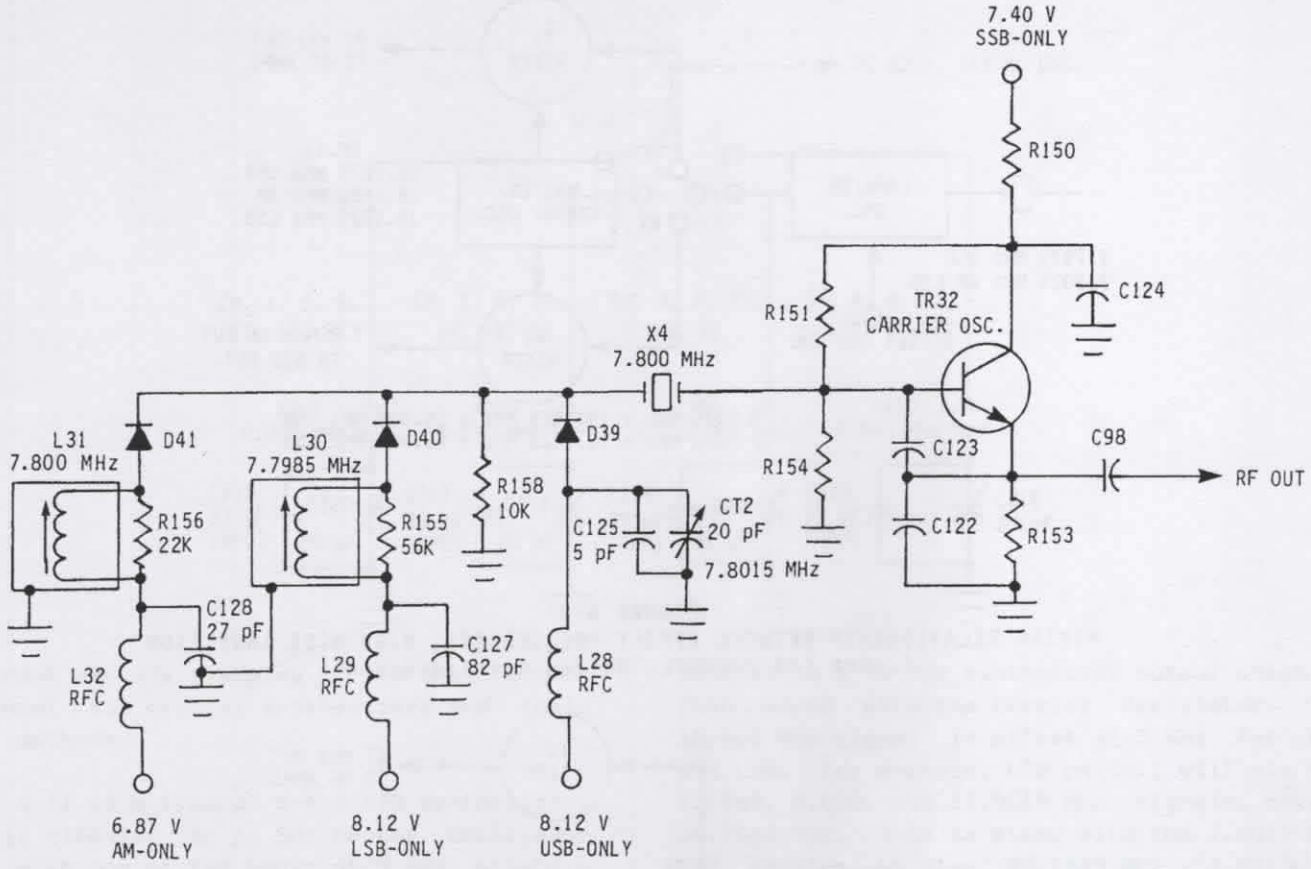
Figure 6-7 is another combination of inductance and capacitance. Again the crystal is in the series-resonant mode, this time cut for the center AM range. Steering diodes D39, D40, D41 will each ground through R158. The series capacitance of CT2/C125 pulls the crystal up to 7.8025 MHz for USB, with C125 for temperature compensation again. L30/C127 pull it down to 7.7975 MHz for LSB. AM is adjusted for exactly 7.800 MHz. R155 and R156 lower the Q of L30 and L31 respectively to broaden tuning; note how R155 is greater, lowering the Q of L30 further since LSB is more critical than AM. L28, L29, and L32 are RF chokes used for power supply isolation. This chassis is a simplification (cheapening?) of the Cobra 140/142GTL chassis, where two carrier crystals were used instead of the single one used here.

Synthesizer Offsets

The Carrier Oscillator shift is only half of the required SSB frequency offset. Regardless of whether crystal- or PLL-synthesis is used, the main synthesizer must also supply a pair of offsets to recenter the USB or LSB signal in the correct passband after mixing. The carrier signal on Transmit is mixed up to 27 MHz with the synthesizer output, and down from 27 MHz to the high IF on Receive.

Without this second offset, the entire 27 MHz SSB signal would be shifted off the center channel frequency by an amount equal to the Carrier Oscillator offsets. For example, back in Figure 6-4 the LSB carrier was offset to 7.8015 MHz and the 19 MHz LSB synthesizer was offset by -1.5 KHz, to 19.3835 MHz. If this signal had remained centered at 19.3850 MHz

FIGURE 6-7
COMBINATION INDUCTANCE/CAPACITANCE OFFSETS
(Cobra 148/2000GTL, Uniden Grant/Madison)



instead, the mixing result would have been 7.8015 MHz + 19.3850 MHz = 27.1865 MHz, exactly 1.5 KHz too high. It's corrected with an offset of -1.5 KHz from the Master Synthesizer. This shift may go up or down, depending upon whether the mixers use high-side or low-side injection.

Refer to Figure 6-8. When the Master Oscillator runs on the low side of 27 MHz, the synthesizer offset shifts in the opposite direction of the Carrier Oscillator offset. A 2.5 KHz shift was added to the AM/LSB carrier but subtracted from the 19.1650 MHz center synthesizer frequency. For Ch.1 AM/LSB, mixing the 7.8025 MHz AM/LSB carrier with the 19.1625 MHz LSB synthesizer output results in 7.8025 MHz + 19.1625 MHz = 26.965 MHz, the correct channel frequency.

In the case of high-side injection, Figure 6-9, both offsets are in the same direction; a shift of 1.5 KHz is added to or subtracted from both oscillators. Thus a 7.7985 MHz LSB carrier is mixed with 34.7635 MHz from the synthesizer on LSB, which produces 34.7635 MHz - 7.7985 MHz = the same 26.965 MHz again.

Trying to keep all these offsets straight and remembering which one goes which direction gets confusing, but it's simple if analyzed in block diagram form. The additional examples from the 23-channel era described shortly will help.

FIGURE 6-8
MIXING RELATIONSHIP BETWEEN OFFSET FREQUENCIES, LOW-SIDE INJECTION
(SBE Sidebander IV, V, Console V)

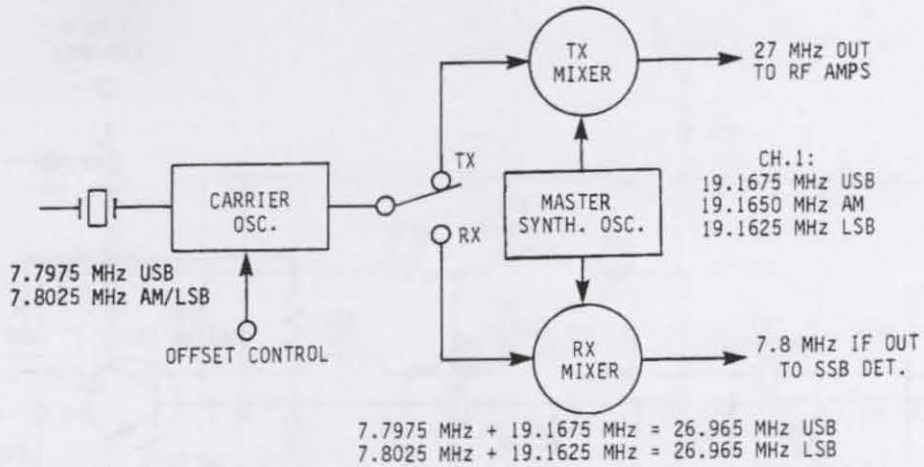
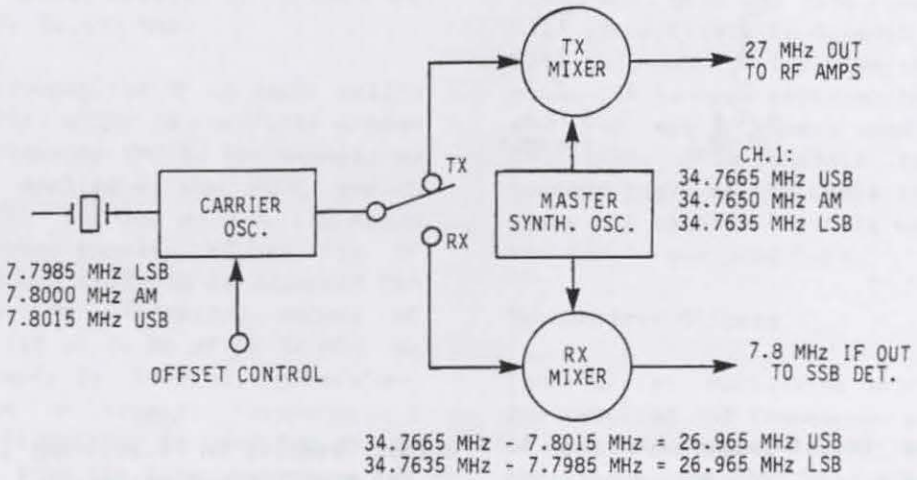


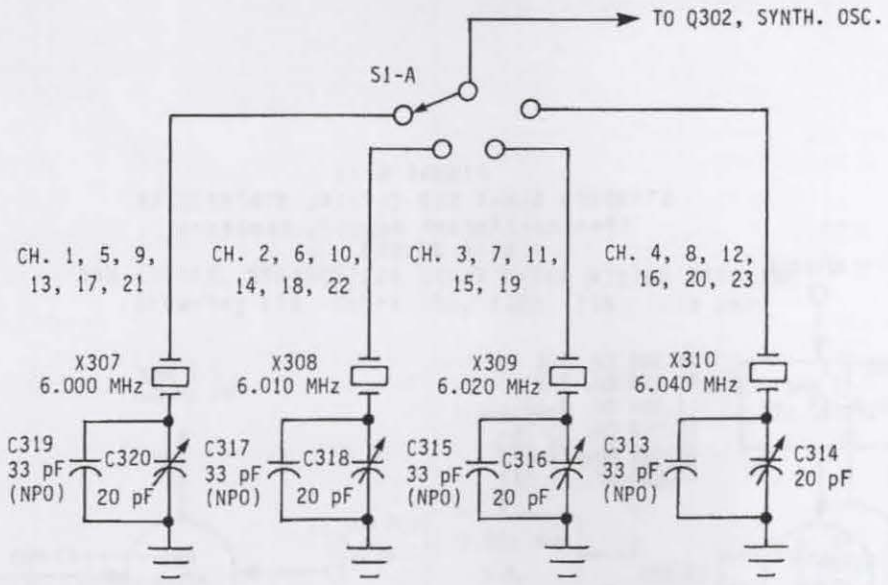
FIGURE 6-9
MIXING RELATIONSHIP BETWEEN OFFSET FREQUENCIES, HIGH-SIDE INJECTION
(Cobra 148/2000GTL, Uniden Grant/Madison)



Crystal Synthesizer Offsets

The crystal synthesizers for 23-channel SSB radios are only slightly more complex than the AM circuits described in CHAPTER 3. Unlike AM synthesizers, SSB crystal synthesizers usually include small trimmer capacitors of about 20 pF on every crystal for exact frequency netting. These trimmers are ceramic for good stability. They're shunted by small fixed ceramic disc capacitors of approximately the same value for temperature compensation, and have a "negative temperature coefficient" of 150 ppm or less. (This means the capacitance will decrease less than 150 parts-per-million per 1°C. increase in temperature.) Figure 6-10 shows the idea.

FIGURE 6-10
SHUNT STABILIZERS FOR CRYSTAL-SYNTHESIZED SSB OSCILLATORS
(Browning LTD, Cobra 132, 132A, 135, Tram D60)



Shown next are six examples of the most common 23-channel SSB crystal synthesizers and their offset methods.

Figure 6-11 is a typical 6-4-4 SSB synthesizer. In this circuit, an 11 MHz Master Oscillator mixes with one of two banks of 7 MHz crystals to produce a 19 MHz output. Two crystals are used for the Carrier Oscillator, as previously described. For example, Ch.1 AM/USB connects the 11.805 MHz and 7.3615 MHz crystals, mixing together to result in 11.805 MHz + 7.3615 MHz = 19.1665 MHz. Mixing this product with the 7.7985 MHz AM/SSB Carrier Oscillator results in 19.1665 MHz + 7.7985 MHz = 26.965 MHz. For LSB, the synthesis will be 11.805 MHz + 7.3585 MHz = 19.1635 MHz + 7.8015 MHz = 26.965 MHz again.

Note that there's no separate AM offset. LSB is offset only 1.5 KHz at the synthesizer output so it remains within the filter passband, and another 1.5 KHz in the final mixing with the Carrier Oscillator. You'll encounter many SSB synthesizers like this one; the three crystal banks may use slightly different frequencies, but will still operate on the 6-4-4 principle.

A slight variation on this circuit is shown in Figure 6-12. Here two 6 MHz and 16 MHz crystal banks mix to produce a 22 MHz signal, and then mix with a fixed 12.800 MHz oscillator. This results in a 34 MHz synthesizer output which is then mixed with the Carrier Oscillator. The 12.800 MHz signal is offset ±1.5 KHz for USB and LSB. For example, USB on Ch.1 will mix the 15.965, 6.000, and 12.8015 MHz signals, making 34.7665 MHz. This is mixed with the 7.8015 MHz USB carrier to give 34.7665 MHz - 7.8015 MHz = 26.965 MHz. This particular scheme is just as complex as the preceeding example, but uses the superior high-side mixer injection instead.

Figure 6-13 has several advantages over the preceeding circuits: a total of three rather than four oscillators are required, only one Carrier Oscillator crystal is required, and no carrier offsets are needed at all. At first glance its extra complexity seems counter-productive from a manufacturing standpoint, since it eliminates two crystals but adds a bunch of other parts instead. However we're talking literally pennies in cost differences between methods. From a marketing standpoint, every $1 in manufacturing cost increase adds roughly $5 to the final retail price!

In this circuit, 11 MHz and 8 MHz crystals mix to produce two different groups of synthesizer frequencies in the 19 MHz and 34 MHz ranges. This means that both low-side and high-side injection respectively are used, which explains why no carrier offsets are needed. This is one

FIGURE 6-11
STANDARD 6-4-4 SSB CRYSTAL SYNTHESIZER
(Pearce-Simpson Bengal, Panther)

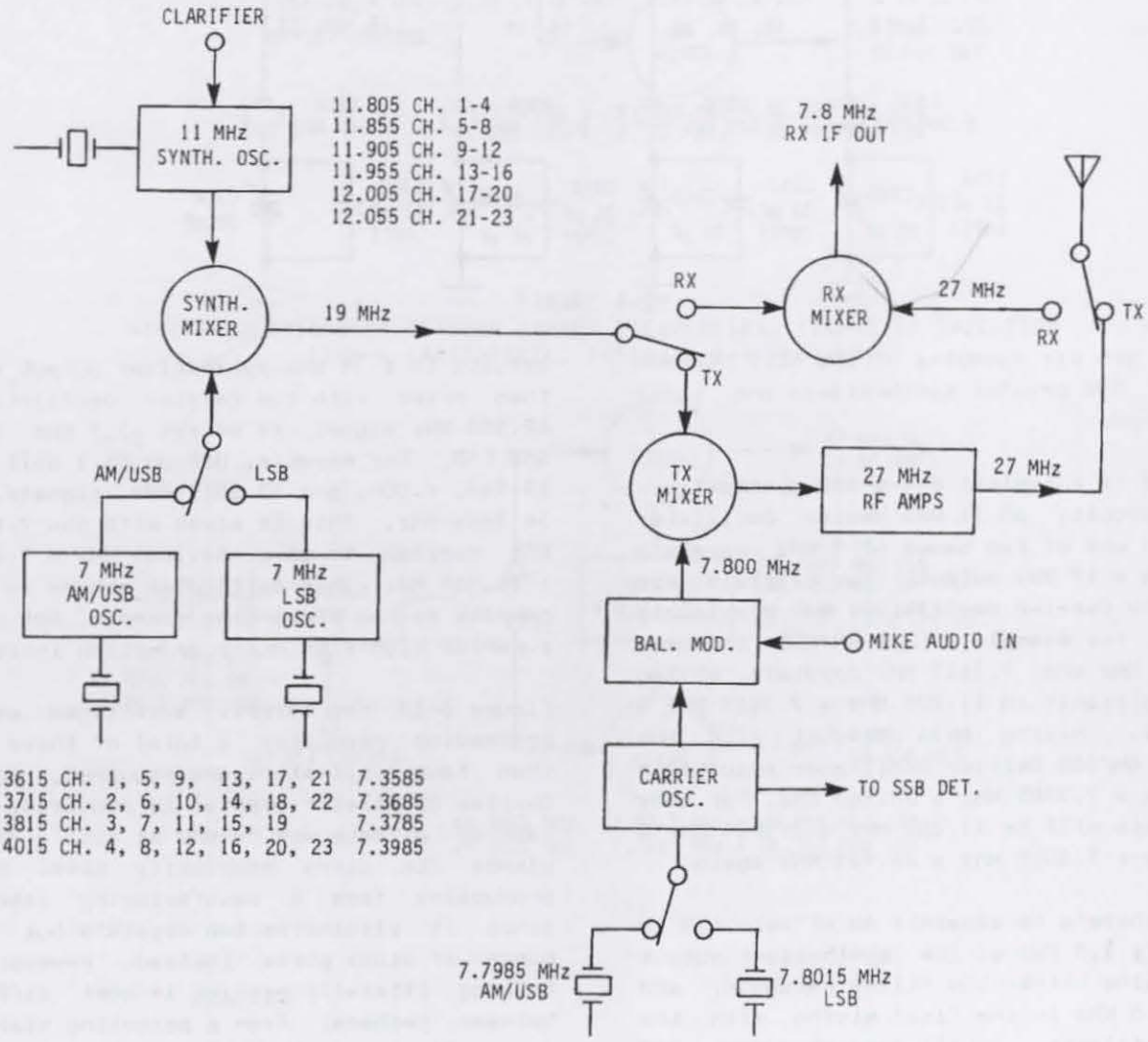


FIGURE 6-12
SSB CRYSTAL SYNTHESIZER USING FIXED MIXING FREQUENCY
(Browning LTD, Cobra 132, 132A, 135, Tram D60)

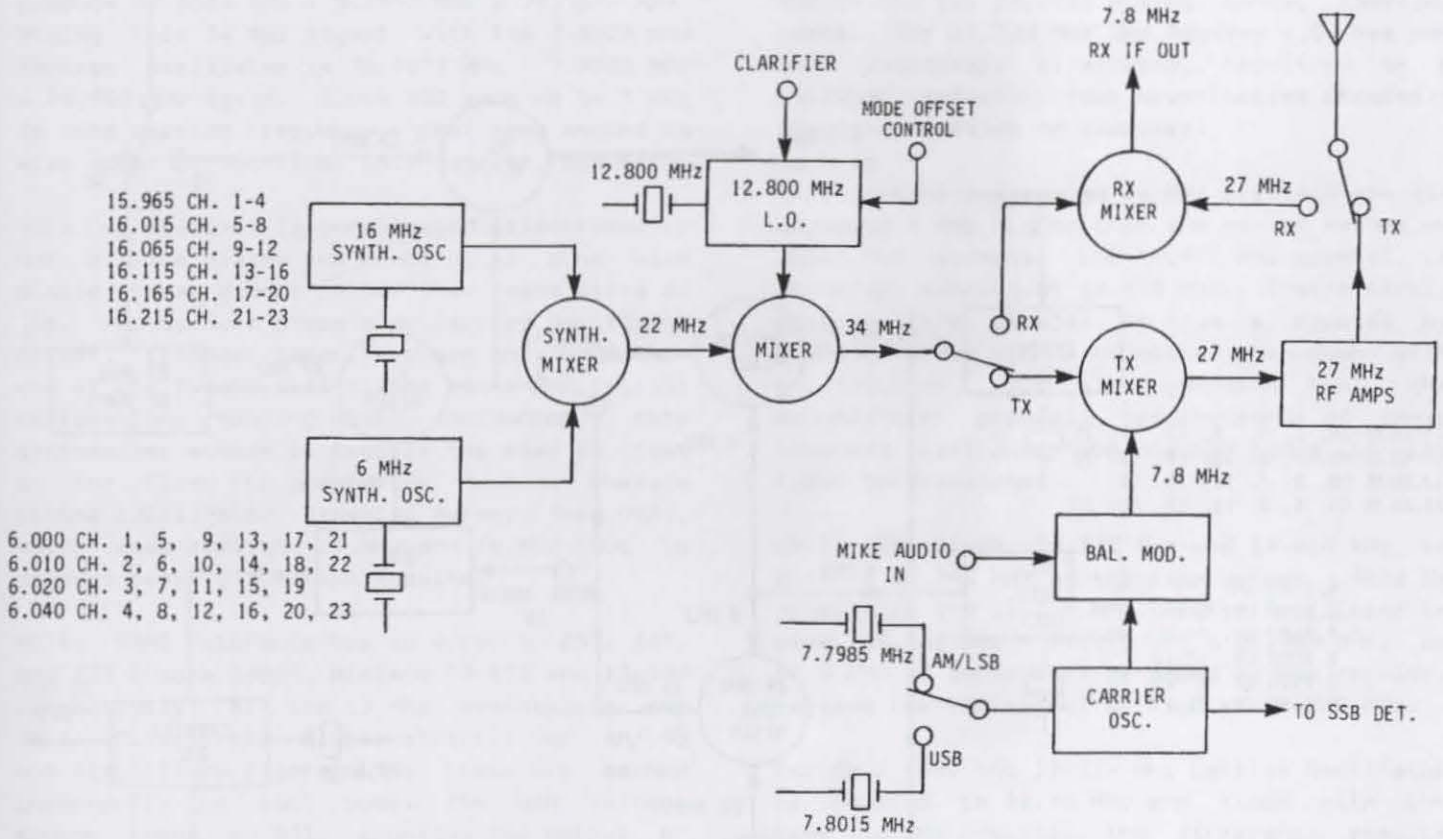
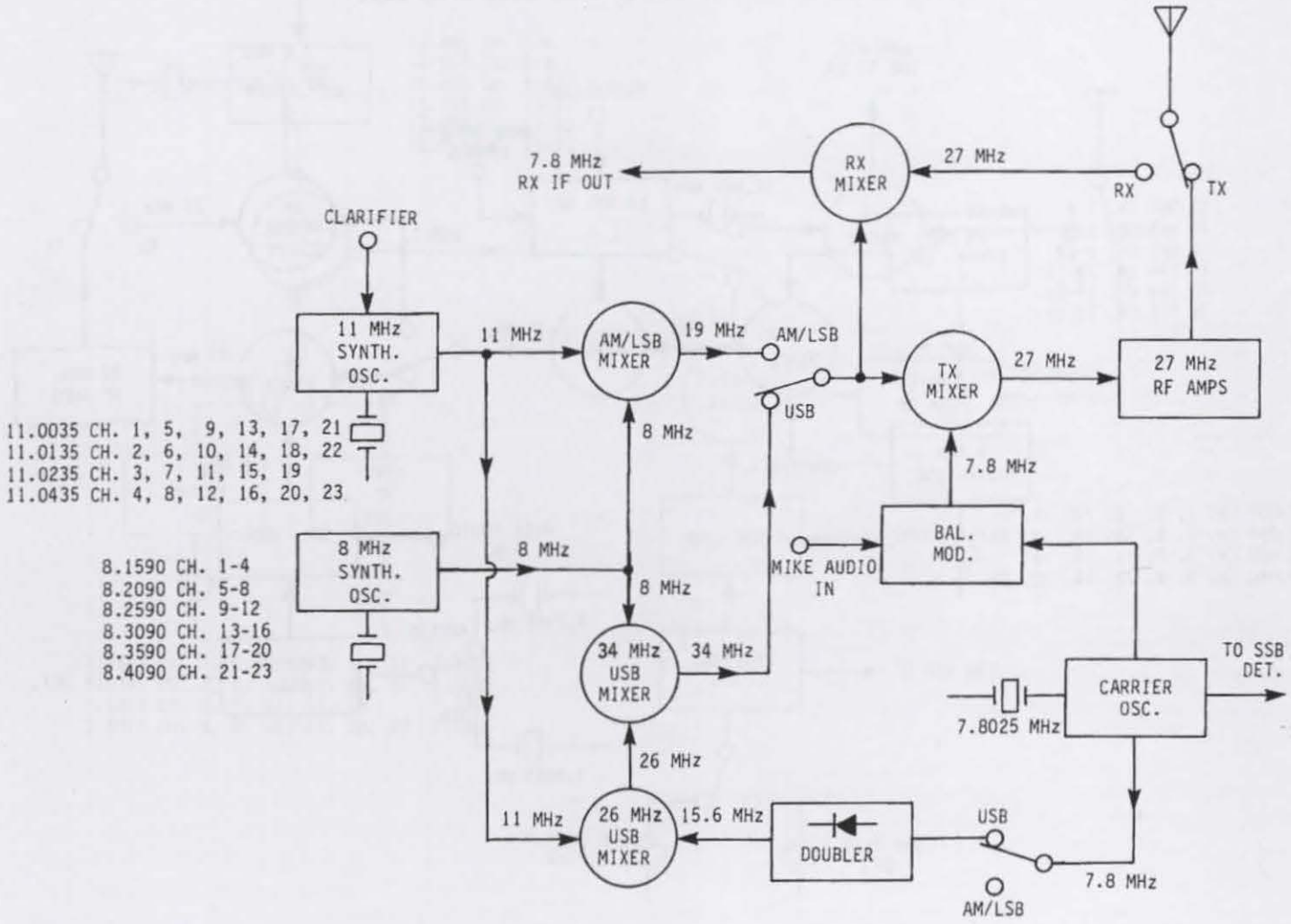


FIGURE 6-13
SSB CRYSTAL SYNTHESIZER USING BOTH HIGH-SIDE & LOW-SIDE INJECTION
(Cobra 138/A, 139/A, Johnson Viking 352, Midland 13-893, 13-895,
Pace Sidetalk 1000M, 1000B, etc.)



of those special cases where AM is associated with LSB rather than USB. For example, the Ch.1 AM/LSB mixes 11.0035 MHz and 8.1590 MHz to yield 19.1625 MHz. Mixing with the 7.8025 MHz Carrier Oscillator, the result is 19.1625 MHz + 7.8025 MHz = 26.965 MHz. Since LSB subtracts up to 3 KHz from the carrier frequency, that same amount is also being subtracted from the final Ch.1 center carrier frequency.

For USB the circuit is a bit more complicated. The 7.8025 MHz signal is first doubled to produce 15.605 MHz and then mixed only with the 11 MHz crystal. This results in 11.0035 MHz + 15.605 MHz = 26.6085 MHz. The 26 MHz composite signal is then mixed with the 8 MHz crystal to produce 26.6085 MHz + 8.1590 MHz = 34.7675 MHz. Mixing this 34 MHz signal with the 7.8025 MHz Carrier Oscillator is 34.7675 MHz - 7.8025 MHz = 26.965 MHz again. Since USB adds up to 3 KHz to the carrier frequency, that same amount is also added to the final Ch.1 carrier frequency.

This synthesizer is complicated electrically, but all the mixing and doubling is done with simple, cheap diodes rather than transistors or ICs. And because there's no Carrier Oscillator offset, trimmer capacitors are only needed on one of the two crystal mixing banks for initial calibration, reducing costs. Incidentally, this synthesizer scheme is exactly the same as that in the first PLL generation Toshiba chassis (Cobra 132/135XLR, Browning Baron, Tram D62), which used separate 19 MHz and 34 MHz VCOs to produce exactly the same results.

NOTE: SAMS Fotofacts has an error in #57, #69, and #73 (Cobra 138/A, Midland 13-893 and 13-895 respectively) at the 19 MHz synthesizer amp TR14. Circuitrace #10 is strictly for AM/LSB and Circuitrace #11 for USB; these are marked incorrectly in each book. The USB voltage source turns on D31, shunting the output of TR14 to ground via C90. This insures that the 19 MHz signal is turned off completely for USB.

Another popular synthesizer evolved in three stages of decreasing complexity. Figure 6-14 shows the first stage, which is basically identical to Figure 6-11 as far as mixing. One major difference is a bank of 7 MHz crystals being tripled to 23 MHz and mixed with separate 14 MHz crystal banks for AM/USB and LSB. This produces a 38 MHz synthesizer signal and high-side injection. The IF is now 11.275 MHz, the second main difference. A separate 11.730 MHz receiver L.O. mixes that down to 455 KHz.

In Figure 6-15, the 7 MHz tripler stage itself has been eliminated, allowing a 23 MHz bank of crystals to be used directly. Otherwise it's exactly the same as Figure 6-14. The 11.730 MHz 2nd L.O./2nd Mixer stages for dual-conversion AM Receive is only used in the better versions.

Figure 6-16 shows the final circuit revision. Note it's virtually identical to Figure 6-13, where separate AM/USB and LSB synthesizer outputs are also used and where no Carrier Oscillator offsets are needed. The synthesizers are now 38 MHz and 16 MHz respectively. This greatly reduces crystal requirements, to just eleven crystals for the entire radio. Trimmer and stabilizing capacitors are only used for one of the two crystal mixing banks, lowering costs. The 11.730 MHz 2nd Receive L.O. has now been completely eliminated, resulting in a somewhat inferior (but nevertheless cheaper!) single-conversion AM receiver.

In this synthesizer the 14 MHz crystals are all adjusted 3 KHz higher than the marked values on USB. For example, the 14.907 MHz crystal is actually running at 14.910 MHz. That's partly because it's cheaper to trim a crystal by pulling it up with a capacitor than down with an inductor. I'm also guessing that the manufacturer probably had thousands of these crystals left over from the LSB banks of the first two versions!

Ch.1 USB mixes 23.330 MHz and 14.910 MHz to give a 38.240 MHz synthesizer output. This is mixed with the 11.275 MHz Carrier Oscillator to give 38.240 MHz - 11.275 MHz = 26.965 MHz. Up to 3 KHz of audio will be added to the carrier, raising the USB signal as high as 26.968 MHz.

For Ch.1 LSB, the 11.275 MHz Carrier Oscillator is doubled to 22.55 MHz and mixed with the same 14 MHz crystal. The difference results in 22.55 MHz - 14.910 MHz = 7.64 MHz. This is mixed with the 23.330 MHz Ch.1 crystal to give 23.330 MHz - 7.64 MHz = 15.69 MHz. This last signal mixes with the carrier to result in 15.69 MHz + 11.275 MHz = 26.965 MHz. Since LSB subtracts up to 3 KHz from the carrier, the final output extends down as low as 26.962 MHz. On AM, transistor switching of some extra shunt capacitance at the 14 MHz oscillator centers its carrier frequency correctly.

Almost every 23-channel AM/SSB radio uses a variation of one of these six synthesizers. Specific crystal frequencies are usually the

FIGURE 6-14
SSB CRYSTAL SYNTHESIZER WITH HIGH-SIDE INJECTION IN ALL MODES
(Midland 13-896, 13-898B, Royce 1-640, etc.)

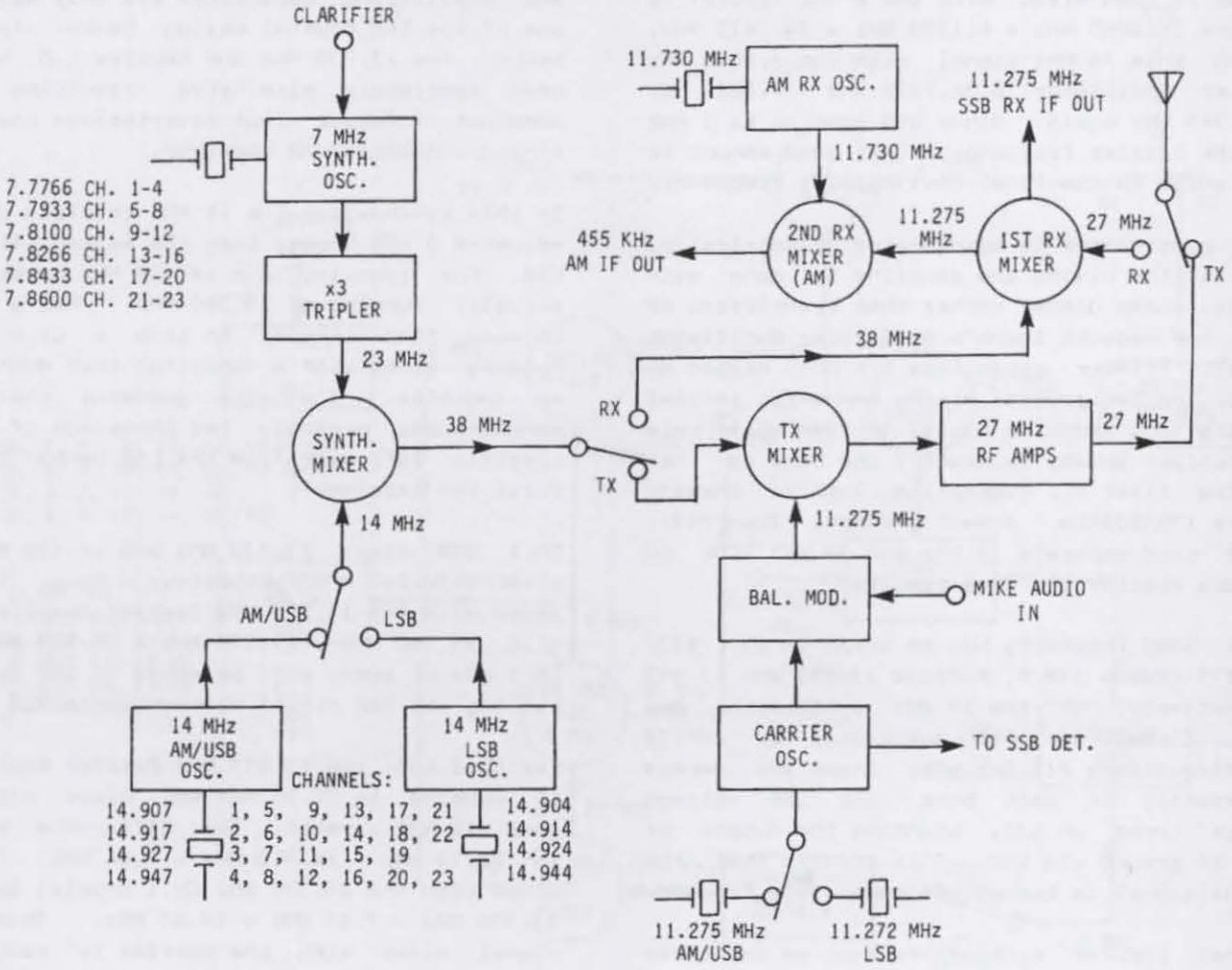


FIGURE 6-15
SIMPLIFIED SSB CRYSTAL SYNTHESIZER OF FIG. 6-14
(Lafayette Telsat SSB100, Realistic TRC47, TRC48, etc.)

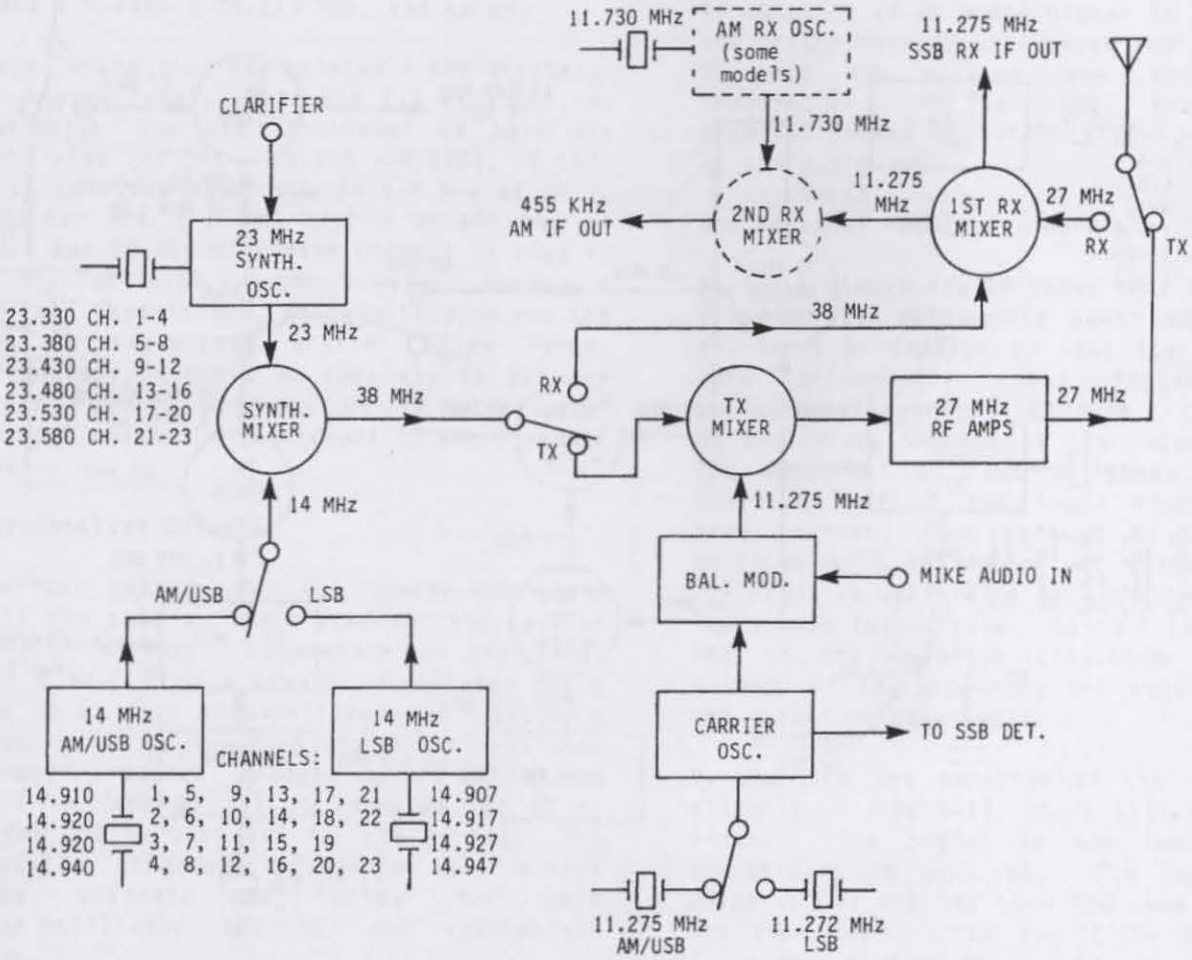
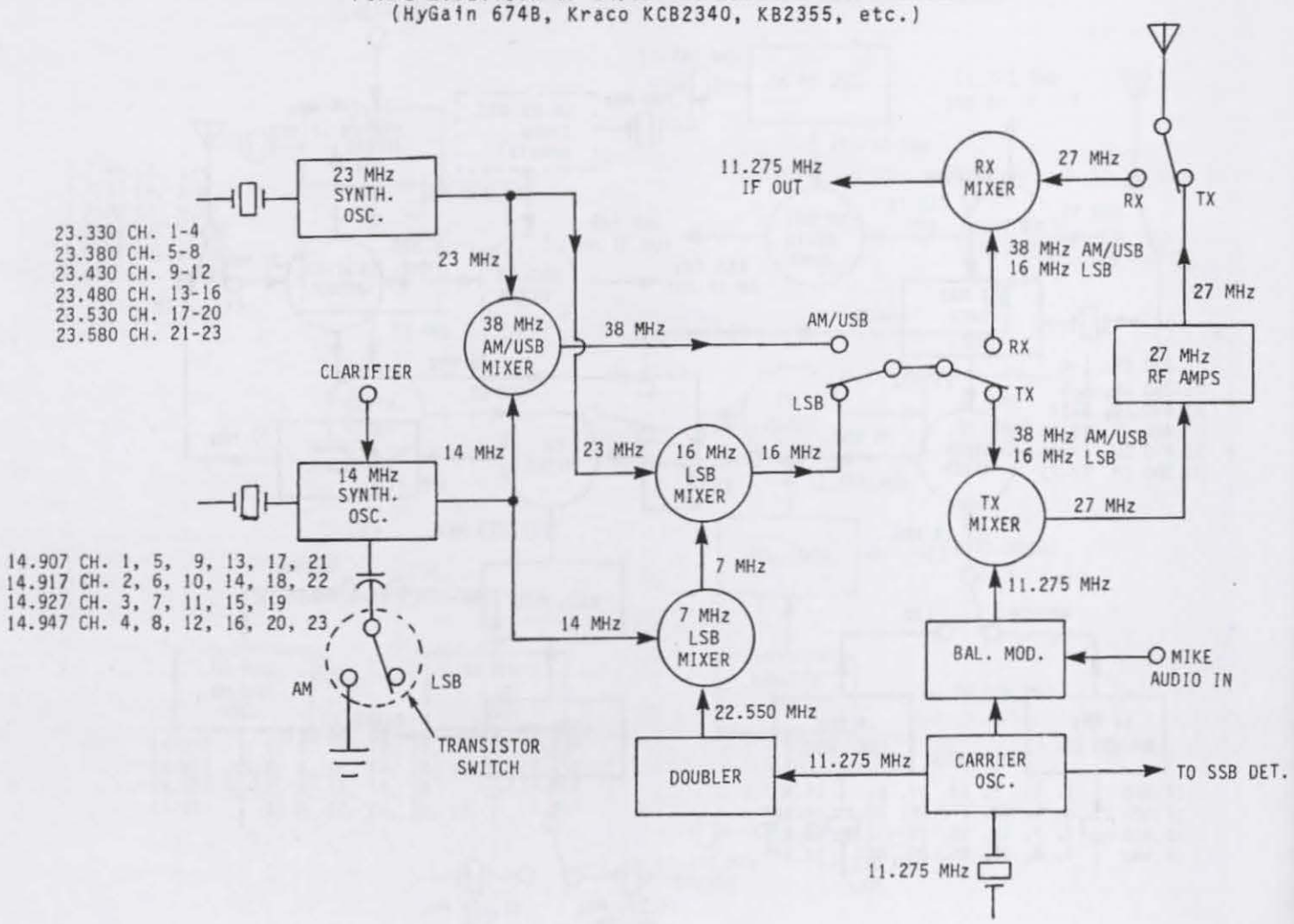


FIGURE 6-16
FINAL EVOLUTION OF 14/23 SSB CRYSTAL SYNTHESIZER
(HyGain 674B, Kraco KCB2340, KB2355, etc.)



only difference. Exceptions include some of the older tube-type rigs, and some of the old classic, premium rigs like the Tram D201 or Browning Mark II or Mark III. Close study of their schematics will reveal the specific mixing schemes. Crystal mixing charts for the most common SSB radios are found at the end of this chapter.

For conversion to the new 10-Meter Ham bands, add a total of 1.245 MHz to each of the six master mixing crystals from the preceding examples, and realign the radio. How did I figure this? If 28.500 MHz is the highest legal Novice SSB frequency, just subtract the former CB Ch.23, which is 27.255 MHz. This is a difference of [28.500 - 27.255] = 1.245 MHz. For example in Figure 6-16, add this amount to each of the six 23 MHz master mixing crystals; [23.330 + 1.245] = 24.575 MHz, and so on.

In cases where they use tripled 7 MHz crystals, (like Figure 6-14), you'd add 1/3 of 1.245, or 0.415 MHz. The old 23-channel CB band was 290 KHz wide (27.255 - 26.965 = 0.290), so this results in a new band from 28.210 MHz at Ch.1, to [28.210 MHz + 0.290 MHz] = 28.500 MHz at Ch.23. And if the Clarifier circuit is tied to this crystal bank, order crystals having a 10 pF Load Capacitance, which will give you the largest possible VXO crystal slide range. Unfortunately, there's no easy way to get the 100 KHz repeater offsets on 10 Meters with 23-channel crystal rigs because of the fixed IF filters.

PLL Synthesizer Offsets

The offset methods for PLL synthesizers are exactly the same as those used for the Carrier Oscillator offsets. Somewhere in the loop, you'll always find a crystal oscillator being pulled up or down by capacitance or inductance and controlled by steering diodes or transistor switches. A typical example is the MB8719 PLL circuit on Page 83; X4 is adjusted for AM by L23, for USB by L59, and for LSB by L22. The synthesizer alignment procedure will always include separate adjustments for both Carrier Oscillator offsets and synthesizer offsets.

THE SPEECH AMPLIFIER

This consists of one or two stages which will amplify the mike output up to a usable level. The only real difference from AM or FM is the destination of the mike audio. The AM path goes to a high-level audio amplifier and the FM path to a reactance modulator. SSB requires only a small fraction of the AM audio power, going instead to a special circuit called a "Balanced Modulator." Each audio path may be directly hard-wired, or use transistor/diode steering. Sometimes separate speech amps are used for each mode, as well as separate trimmers for AM and SSB mike levels. The AMC feedback loop is usually shared with SSB too. See CHAPTER 5 for circuit details.

THE BALANCED MODULATOR

The key to generating the SSB signal is in the Balanced Modulator, a special type of bridge circuit. The BM bridge consists of non-linear elements like diodes, or transistors biased to non-linearity. The Carrier Oscillator signal is applied and currents flowing within the bridge cancel each other out, resulting in zero RF output. If an audio signal is then applied, the bridge becomes unbalanced and the audio and RF mix to produce sum and difference frequencies. The net result is a double-sideband RF output signal, but changing at the audio rate.

How Balanced Modulators Work

At first glance the BM looks very much like the Class B push-pull audio power amp previously discussed in CHAPTER 4. But its operation is very different. See Figure 6-17, a conventional push-pull circuit. To operate as an amplifier, signals at the bases of TR1 and TR2 must be 180° out of phase. With the positive half of the input signal at TR1's base, current flow through T2 produces the positive half of the output voltage. During the negative half TR1's base goes negative, but TR2's base is positive. Current now flows from TR2 in the opposite direction through the primary of T2, producing the negative half of the output voltage cycle.

By changing the location of the input signal slightly, Figure 6-18, there will be no output signal. The signal is now applied to the transistors in parallel. The inputs at the bases of TR1 and TR2 have the same polarity at the same time. The result is that current flows down T2 from TR1 at the same time current is flowing up T2 from TR2, and vice-versa. Current flow through both transistors is equal but opposite; the magnetic fields cancel each other so there's no output signal. The circuit as it's shown here doesn't appear to be doing any useful work. But if the input signal happens to be a CB Carrier Oscillator, the result is a carrier which is balanced out or suppressed.

FIGURE 6-17
STANDARD PUSH-PULL AMPLIFIER CIRCUIT
(Courtesy Prentice-Hall Inc.)

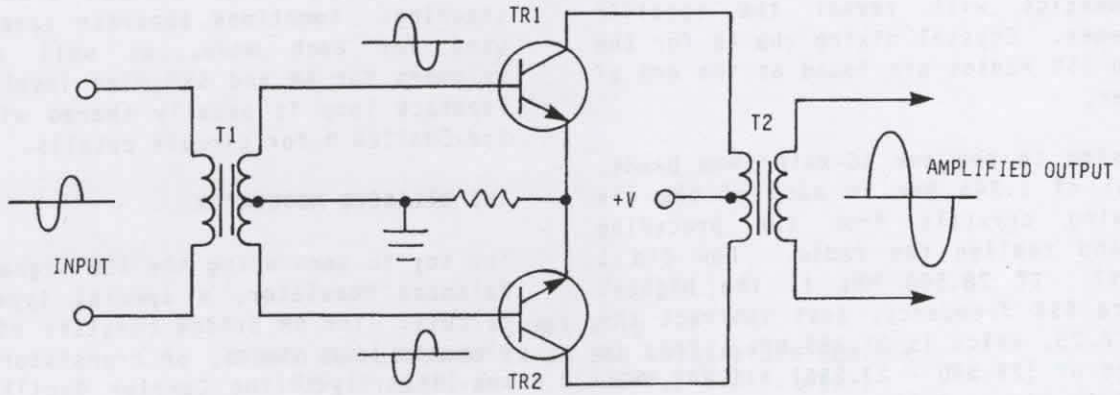


FIGURE 6-18
PUSH-PULL CIRCUIT WITH SIGNAL APPLIED IN PHASE
(Courtesy Prentice-Hall Inc.)

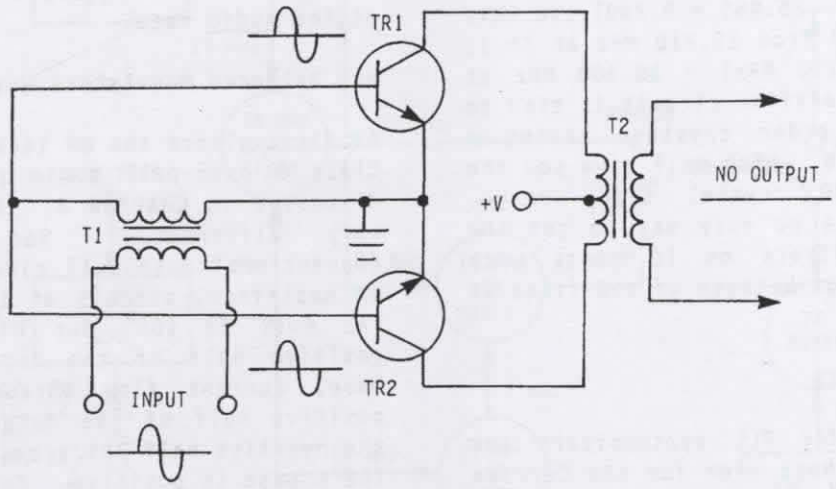
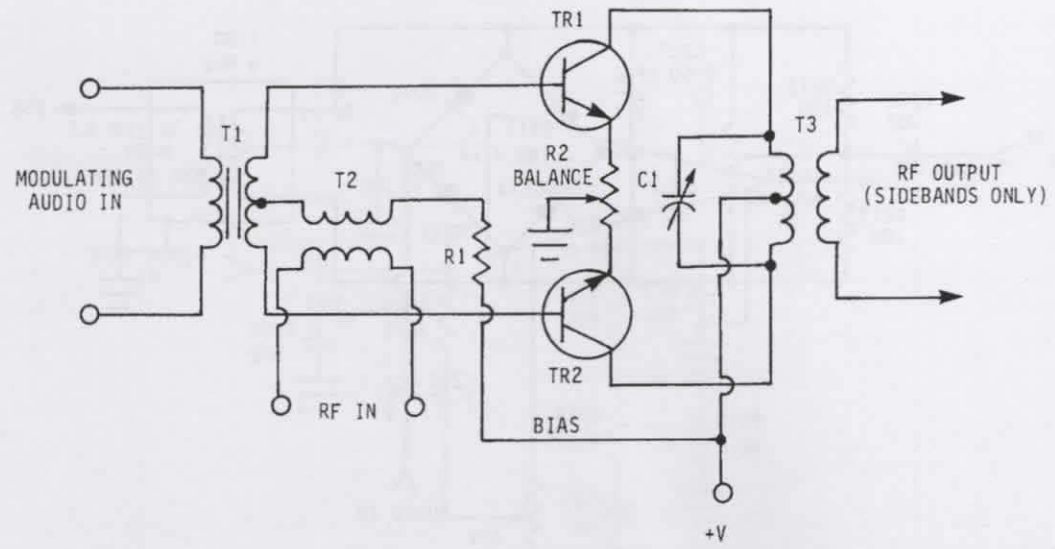


Figure 6-19 shows the final modification. Look familiar? It's a simplified combination of the previous two circuits. The RF carrier is applied in the signal-cancelling manner of Figure 6-18 (in parallel), and the audio in the conventional push-pull manner of Figure 6-17. The carrier will not appear in the output.

But the effect of the audio is different: on the positive swing of the audio voltage, the base of one transistor goes negative while the other is positive, and vice-versa for the negative audio swing. Current can now flow on both halves of the audio through alternating transistors, inducing an RF output current in the tank circuit of C1/T3. The audio input upsets the cancelled RF carrier at the audio rate, producing only the RF sidebands. The tank circuit has such high impedance to audio frequencies that they don't appear in the output either. R1 supplies the proper bias, and R2 balances the transistors for equal currents.

When both RF and audio are simultaneously applied to a non-linear balanced bridge like this, RF currents of the carrier frequency, audio frequency, and the sum and difference frequencies flow within it. The audio input in effect controls the bias on the transistor bases to produce a modulated RF output. But the carrier frequency currents cancel out, and the modulating audio voltage doesn't appear in the

FIGURE 6-19
SIMPLIFIED BALANCED MODULATOR
(Courtesy Prentice-Hall Inc.)



output either because its injection level is purposely made low relative to the RF level. The modulated RF that does appear contains only the sum and difference frequencies; i.e., the USB and LSB. A double-sideband, suppressed-carrier signal has been created.

The Diode Ring Balanced Modulator

In CB circuits, discrete transistors and most transformers aren't used due to the high cost. Instead diodes are used in the older models and ICs in all newer radios. Since diodes are non-linear devices, the two inputs mix to produce sum and difference sidebands. Figure 6-20 is a typical diode ring BM. The expensive center-tapped transformers of the earlier examples are eliminated by substituting balanced RC circuits instead. R214 and C207 are adjusted for maximum carrier null on the wattmeter. The four diodes form a ring-shaped balanced bridge circuit.

Assume that during the positive half of the RF input cycle, the top of T200 is positive and the bottom negative, and there's no audio input. In this condition D212 and D214 will conduct, so current flows up the primary of T200. On the negative half of the RF cycle these conditions are reversed. D213 and D211 conduct and current flows down the primary of T200. Since these currents are exactly equal and opposite, they cancel each other and there's no RF output at the secondary of T200.

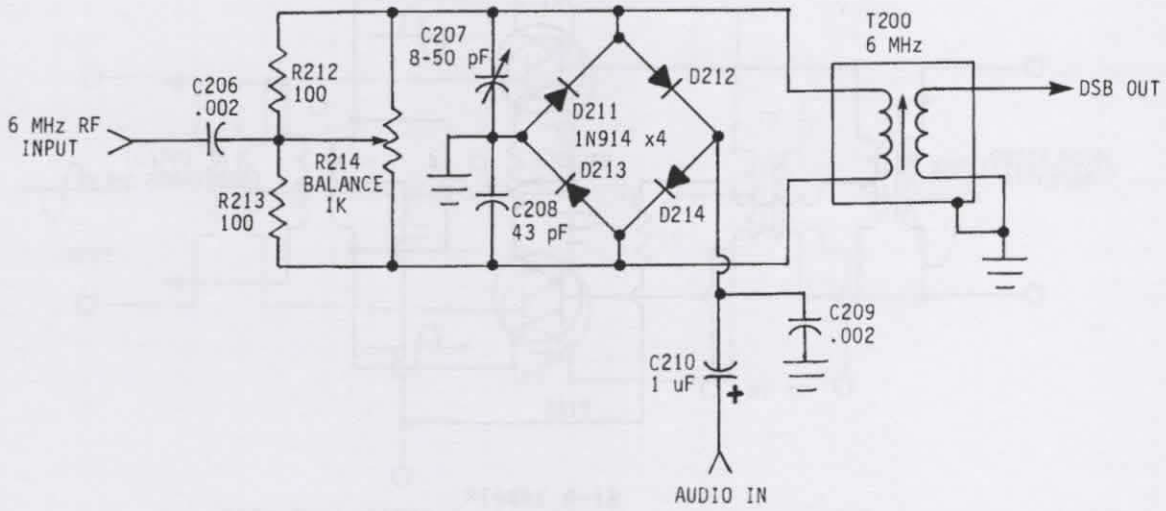
When audio is added to the RF, the diodes mix both signals to produce sum and difference frequencies. The RF injection voltage is purposely made larger than the audio voltage so diode conduction will be determined by the RF portion, typically about 1.0 V of RF and 0.5 V or less of audio. When audio is simultaneously applied with RF, the currents flow in the same directions as before except they're unequal; the bridge is unbalanced. The impedances of T200 and C209 are such that significant audio voltage won't develop at T200's secondary, but RF voltage will. This RF voltage is only that of the sum and difference frequencies, since the carrier frequency has been balanced out.

NOTE: D211 was mistakenly drawn backwards in SAMS Fotofacts #88 for the Tram D201, but is correct as shown here.

In the ring type BM, good balance is essential for proper operation. The individual ring diodes must be carefully matched for equal forward and back resistances to maintain balance. But since they can't ever be perfectly matched, adjustments like C207 and R214 are always included in such circuits.

This circuit, using ordinary 1N914 type silicon switching diodes, is capable of up to -60 dB carrier suppression, an excellent figure. Typical spec for a good CB is -55 dB. For the interested experimenter this may sometimes be

FIGURE 6-20
DIODE RING BALANCED MODULATOR
(Tram D201/D201A)



further improved by replacing the diodes with "hot carrier" types. These diodes are specially constructed to have extremely fast switching times, lower forward conduction voltage and reverse current, less noise, and higher breakdown voltage than ordinary silicon diodes.

The IC Balanced Modulator

The current CB method for the BM uses ICs. One advantage besides saving space is that since the silicon junctions are all formed on a single common substrate, they are extremely well-matched and share a common temperature environment. They also have built-in amplifiers to provide useful x2 or x3 voltage gain, which reduces the drive requirements from the Carrier Oscillator. The harmonic output is lower too.

Since diodes are low-impedance devices when conducting, a buffer stage must be included between the Carrier Oscillator and the input of diode-ring BMs. ICs often include buffering, which further reduces the number of parts. ICs used include the SL640/1640, MC1496, and AN612. The AN612 is by far the most common in CBs.

Figure 6-21 shows a typical circuit. Balance control VR4 is all that's needed. Note the small value of oscillator input coupling via capacitive divider C98/C207. The level of carrier injection affects the degree of suppression. The optimum input level is about 50-100 mV, which is what's found in most CBs. The loose coupling also prevents loading and frequency pulling of the Carrier Oscillator, so a buffer stage generally isn't needed.

UNBALANCING FOR AM OR FM TRANSMISSION

The BM must be unbalanced in the AM or FM modes so the Carrier Oscillator (which runs on AM and FM too) can mix with the synthesizer output to produce the 27 MHz carrier signal. There are several methods used to accomplish this.

With diode rings, the schematic usually reveals that the ring is unbalanced by the injection of an AM-only voltage, is bypassed completely, or a separate path is formed between the Carrier Oscillator and Transmit Mixer. In Figure 6-22, extra voltage is added to the ring on AM via CR206 and an AM-only Transmit voltage source. For USB/LSB, only mike audio flows along this path. Heavy filtering by C614, L602, and R612/C615 keeps RF out of the power supply and mike circuits.

Figure 6-23 shows how a special AM-only path is made when CD5 and CD6 turn on. This connects the Carrier Oscillator directly to the Transmit Mixer stage. A second diode switch, CD7, conducts only on SSB and shunts C11 across the Carrier Oscillator path, effectively killing any RF and forcing the Carrier Oscillator to take the path to the BM instead. CD13 is for isolation from other mode switching voltages.

In Figure 6-24, the MODE switch itself simply hard-wires the AM path completely around the

FIGURE 6-21
IC BALANCED MODULATOR
(Cobra 148/2000GTL, Uniden Grant/Madison)

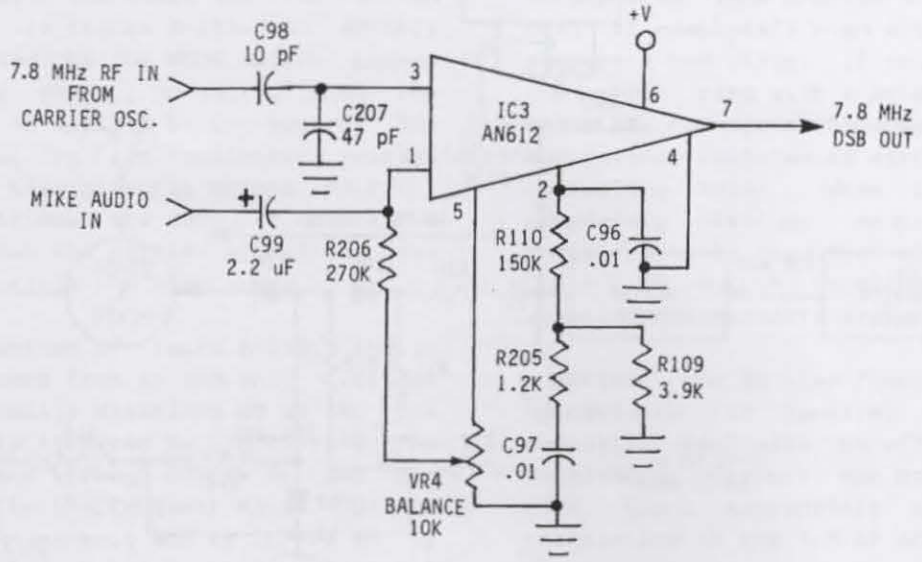


FIGURE 6-22
UNBALANCING VIA AM-ONLY RING VOLTAGE
(Johnson Messenger 4730, Viking 4740)

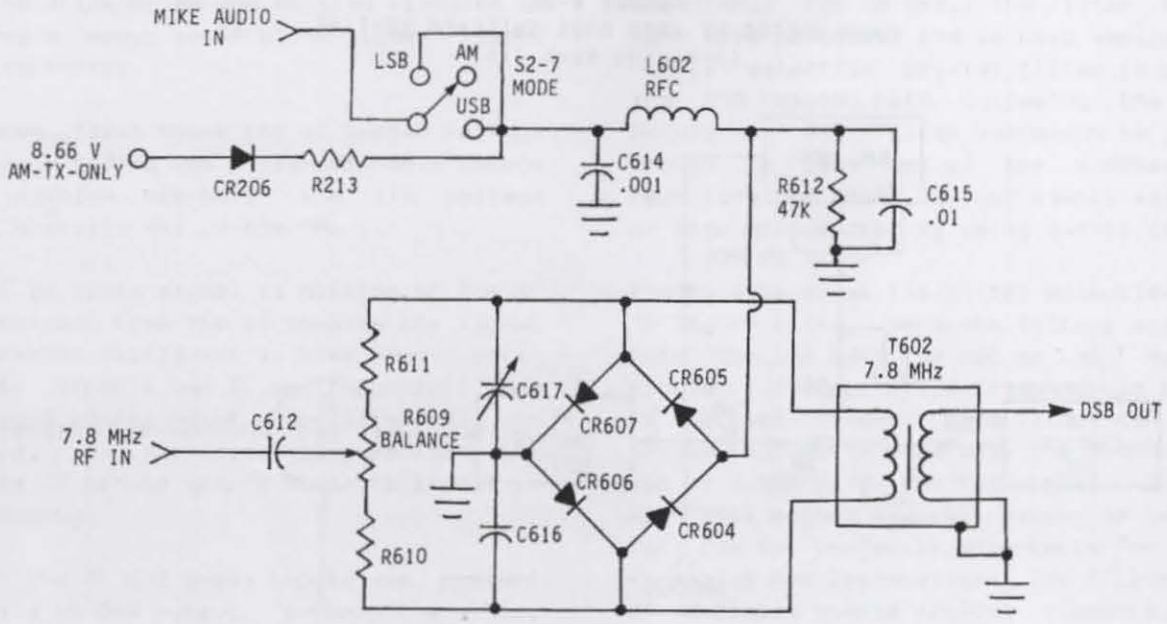


FIGURE 6-23
UNBALANCING BY SPECIAL AM-ONLY PATH
(Browning LTD, Cobra 132/135, 132A, Tram D60)

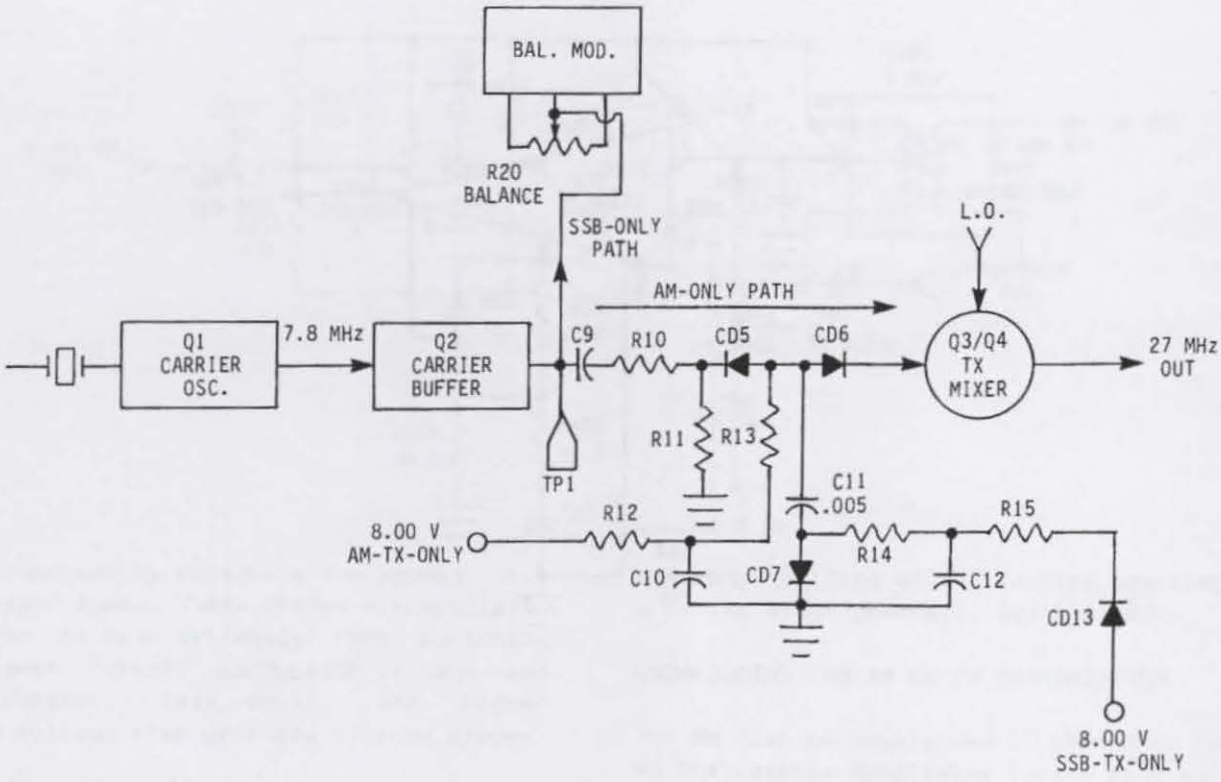
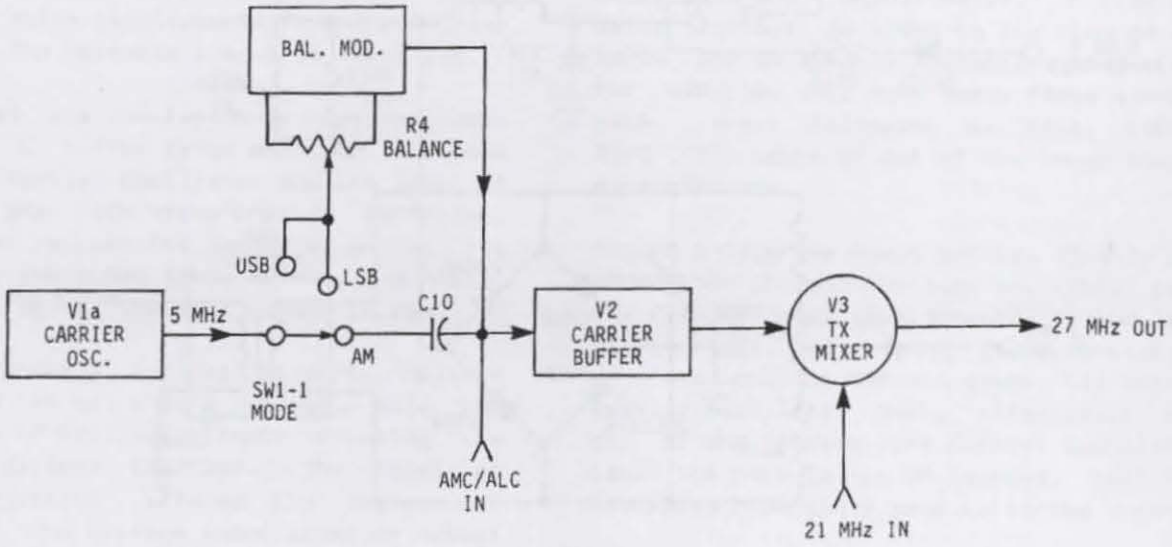


FIGURE 6-24
UNBALANCING BY HARD MODE-SWITCHED ROUTING
(Browning Mark III)



BM, passing instead directly through C10 to the Transmit Mixer.

With ICs, the switching is simpler. Since they have a BALANCE trimmer, a slight voltage change on AM will unbalance it. Figure 6-25 shows two ways it's done with the AN612 IC. The Uniden method is shown in Figure 6-25A. An AM-only voltage controlled by the MODE switch causes IC3 Pin 1 to drop about 1.50 volts. When the AM-only voltage is applied to the base of TR21 it conducts, pulling its collector voltage down. Since it's tied directly across IC3 Pin 1 and the BALANCE trimmer via R206, it upsets the balance and allows the carrier signal to pass through. It also kills the mike audio.

In the Cybernet method of Figure 6-25B, the IC power itself comes from an SSB-only voltage source, automatically disabling it on AM. The voltage is heavily filtered by L16/C77/C78. The carrier is coupled through C74 to RF amp Q15 instead and then to the Transmit Mixer. Q15 is only used for AM-Transmit and is turned on by R67/D14/R65. On SSB, the carrier signal to Q15 is shunted out by C85 because diode Q45 is now conducting, forcing the SSB signal to take a separate RX IF path. (Not shown.) Q15 is labelled schematically as a "carrier insertion" stage when used for AM Transmit, since it injects one of the required mixing signals.

BM TROUBLESHOOTING

Problem isolation of BM and related circuits is done using a 'scope or RF probe/signal tracer and a DC voltmeter.

For IC types, first check the IC supply voltage itself; many radios use a Transmit-only source and the problem may be in the T/R voltage switching circuit, not in the BM.

If the RF or audio signal is missing at the IC input, backtrack from the IC towards the signal source (Carrier Oscillator or mike amps) until it's lost. Since a bad IC could possibly load down an input to the point where it appears to be missing, you may need to unsolder the appropriate IC pin to verify that the signal is in fact missing.

When both the RF and audio inputs are present but there's no DSB output, suspect the chip, especially if indicated DC pin voltages are way off. If the circuit includes a tuned output transformer to couple the DSB signal to the next stage, check this for shorts or opens. Same for coupling capacitors. The sideband IF filter is another possible suspect; if shorted or leaky it could load down the DSB output.

For diode ring type modulators, if carrier suppression is a problem and you're unable to null it completely even with the adjustments, suspect a bad diode. If you find one, replace the whole ring with a matched set. You can match the new diodes by measuring their forward and reverse resistances with an ohmmeter before installing them. When the DSB output is completely missing, 'scope the RF and audio input paths to find the missing signal. The input or output coupling transformers and associated components are other possibilities.

Sometimes the BM also functions as a Balanced Demodulator for Receive; in such cases SSB reception may also be affected. Or the AM unbalancing circuit may be working all the time. Check appropriate switching diodes or transistors in the T/R or AM/SSB circuits.

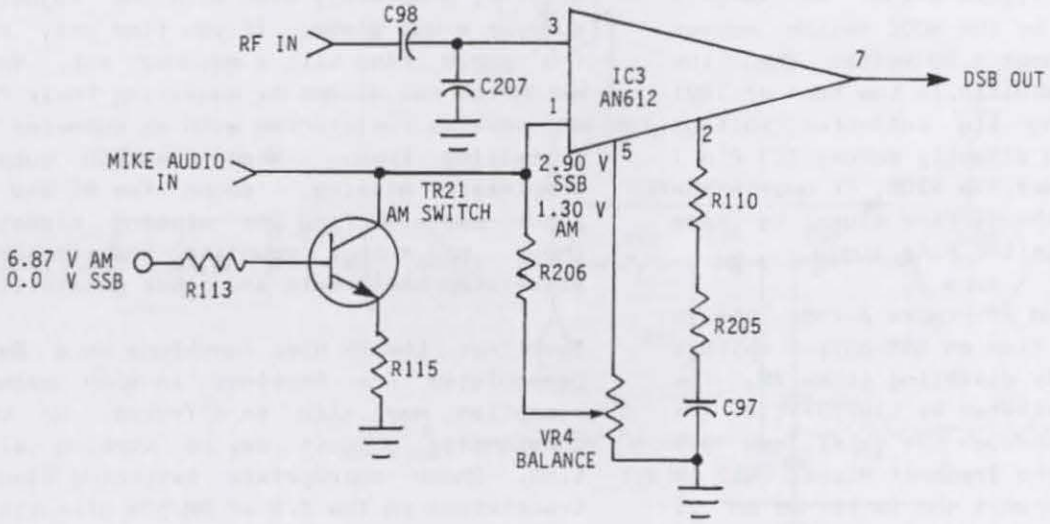
SIDEBAND SELECTION METHODS

After the DSB suppressed-carrier signal is generated, the unwanted sideband must be removed. There are two ways to do this: by taking advantage of the phase relationship between USB and LSB, or by sharp filtering. The phasing method is very complicated and tricky at high IF frequencies, making it unsuitable for CB use. The filter method is much more practical and is used exclusively. A highly selective crystal filter is placed in the DSB signal path following the Balanced Modulator. The filter bandwidth is just wide enough to pass one of the sidebands while rejecting the other, a task easily accomplished at high frequencies by using quartz crystals.

Figure 6-26 shows two filter selection methods. In Figure 6-26A, separate filters are switched into the DSB path for USB or LSB. Note that a single 7.8 MHz carrier frequency is used with no offsets needed; each filter can be made narrow enough to pass only the 7.800-7.803 MHz USB or 7.800-7.797 MHz LSB signal. The problem with this method is cost, making it impractical for CBs but perfectly acceptable for the more expensive Ham transceivers. The filters consist of multiple quartz crystal elements, usually six or eight of them in a sealed unit. It's an expensive part, and using two of them would be unthinkable in a mass-produced CB radio.

FIGURE 6-25
UNBALANCING IN IC-TYPE BALANCED MODULATORS

(A)
UNIDEN METHOD
(Cobra 148/2000GTL, Uniden Grant/Madison)



(B)
CYBERNET METHOD
(PTBM048 chassis: HyGain 2705, JC Penney 981-6247,
Lafayette Telsat SSB140, Midland 79-892, etc.)

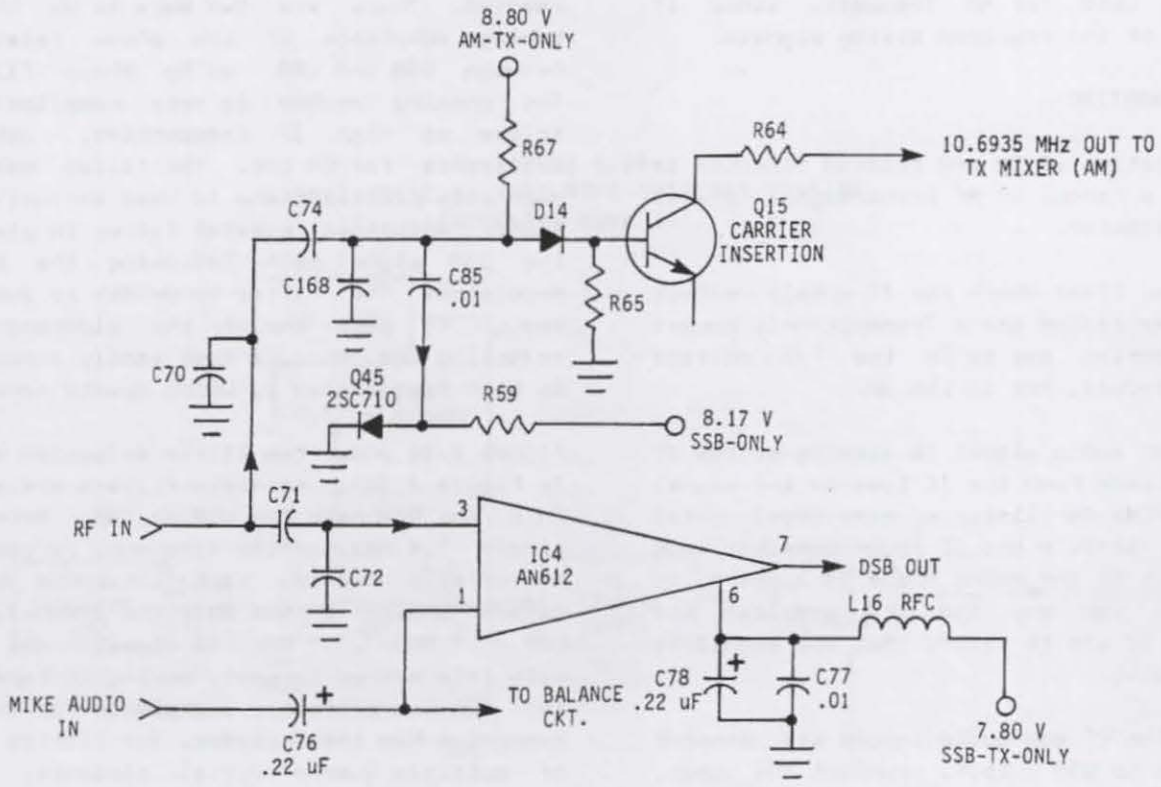
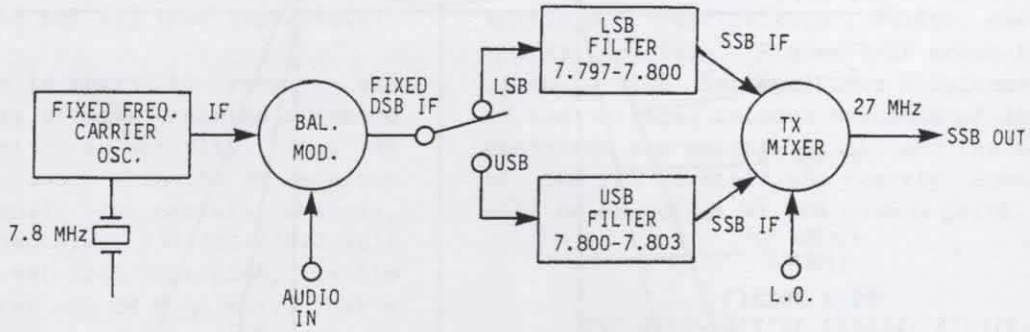
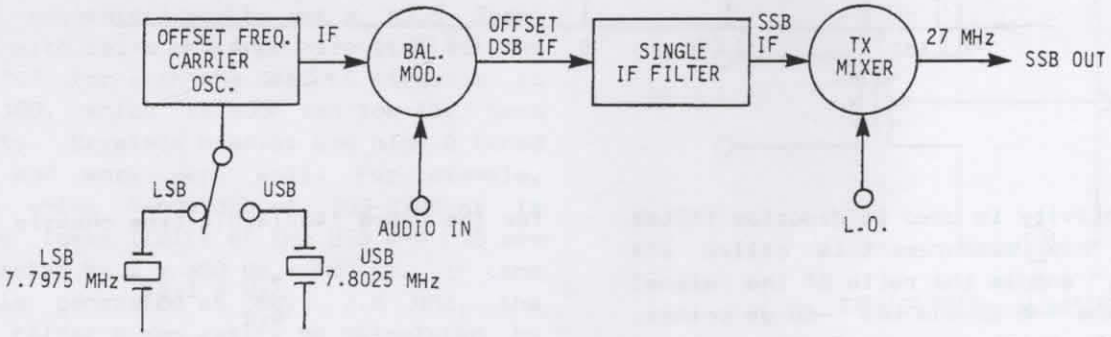


FIGURE 6-26
SIDEBAND SELECTION METHODS

(A)
SINGLE CARRIER FREQUENCY/DUAL FILTER METHOD



(B)
DUAL CARRIER FREQUENCY/SINGLE FILTER METHOD



By contrast, an ordinary Colpitts crystal oscillator is relatively cheap, so two crystals can be switched using diodes or transistors. Or a single Carrier Oscillator crystal can be pulled up or down slightly using capacitors and inductors. This is seen in Figure 6-26B. The reasons and methods for producing such offsets were discussed earlier. The DSB signal is thus shifted up or down slightly around the center IF frequency, allowing the chosen sideband to pass through a single multipole crystal filter. Summing up, the first method uses a constant IF with two individual sideband filters, while the second (CB) method uses a constant filter frequency with two separate IFs instead.

Characteristics of Crystal Filters

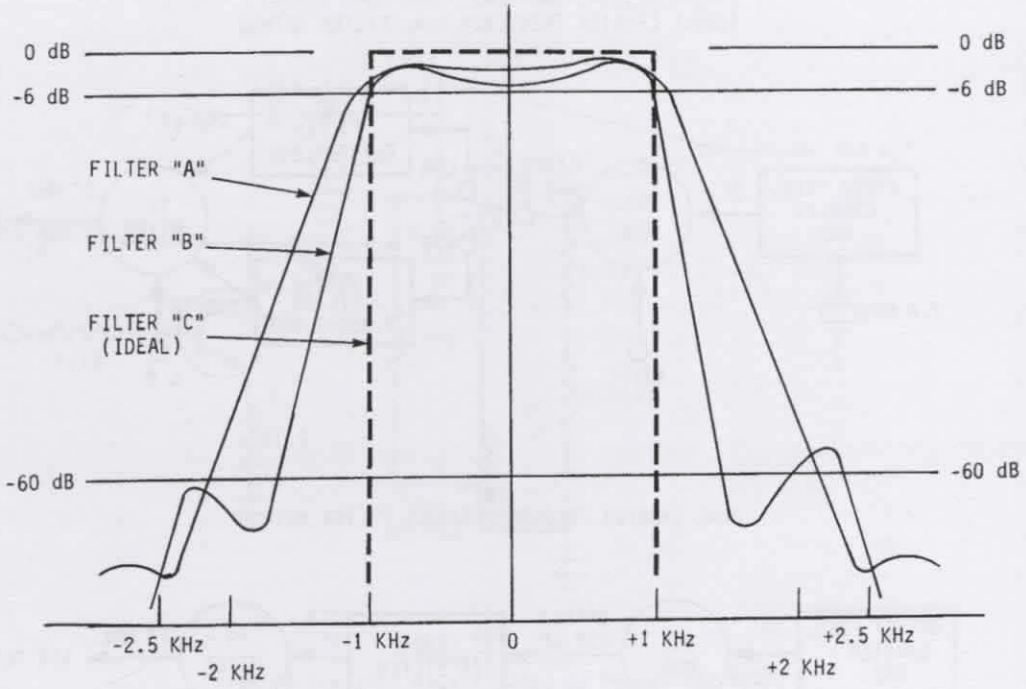
The ideal crystal filter has a "bandpass" characteristic, which means its response is perfectly flat (no ripple) across the desired frequency band, rapidly attenuating frequencies outside this range. The degree of attenuation is called the "skirt selectivity" because the response curve of frequency vs. attenuation is shaped like a woman's skirt. (See Page 105.)

Since a band of audio frequencies from about 300-2500 Hz is used, this implies the bandwidth of the filter must be about 2500 Hz - 300 Hz = 2200 Hz wide, dropping off rapidly outside this limit. Figure 6-27 shows response curves for an ideal filter and two typical real filters. Notice the skirts of Filter "A" aren't as sharp as those of Filter "B," which uses additional crystal networks to increase selectivity.

Filter Shape Factor

A real crystal filter can't drop straight down (completely vertical skirts, as in Filter "C") outside its passband, so a standardized measure

FIGURE 6-27
COMPARISON OF SSB FILTER RESPONSE CHARACTERISTICS



of skirt selectivity is used to describe filter performance. This measurement is called its "Shape Factor," and is the ratio of the signal bandwidth at the -6 dB and the -60 dB points. Obviously if the skirts were perfectly vertical like the ideal filter, the bandwidth at both points would be exactly the same, and the Shape Factor would therefore be 1:1, or simply "1."

The Shape Factor indicates the degree to which the real filter differs from the ideal; the closer to 1.0, the better. For good unwanted sideband suppression, a Shape Factor of 2.0 or less is desirable. This means the bandwidth's no more than twice as wide at -60 dB as it is at -6 dB. The following shows SSB selectivity specs for two popular Uniden chassis, from which we'll compute their Shape Factor:

MODEL	-6 dB	-60 dB
Cobra 140/142GTL type:	4.2 KHz	7.0 KHz
Cobra 148GTL-DX type:	2.1 KHz	3.3 KHz

The Shape Factor is simply the bigger number divided by the smaller number. The Shape Factor for the Cobra 140/142GTL type chassis is

$$\frac{7.0}{4.2} = 1.67$$

Similarly, the Cobra 148GTL-DX type chassis has a Shape Factor of

$$\frac{3.3}{2.1} = 1.57$$

Both chassis therefore have excellent filter characteristics. However there's one big difference: the 140/142GTL filter begins with a much wider bandwidth of 4.2 KHz. Why? Because it uses a single-conversion receiver for AM as well as SSB. The 148GTL-DX is dual-conversion on AM/FM, which means only the SSB signal goes through the filter; AM and FM take a different IF path. The 140/142GTL circuit must pass SSB and AM through its filter, which must be wider to accomodate a wider AM bandwidth. Its filter is a compromise, being too wide for SSB and too narrow for a typical 6 KHz AM signal. The AM audio response is thus limited to 2.1 KHz, just like on SSB. (Half of 4.2 KHz = 2.1 KHz, since only one AM sideband will ever be detected.)

Incidentally, many manufacturers don't list their selectivity specs at both standard points on the curve, often specifying just the -6 dB bandwidth. This is deceptive, because there's no way to know how sharp the skirts are without the second figure. I have a feeling they don't want to advertise this particular spec, probably because it's not all that impressive!

When the SSB filter is shared by Transmit and Receive, its quality affects unwanted sideband suppression and receiver selectivity. (And AM receiver selectivity too, when the AM receiver is single-conversion.) In certain chassis, such as the Sears Roadtalker 934.3826/3827/3831 and the J.C. Penney 981-6241/6246/6248, the SSB selectivity specifies -60 dB @ ±5 KHz. That's wide enough to pass the complete DSB signal, and it shows up in poorer receiver selectivity and adjacent-channel rejection.

Filter Q

The most economical way to get a good Shape Factor is with pairs of tuned circuits. But the maximum "Q" for even the best LC circuits is perhaps 300, which is much too low for good selectivity. Crystals however are high-Q tuned circuits and work very well. For example, assume a voice bandwidth of 300-2500 Hz is used; the lower limits of the USB and LSB are thus separated by 2 x 300 Hz = 600 Hz. If the carrier is generated at say, 7.8 MHz, the required filter Q can easily be calculated by starting with the basic formula,

$$BW = f_R \div Q,$$

where BW = bandwidth at the half-power (i.e., -3 dB) points,
f_R = resonant frequency,
Q = selectivity factor.

Rearranging this and solving instead for Q,

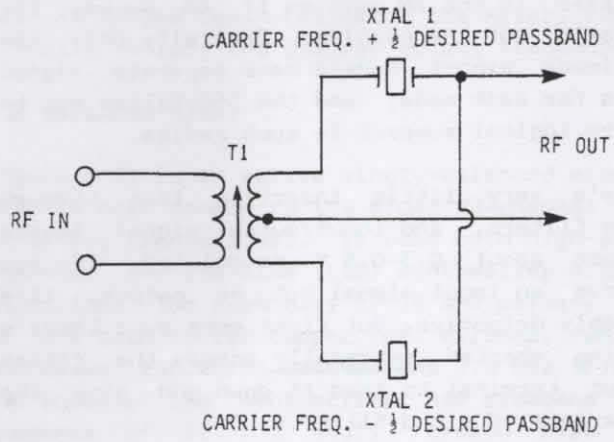
$$Q = f_R \div BW, \text{ or } \frac{7.8 \text{ MHz}}{600 \text{ Hz}} = 13{,}000$$

Such extremely high selectivity factors can only be achieved by using crystal or mechanical filters. Crystals are available with Qs from about 10,000 to over 100,000. It's precisely that selectivity which makes single-conversion SSB receivers possible in the first place. Good selectivity and image rejection are obtained at a relatively high IF, without the need for double-conversion as in AM. Provided there's no stray circuit capacitance to leak the signals around them, inexpensive crystal filters can be made for frequencies as high as 50 MHz.

The Half-Lattice Crystal Filter

Good CB sideband selectivity is achieved using multiple "half-lattice" filter networks of quartz crystals. Figure 6-28 shows the basic circuit. The lattice forms a balanced bridge; if the voltages between the ends of T1 and its centertap are exactly equal, and the impedances of the two crystals are exactly equal, there will be no output at the common point.

FIGURE 6-28
THE HALF-LATTICE CRYSTAL FILTER



The two crystals must differ in frequency by an amount equal to slightly less than the desired passband. For example, a filter with a 2.4 KHz passband centered at 7.8 MHz might use crystals of roughly 7.8 MHz ±1 KHz, or 7.799 MHz and 7.801 MHz. In CHAPTER 3 we discussed crystal oscillators operating in the series-resonant or parallel-resonant modes. The technical names for these modes are the "zero of impedance" and the "pole of impedance" respectively. The parallel crystal mode is slightly higher in frequency than the series mode.

It turns out that the filter bandwidth is determined by the spacings of these poles and zeros, so the exact crystal frequencies depend upon actual operating modes, and crystal calculations will be more complex than the preceeding example would indicate. The passband response is kept flat by careful adjustment of the terminating impedances, and by making the series-resonant frequency of one crystal equal

to the parallel-resonant frequency of the other crystal. This maintains the bridge balance.

The Multiple-Lattice Crystal Filter

The simple half-lattice filter is only capable of about -30 dB sideband suppression, which isn't good enough. (The FCC minimum is -40 dB, with -55 dB more typical.) To increase this, two more filter sections are added in series. This results in much sharper skirts while maintaining the desired bandwidth. Typically six quartz crystals are used to cascade three half-lattice filter sections.

A six-pole crystal filter like this is usually constructed in a sealed metal can having only input, output and ground terminals, and isn't serviceable. But filter failure is very rare and easy to diagnose. In many radios the filter is also in the AM path so if AM works, the filter's not the problem. Generally only the multimode export models have separate signal paths for each mode, and the SSB filter may be a more logical suspect in such radios.

There's very little insertion loss through these filters, and input/output signal levels measure about 0.3-0.5 V unmodulated. If you observe an input signal but no output, it's probably defective. But first make sure there's nothing shorted externally across the filter output terminal to load it down and give the appearance of a bad filter.

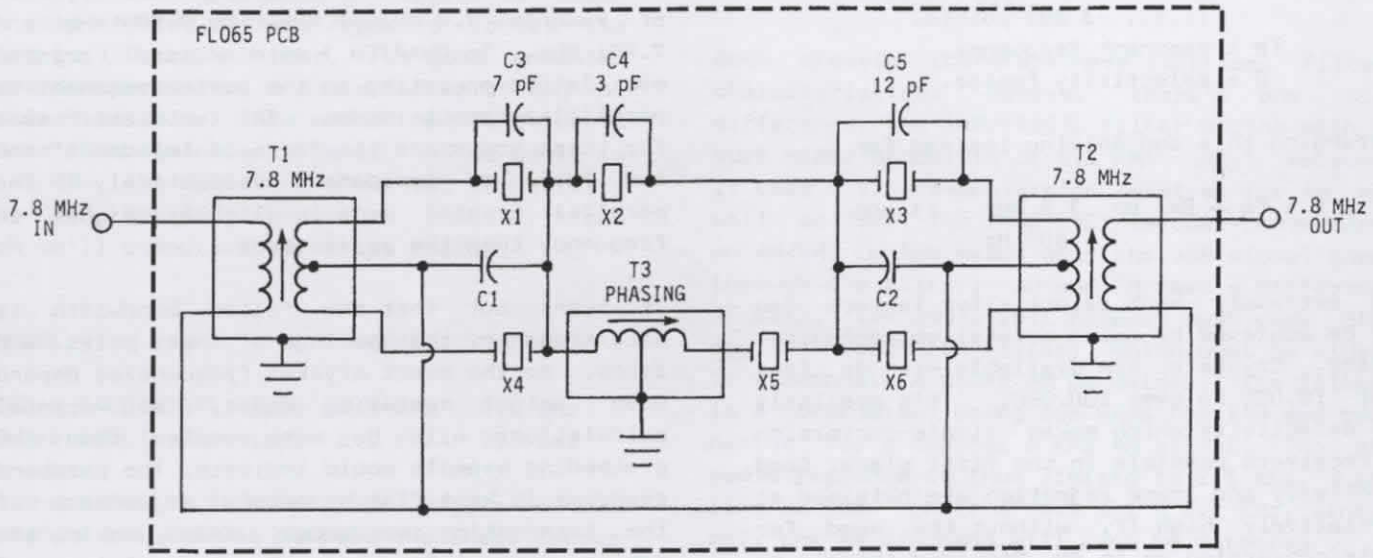
A notable exception to the sealed filter is the discrete Uniden filter found in the popular Cobra 140/142GTL, Cobra 148/2000GTL, and their equivalent chassis. Apparently they decided it was cheaper to make their own than buy them from somebody else, so they simply built them on a small PC board which fits into the main PC board. Figure 6-29 shows the FL065 SSB filter circuit. Yes, I actually dissected one and traced out the schematic for you!

T1 and T2 peak the input and output for maximum at the 7.8 MHz design frequency, and also provide impedance transformation. The higher the impedance, the higher the Q and therefore the selectivity. C3, C4, and C5 trim X1, X2 and X3 respectively, which are the higher frequency crystals. Without trimmers, the filter skirts would tend to broaden out towards the bottom. These filters are individually tested after construction, and the fixed trimmer values may vary slightly from those shown here.

Unfortunately, trimmers also add undesirable reactances which allow nearby frequencies to pass through. Even the metal plates of the crystal holders can add stray capacitance. To eliminate these effects, phasing coil T3 is included. This adds an equal but opposite-phase reactance to cancel the capacitive reactance.

There are other leakage reactances in series with the crystals which would lower their resonant frequencies if not controlled. These

FIGURE 6-29
INSIDE THE DISCRETE UNIDEN FL065 SSB CRYSTAL FILTER



are eliminated by C1 and C2, which resonate with the leakage inductances of T1 and T2 to cancel them out. This makes it possible to use cheap, non-critical coupling transformers.

It's unlikely these discrete filters can be repaired, although you might try it. First determine if a signal is passing through the filter. Then if there's no question of a bad crystal, confirmed by signal tracing and a crystal checker, try replacing it with one at 7.8 MHz. (Obviously there's no way to know the original's exact specs.) For you experimenters, replace the crystal, inject the 7.8 MHz from your signal generator at the input terminal, and peak all coils for maximum RF at the output terminal. Replace it in the main board and check the unwanted sideband suppression. If it works you've learned something new, reduced the repair cost, and impressed the customer.

While this section has been very theoretical, a good technician should understand what's going on inside the "black box" even though he can't do much about it. Crystal filter design is very complicated and I've just touched on the basics here. If you're really interested, check the RADIO AMATEUR'S HANDBOOK or similar references.

THE TRANSMITTER MIXER

Compared to FM, AM, or CW (which is simply unmodulated AM), an SSB signal is a complex waveform which can't be mixed up to a higher frequency because the RF stages must be linear; mixers are non-linear circuits by definition. Instead the SSB signal must first be generated at a lower frequency by the Carrier Oscillator. Once the SSB signal is generated, it can then be raised to 27 MHz for power amplification.

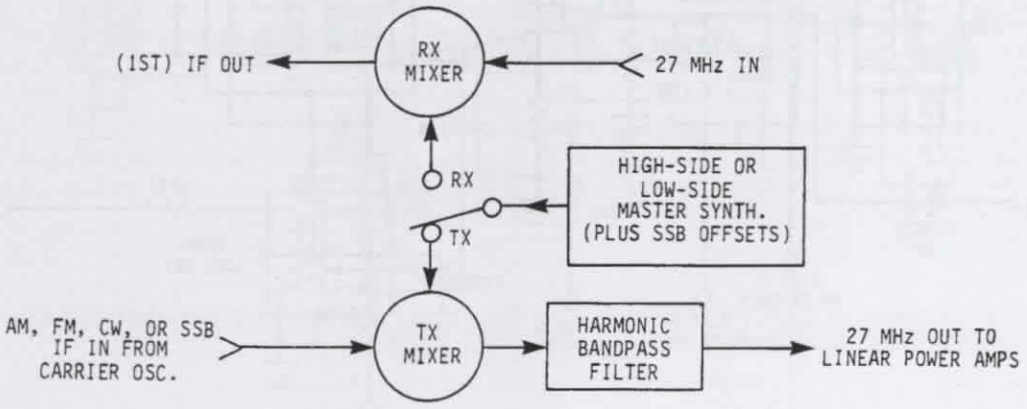
This up-conversion process is a form of mixing called "conversion," "translation," "mixing," or "heterodyning." It's just like the process of mixing in receivers, but reversed: instead of mixing an incoming 27 MHz signal with the output of the synthesizer to produce the IF, the synthesizer mixes with the IF (the Carrier Oscillator) to produce the 27 MHz transmitter signal. This signal is then amplified only by linear stages, or extreme distortion (splatter) will result. Figure 6-30 shows both processes.

The Transmit Mixer works in all modes, since the BM is unbalanced for AM/CW (and FM) and is like the mixers described in CHAPTER 5. Both high-side and low-side injection are used, with the mixer always being an active device because gain is needed too. Following the Mixer, tuned circuits select the desired output frequency.

The Balanced Mixer

Figure 6-31 is an active singly-balanced mixer. This is most common to the older 23-channel and early PLL transceivers. It uses both high-side (AM/USB) and low-side (LSB) synthesizer signal injection. The secondary of T8 and primary of T9 are both center-tapped for balance, which increases isolation between the 7.8 MHz IF and the input of the synthesizer. R69 broadens the response of T8. A small forward bias is provided by R77 and voltage divider R75/R76, but like all mixers it's still a Class C stage. C60 and C61 decouple RF. The optional R175 (dotted lines) broadens the response of T9 if

FIGURE 6-30
T/R MIXER PRINCIPLES



needed. T9, T10, and T11 form a bandpass filter to remove all mixing products except 27 MHz. The low values of C62 and C63 result in loose coupling (high Q) for maximum selectivity.

The MOSFET Mixer

A dual-gate MOSFET mixer, Figure 6-32, offers superior signal-handling ability with reduced

FIGURE 6-31
SINGLE-BALANCED ACTIVE TX MIXER
(Browning Baron, Cobra 132/135XLR)

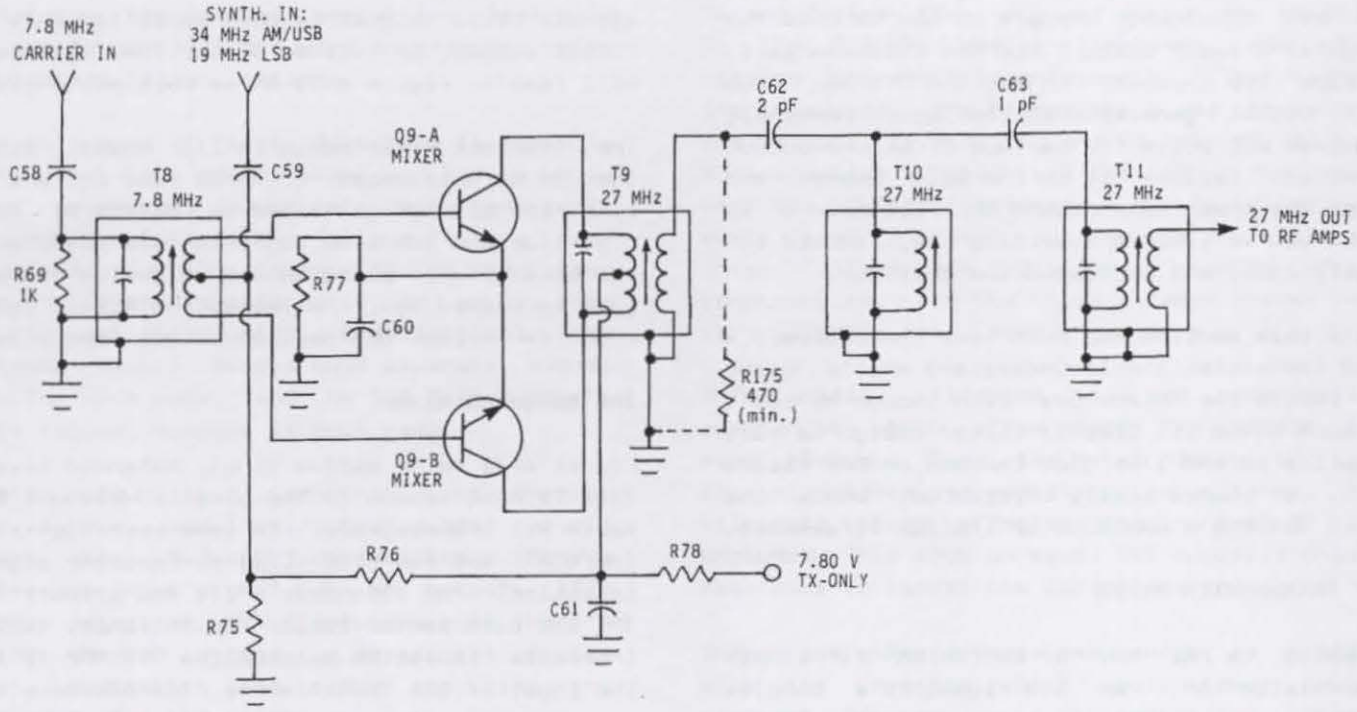
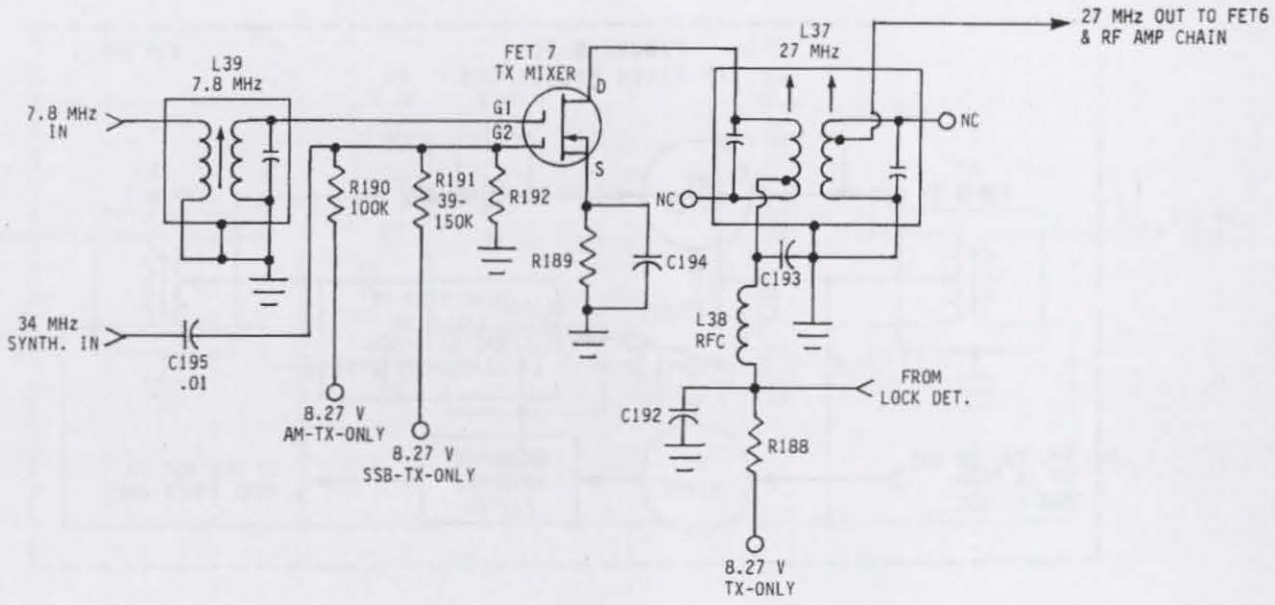


FIGURE 6-32
DUAL-GATE MOSFET TX MIXER
(Cobra 138/139XLR, President Adams, Realistic TRC458, etc.)



harmonic and IMD distortion. The 7.8 MHz IF carrier signal is coupled to gate 1 by L39, and the 34 MHz VCO synthesizer signal coupled to gate 2 by C195. Note the value of C195, typical of high-impedance FET or tube circuits. MOSFETs need positive gate voltage to amplify, supplied by R191 on SSB and R190 for AM. The separate AM and SSB gate voltages are used to optimize mixer performance in each mode. C192, C193, and L38 decouple RF from the power supply.

The primary of L37 has been tapped down at a relatively low-impedance point to preserve the IMD and cross-modulation characteristics of FET7. Otherwise excessive drain voltage would develop on signal peaks, which can overload the drain tank circuit and increase harmonics and distortion. This can be a problem at the kind of low drain voltages (6-8 VDC) that are used in CB mixers, since the driving signals may be relatively large. The secondary is tapped at a high-impedance point to maintain a high Q for harmonic rejection, and to help match the high input impedance of FET6 which follows it.

Also connected to the drain supply at R188 is the PLL Lock Detector circuit. If the loop becomes unlocked, this point is pulled LOW and turns off FET7 so the radio can't transmit on the wrong frequency. Connection to the Transmit Mixer is the most common control point for PLL Lock Detector/Transmit Inhibit circuits.

The IC Mixer

All modern SSB CB models use IC mixers for simplicity and high gain. The ICs contain double-balanced mixer circuits which offer maximum suppression of IMD and other distortion products, and maximum isolation between the input and output ports. Figure 6-33 shows the Uniden circuit with the SO42P mixer chip. The 7.8 MHz carrier is coupled to one input by L48, and the 34 MHz VCO to the other input by L47. The 27 MHz output is across pins 2 and 3, which are the collectors of the IC's balanced output transistors. L46 and L45 are part of a 27 MHz bandpass filter and are lightly coupled by C163 to maintain its high Q. R190 is a balancing resistor chosen for best mixer performance at the particular frequencies used, which is why it's external to the chip. In some models R190 may be replaced by a jumper wire, with only the internal IC resistors needed.

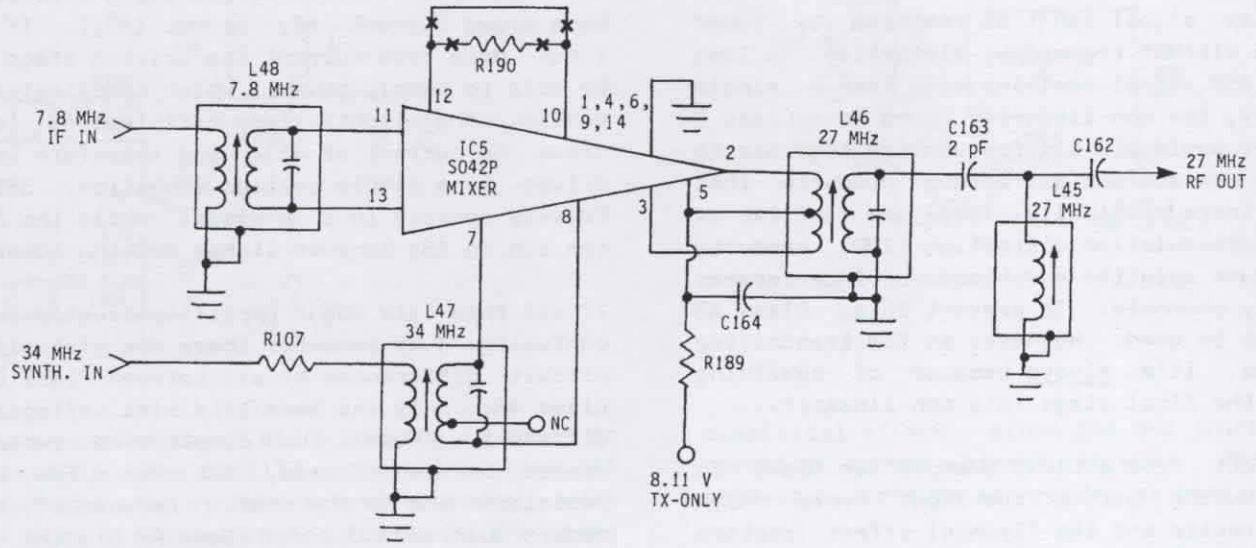
MIXER TROUBLESHOOTING

Symptoms of a bad Transmit Mixer include:

1. No Transmit, any mode.
2. Low RF power output.

The circuit is checked exactly the same way as a receiver mixer. Since the mixer operates in all Transmit modes, these symptoms will show up

FIGURE 6-33
UNIDEN IC-TYPE TX MIXER
(Cobra 148/2000GTL, Uniden Grant/Madison)



in all modes, not just SSB. First determine if both inputs are present using a 'scope and frequency counter. In transistorized radios the synthesizer input will typically measure about 1.0-1.5 V P-P, while the carrier signal will be about 200-500 mV at the filter output. These mixers generally have a small amount of voltage gain, depending upon whether there are three or four RF amps following it. Output levels in the preceeding examples are all about 0.6 V P-P.

If an input is missing, backtrack towards its source until you find the open circuit. Radios with electronic T/R switching use steering diodes to route the carrier signal, and a bad diode will stop the transmitter cold. If both inputs are present, 'scope the output and interpret device voltages. The active device is the most likely failure. Passive components to check are the transformers (including their alignment!) and coupling or bypass capacitors.

LINEAR RF POWER AMPLIFIERS

The signal is amplified to the 12 W PEP level by "linear" RF power stages. This is a form of amplification in which the output is an exact copy of the input, only bigger. Compare this to the Class C RF power amp used for AM or FM; it generates many distortion products, but they're not important because tuned circuits restore the original sine wave via the flywheel effect. But SSB isn't a sine wave; it's a complex waveform composed of an infinite number of frequencies, from the unmodulated carrier to the carrier $\pm$ the highest modulating frequency. (Except when using a single audio tone input.)

A complex signal can't be restored by tuned circuits without tremendous distortion. As long as the SSB signal contains more than a single frequency, the non-linearity found in a Class C amplifier would mix all frequencies together to produce new sum and difference products that weren't there originally. These are familiar as the intermodulation distortion (IMD) products that cause splatter and bleedover interference to nearby channels. To prevent this, Class AB bias must be used. Whenever an SSB transmitter splatters, it's <u>always</u> because of something driving the Final stage into non-linearity.

The output from a Class C amplifier flows in pulses during part of the input cycle only. Tuned circuits and the flywheel effect restore the pulses to complete sine waves. The positive bias needed for amplification develops only when the input signal is large enough to overcome the reverse bias, and this happens only a fraction of the time. Such bias is possible with a sine wave input because it has a known and constant amplitude for which bias values can be calculated.

An SSB signal has no such predictability, and its amplitude is continuously changing with speech. If Class C biasing was used, only the highest signal peaks would be amplified; most of the input signal would be ignored. So the amplified signal wouldn't be a faithful copy of the input signal. This implies that the gain of an SSB RF power amplifier <u>must be constant</u> regardless of the input signal level, and this can only be achieved with a linear amplifier.

Class AB Biasing

An amplifier biased so collector current flows more than 50% but less than 100% of the input signal time is known as a "Class AB" amplifier. This condition is a compromise between the Class A and Class B type amplifiers discussed earlier. Compare this to the Class C amplifier, which has output from about 25% to 40% of the input drive time. Because the Class AB linear amplifier operates on the majority of the input signal time (typically about 78%), the missing portion can be reproduced by the flywheel effect with minimum distortion. The output is a linear or more exact copy of the input.

Class AB biasing isn't as efficient as Class C, but does have higher gain and smaller drive requirements. Class AB is subdivided into AB_1 and AB_2, with the difference being whether the base draws current (AB_2) or not (AB_1). If the input does draw current the driving stage must be able to supply power, which complicates its design. The slightly less efficient AB_1 stage draws no current at all, and therefore can be driven by a simple voltage amplifier. SSB CB Drivers operate in this class, while the Final can run in AB_2 because it has driving power.

If all this talk about amplifier classes seems confusing, just remember there are virtually no circuit differences at all between Class C and Class AB; only the base/grid bias voltages are different. There's no complicated switching needed between classes, but even a few extra resistors add to the cost. Because of this, modern multimode CBs run Class AB all the time, even for AM and FM. It's just not as efficient. In the early days when costs weren't so

critical, manufacturers sometimes did switch the bias between AM and SSB in solid-state transmitters. (Tube-type transmitters always do.) Because linear amps have more gain than Class C RF amps, problems of instability and transistor heating are more serious and require more careful design and attention.

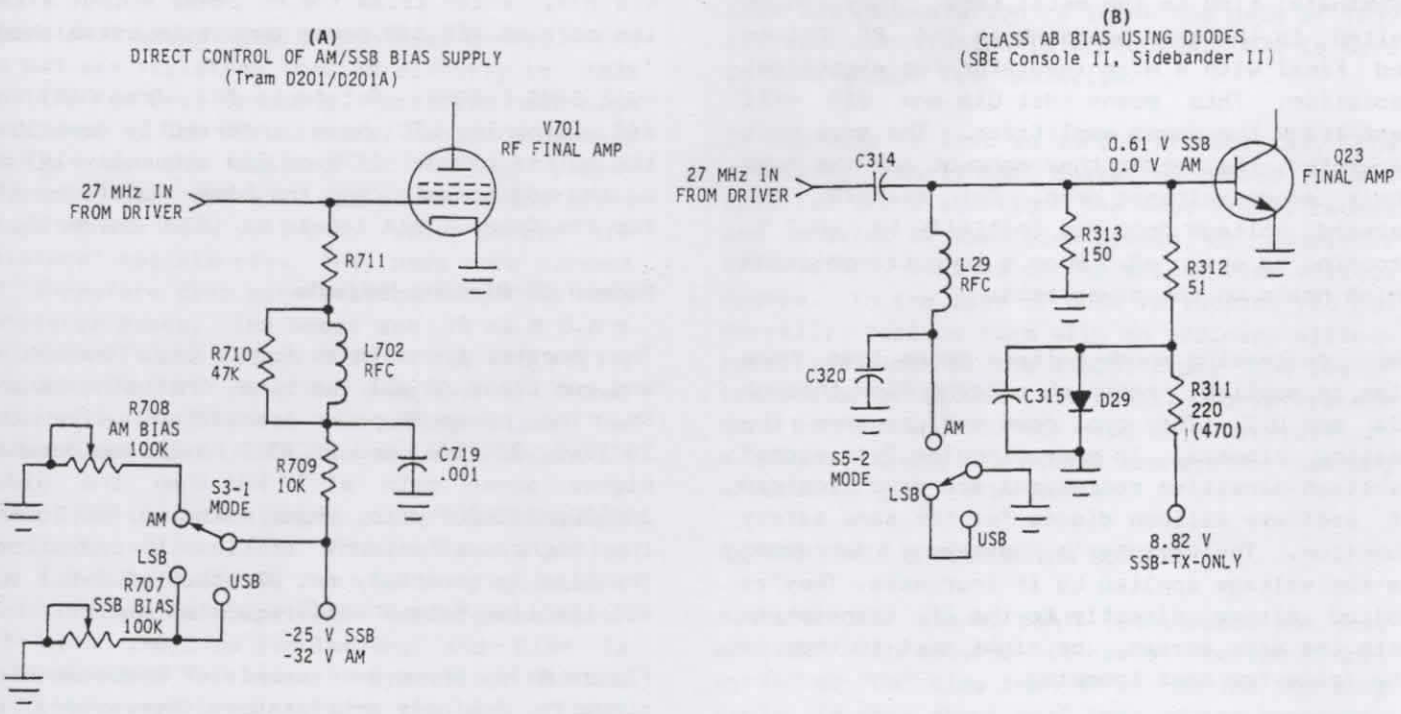
Switchable Biasing Methods

The following examples are in chronological order of CB evolution, and demonstrate what to expect when servicing the equipment you're likely to see on the bench. In most cases only the Final stage is drawn for simplicity, but the Driver will have a similar bias circuit.

Figure 6-34 shows switchable Class AB/C bias. In Figure 6-34A, the control grid of V701 has its bias applied through a voltage divider consisting of R708/R709 for AM, or R707/R709 for SSB. Voltage dividers are common biasing techniques because they help stabilize the voltage. A stiff bias supply is necessary for good linearity and IMD characteristics in all linear amps. C719 and L702 decouple RF from the bias supply. R710 swamps out L702, lowering its Q to aid stability. The specified bias voltages of -25 VDC SSB and -32 VDC AM seem reasonable because Class C by definition implies a higher negative grid bias, forcing the tube further into the cutoff region.

In Figure 6-34B, the forward SSB bias of about 0.6 V is established using D29. R311 limits current to a safe level and with R312 forms a voltage divider for stability. The voltage supply to R311 is only present on SSB. The use of a diode for biasing is a very common method, although not always giving the best IMD value for a particular transistor. Note the use of L29, an RF choke for AM only. This raises the base impedance of Q23 and along with the simultaneous removal of the base bias switches the transistor to the Class C condition. R313 lowers the Q of L29 for better stability.

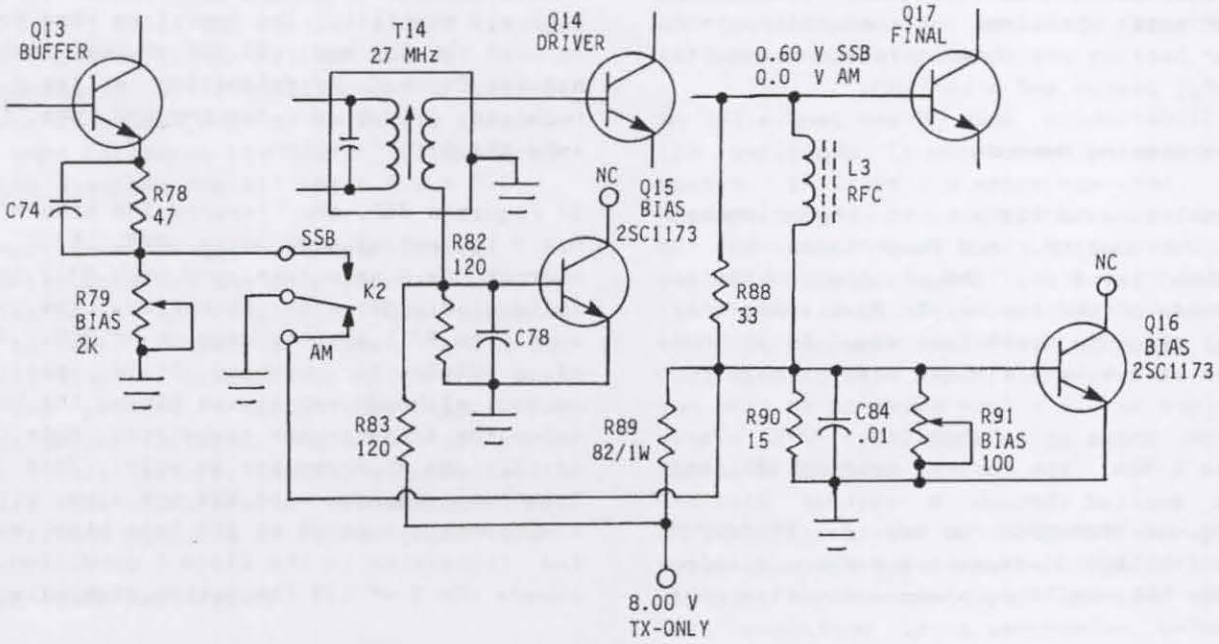
FIGURE 6-34
AM/SSB BIAS SWITCHING METHODS



A clever variation of diode biasing is shown in Figure 6-35. The 2SC1173 power transistors Q15 and Q16 are used as heat-tracking diodes, with the diode terminals being formed by the base (anode) and emitter (cathode). The collectors are also tied to the bases but have no electrical effect, since the b-c junctions are normally reverse-biased anyway. The metal collector surfaces are needed as heat sensors.

A transistor is merely two back-to-back diodes sharing the same substrate. The plastic TO-220

FIGURE 6-35
USE OF POWER TRANSISTORS FOR BIAS DIODES
(Browning LTD, Cobra 132A/135A, Tram D60)



power devices have their collectors (center terminals) tied to the metal tabs. They can be bolted to the same heatsink as the RF Driver and Final with a mica insulator for electrical isolation. This means that Q15 and Q16 will heat-track the power amplifiers. The more heat generated, the harder they conduct and the more their anode voltages drop. For example, the forward voltage drop may initially be +0.7 V, dropping to say, +0.5 V on a long transmission which heats up the power amps.

This decreasing anode voltage means less base bias is applied, reducing current flow through Q14 and Q17. They cool down and reverse the heating process. In many circuits "varistors" (voltage-sensitive resistors) are used instead of ordinary silicon diodes for the same safety function. The varistor's resistance decreases as the voltage applied to it increases. They're bolted either directly to the RF transistors with the same screws, or right next to them on the frame for heat tracking.

The 8.0 V Transmit-only source is effectively grounded through R89 and the relay on AM, pulling it down and disconnecting it from the base of Q17. Instead L3 and R88/R90 establish the b-e impedance to develop Class C bias. For SSB, voltage is applied to divider R88/R89/R90 and trimmer R91 to set the 0.6 V base bias on Q17. The bias on buffer Q13 is adjustable on AM via R79, which trims the RF power output after the correct PEP SSB power output is establshed.

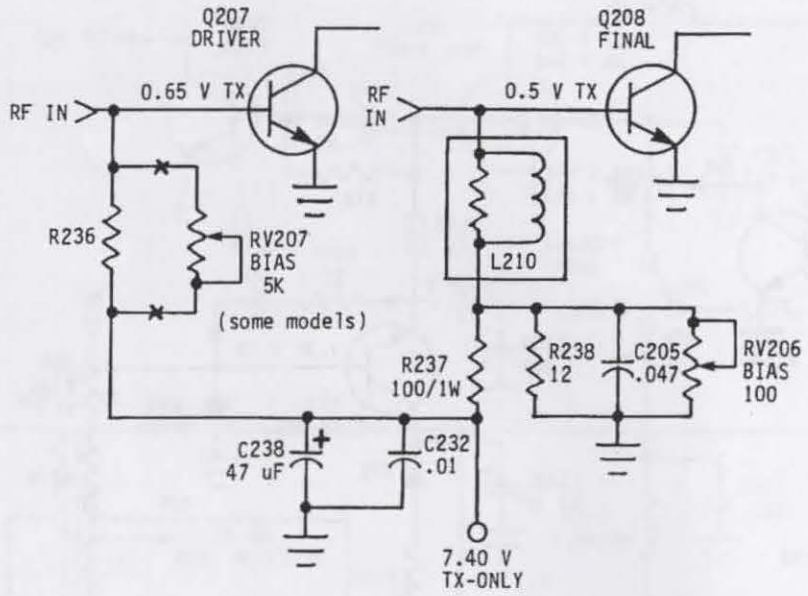
NOTE SAMS ERRORS: Fotofacts #62 (Tram D60) and #66 (Browning LTD) have incorrectly described the buffer trimpot (R98 or R85 respectively) as an AMC adjustment, not the bias. Fotofacts #73 for the Cobra 132/A labels it (R79) correctly.

Modern CB Biasing Methods

The current trend is to ignore bias switching and run Class AB all the time, including AM and FM. The newer RF power transistors like the 2SC1969, 2SC2166, and 2SC2312 have considerably higher power gain at 27 MHz than the older 2SC1306/2SC1307 pair, which makes up for losing the higher efficiency of Class C operation. The bias is generally set at about +0.5-0.7 VDC all the time from a well-regulated source.

Figure 6-36 shows an example of a common bias circuit. A highly regulated voltage source is applied to the Final by a voltage divider consisting of RV206, R238 and R237. L210 is an RF choke to maintain the base impedance of Q208, and the parallel resistor lowers its Q. R237 has a 1-watt rating due to the high current being drawn in the Final stage. In some similar Cybernet models, the Driver bias isn't

FIGURE 6-36
TYPICAL MODERN AM/SSB BIAS SUPPLY
(GE 3-5825B, 5875A, Midland 78-574, 78-891, 78-999, SBE LCBS-4)



adjustable and comes from the same voltage source using fixed resistors only.

Figure 6-37 shows the Uniden bias method. D50 and D49 are varistors bolted directly to TR38 and TR36 for heat tracking. Varistors have high resistance at low DC voltages, which decreases rapidly as the applied DC voltage rises. Increasing the drive to the power transistors raises their base voltages, which lowers the varistors' resistances. They pass more current and therefore drop more voltage away from the transistor bases. The specs are 20 ma @ 0.6 V for the MV1Y and 100 ma @ 1.3 V for the MV13Y, although the MV1Y is often used even in Final circuits having 30-40 ma of resting bias. The correct lead identifications are also shown.

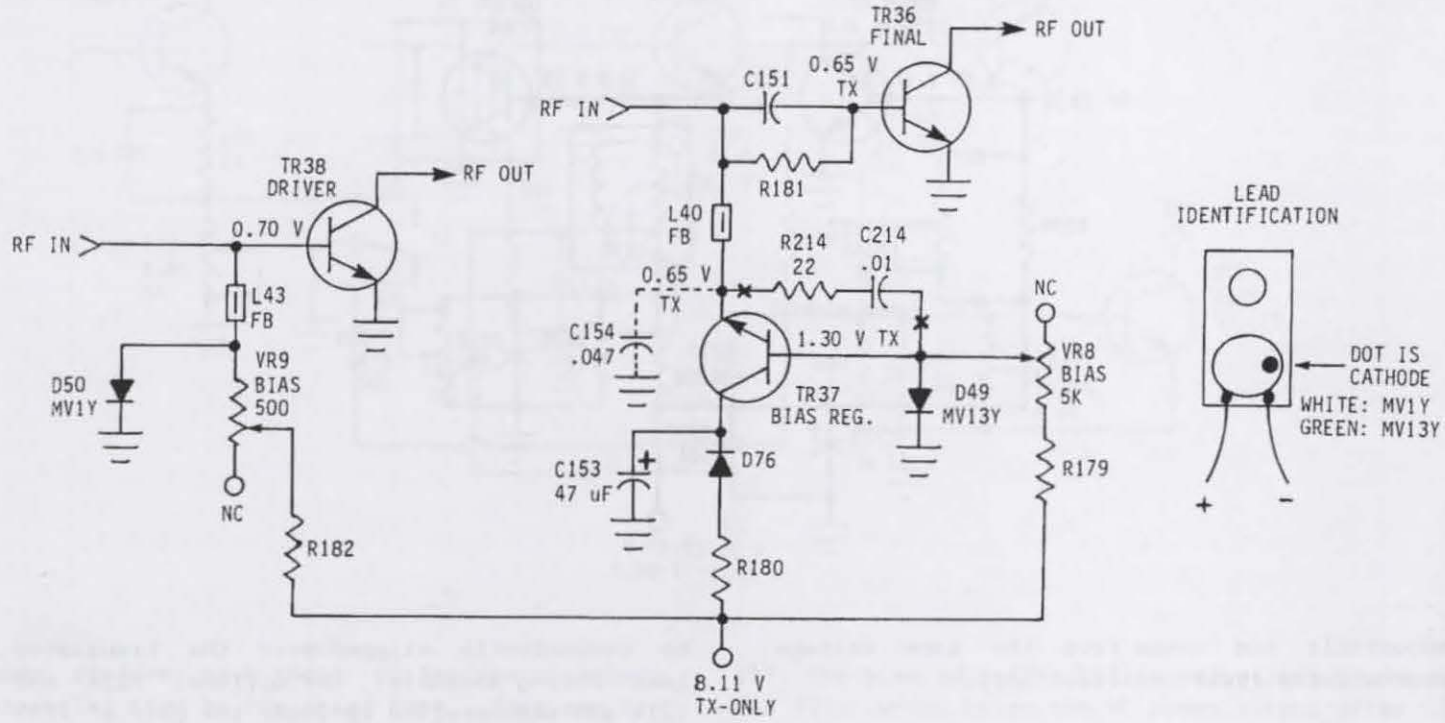
Driver TR38 uses the simple diode bias already described, while Final TR36 includes a series pass transistor (TR37) for better regulation, since it draws more current. The large value of C153 also improves regulation, and C154 is sometimes added for extra RF bypassing. D49 has a 1.30 V forward drop, setting the base of TR37 at this voltage. The additional 0.65 V b-e drop results in the desired bias of about 1.30 V - 0.65 V = +0.65 V at the emitter of TR37 and the base of TR36. L43 and L40 are ferrite beads which act as RF chokes to maintain high RF base impedance, but are cheaper than coils and can be conveniently slipped over the transistor lead during assembly. The optional R214 and C214 add degeneration to lower the gain of TR37 if self-oscillation is a problem. D76 is used in some models for isolation.

If the bias is lost in an SSB transmitter, the resulting non-linear operation causes severe splatter and distortion. The most likely causes are shorted or open bias diodes or regulator transistors, or loss of the actual bias voltage source. In the case of open varistors, you can normally replace them with an ordinary silicon rectifier diode of the 1N4001 type, and the RF transistor still won't overheat. Varistors are hard to find and you may need to substitute in a pinch. Check for excess transistor heating afterwards just to be sure!

AM/SSB POWER & MODULATION CONTROL

Since an SSB signal isn't continuous but only present with speech, it has a shorter "duty cycle" or "ON" time than AM or FM. The SSB duty cycle is only about half that of the constant-carrier modes, which is one reason the legal SSB power limit is approximately double that of AM. In other words, the 12-watt PEP peaks when averaged over time produce about the same amount of tube or transistor heating as that of a 4-watt AM or FM carrier.

FIGURE 6-37
BIAS USING VARISTORS & TRANSISTOR REGULATOR
(Cobra 148/2000GTL, Uniden Grant/Madison)



To account for this power difference, the gain of the RF amps must be changed between modes. Even if it were legal, a 12-watt AM/FM carrier would quickly burn out the power tubes or transistors, since they're not rated high enough to dissipate this much continuous power. Manufacturers never overbuild these circuits when a cheaper device will do.

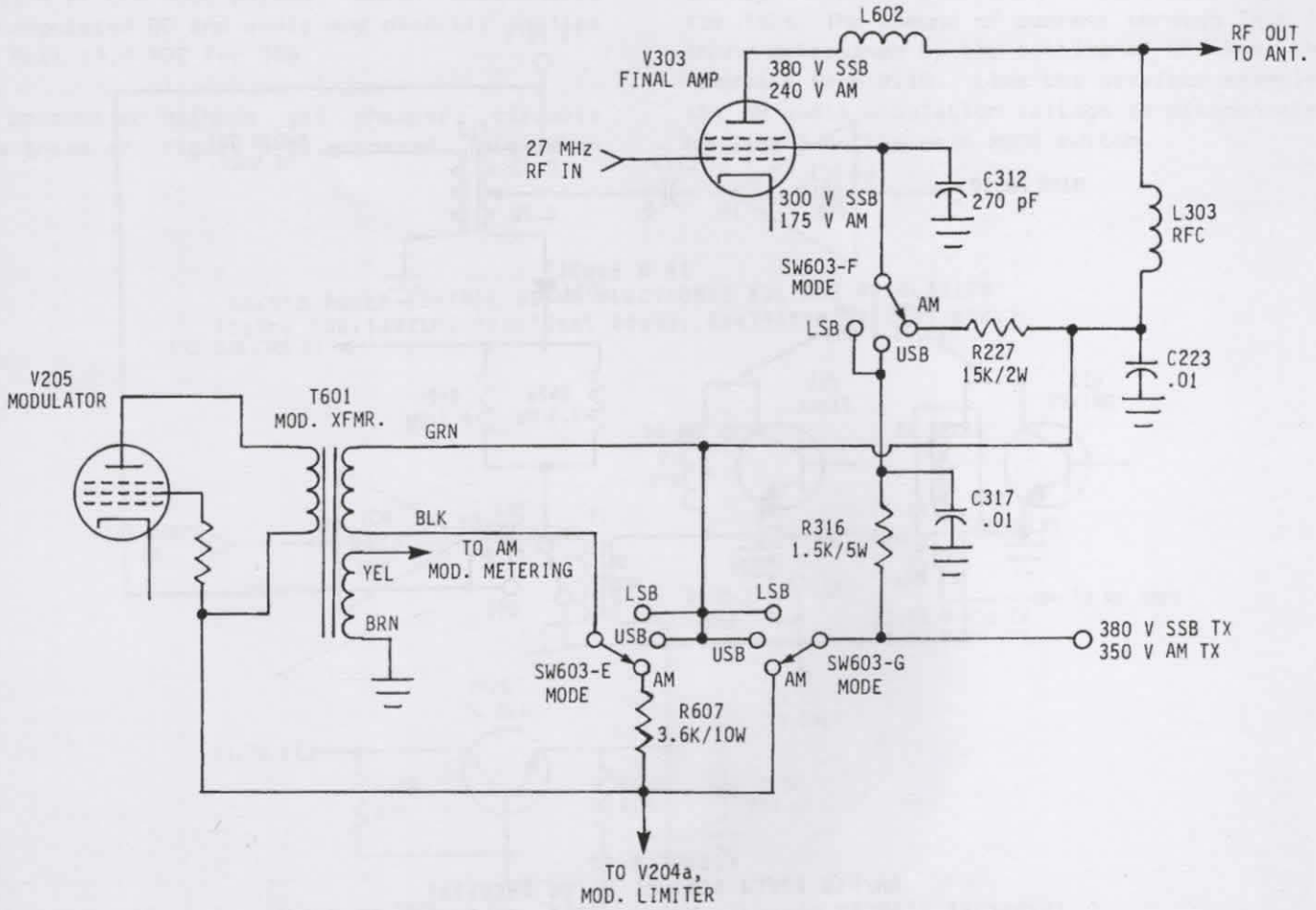
Safe control of the amplifier duty cycle is done by reducing the Driver and Final DC collector voltages in solid-state AM/FM radios, or by reducing the Final plate and screen voltages in tube radios. As this voltage is lowered, less current flows so the RF power output is lowered. In tube circuits the AM Final plate and screen voltages are lowered by series dropping resistors. For solid-state transmitters, the transistors receive the full 13.8 VDC collector supply on SSB. (Minus any voltage drop through the series resistance of the hash suppression choke or other wiring.) This produces a 12 W PEP output, while on AM or FM the supply is lowered to about 5.0-7.5 VDC to produce the 4 W constant carrier output.

The AM/FM collector supply voltage comes from a separate adjustable regulator circuit, called "AM POWER," "AM CARRIER," or "AM REG." In older equipment, fixed series dropping resistors were often used. Since all voltage control is ultimately tied to the MODE switch, a dirty or broken switch contact could easily cause the "No Transmit" symptom in a particular mode.

A second mode switching function associated with this voltage change involves the modulated audio path. In the case of high-level AM, the audio modulating voltage is added to the plate or collector voltage to produce amplitude variations. (For SSB, low-level AM, and FM, the modulation was already produced at an earlier transmitter stage.) Therefore any high-level AM modulating voltage must be disconnected for SSB (and FM), and this control is generally made using another section of the same MODE switch that controls the DC supply voltages.

Figure 6-38 is an example of power control in a tube-type radio. Large power resistors are placed in series with the high-voltage supply.

FIGURE 6-38
TUBE TYPE AM/SSB TX POWER CONTROL
(Browning Mark 4, Mark 4A)



On AM, the +350 VDC supply is directed via R607 to the plate of Final amp V303, and to its screen through R227 and SW603-F. R607 and the GREEN/BLACK secondary winding of modulation transformer T601 are in series with the DC supply and V303, so both DC and audio are applied to it. On SSB, the main DC supply increases to +380 VDC and completely bypasses R607, T601, and R227. A second, smaller screen dropping resistor (R316) is now used to raise the SSB screen voltage. The plate and screen supply to Modulator V205 are also disconnected, killing the audio voltage. The large difference in plate and screen voltages of V303 between modes accounts for the RF power difference.

Series dropping resistors were also found in many older solid-state circuits like that of Figure 6-39. The MODE switch again controls the DC and audio paths. On SSB, the full supply voltage of 13.75 VDC is applied directly to the RF amps while simultaneously disconnecting the modulated audio. On AM, the DC supply passes through the primary of T13, CD34, R92A/R92B, and S4. The resistors are factory chosen as required to produce the 4-watt output. Two or three low power (1-3 W) types are paralleled, being cheaper than one large 5-watt or 10-watt power resistor. Multiple resistors also help split the current to reduce individual resistor heating. Even the small winding resistance of T13 (0.6Ω) is enough to drop some voltage too, considering there's typically about 1.0 A of collector current flowing. CD34 adds another 0.6 V drop, leaving 9.0 VDC for the collectors.

In Figure 6-40 the AM DC voltage is adjusted by wirewound rheostat VR4, a very crude method. Because of the high current flowing, this pot is physically large, bulky, and expensive. It's found in the earlier Cybernet models like the Colt Black Shadow, HyGain 2705 (V)/3108 (VIII),

FIGURE 6-39
AM/SSB POWER CONTROL USING FIXED SERIES RESISTANCE
(Browning Baron, Cobra 132/135XLR, Tram D62)

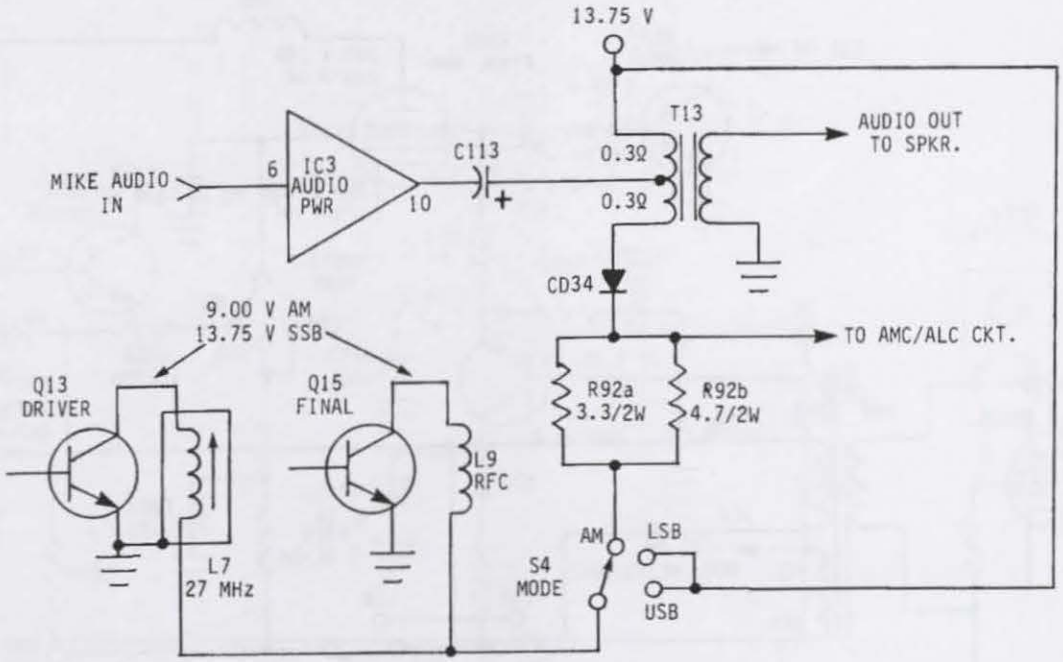
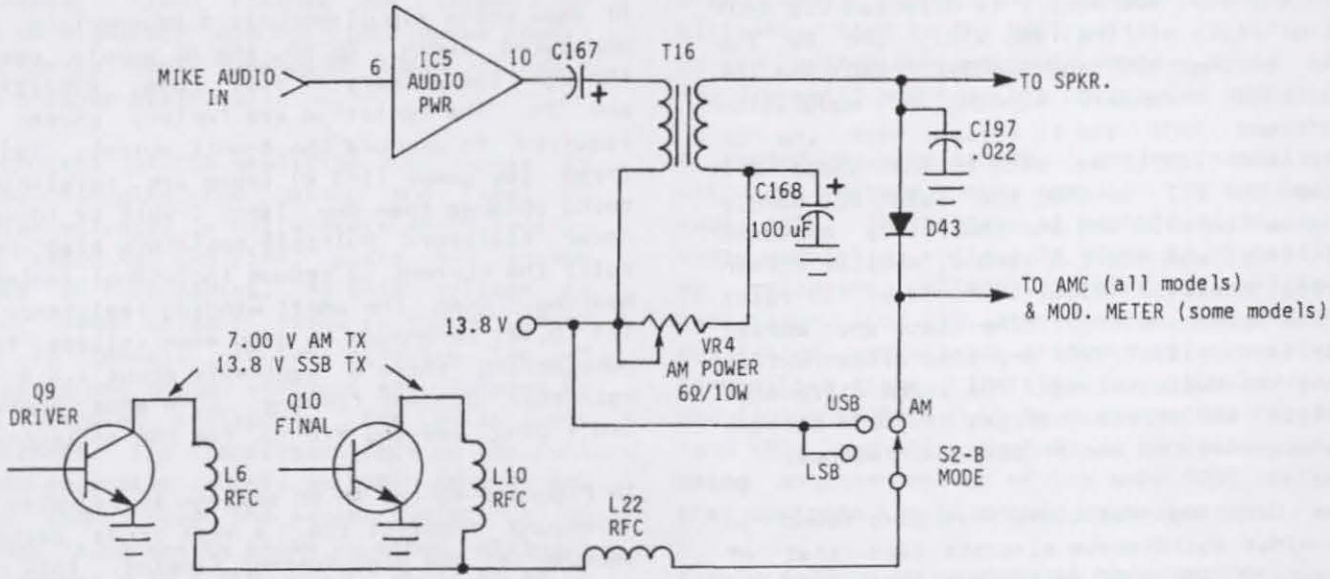


FIGURE 6-40
AM/SSB POWER CONTROL USING RHEOSTAT
(Cybernet PTBM048 chassis: HyGain 2705, JC Penney 981-6247,
Lafayette Telsat SSB140, Midland 79-892, etc.)



J.C. Penney 981-6247, Lafayette Telsat SSB140, Midland 78-574, 79-892, RCA 14T302, and the G.E. 3-5875A "Superbase." The modulated audio path is controlled further downstream by a section of the MODE switch, which disconnects the regulated DC and audio and directly applies the full 13.8 VDC for SSB.

As production methods got cheaper, circuits like those of Figure 6-41 appeared. This is an ordinary series-pass voltage regulator. TR25 is the regulator, and TR26 its controller. The harder TR25 conducts, the more current it will pass, and therefore the higher the supplied voltage. Zener D26 sets the conduction point for TR26. The amount of current through TR26 is then determined by the setting of VR8 and the feedback from R110. Like the previous example, the AM audio modulation voltage is disconnected by S402-3 on the main MODE switch.

FIGURE 6-41
AM/SSB POWER CONTROL USING ELECTRONIC VOLTAGE REGULATION
(Cobra 138/139XLR, President Adams, Realistic TRC458, etc.)

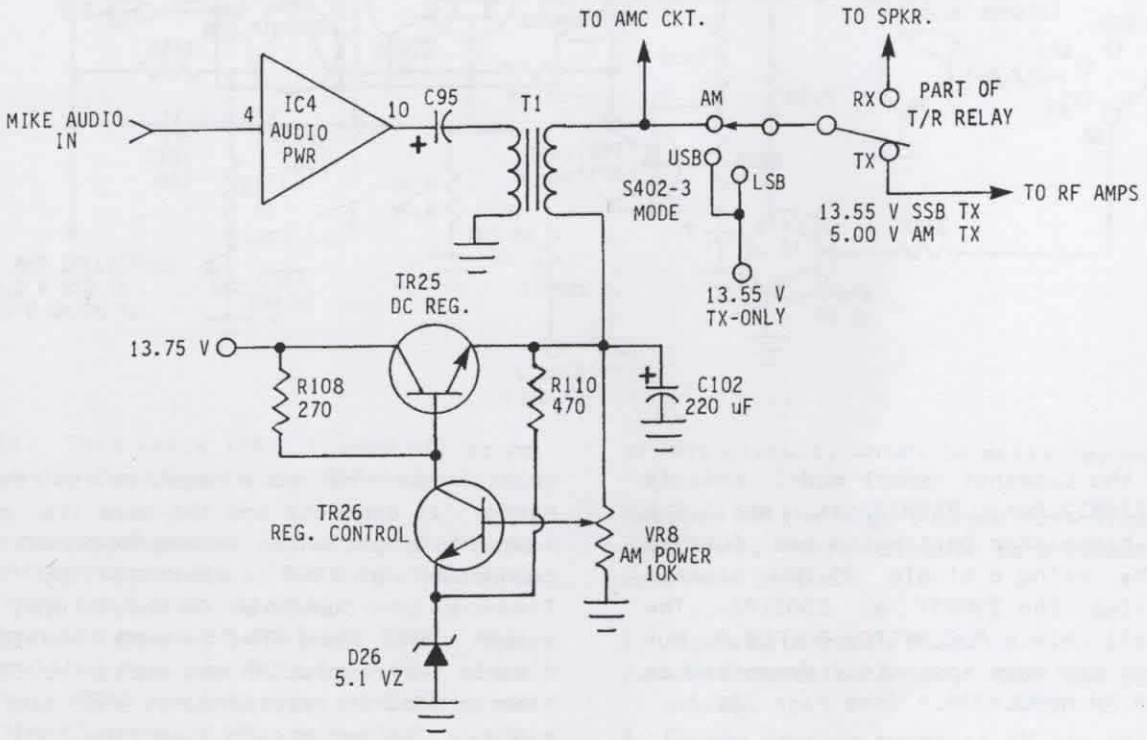
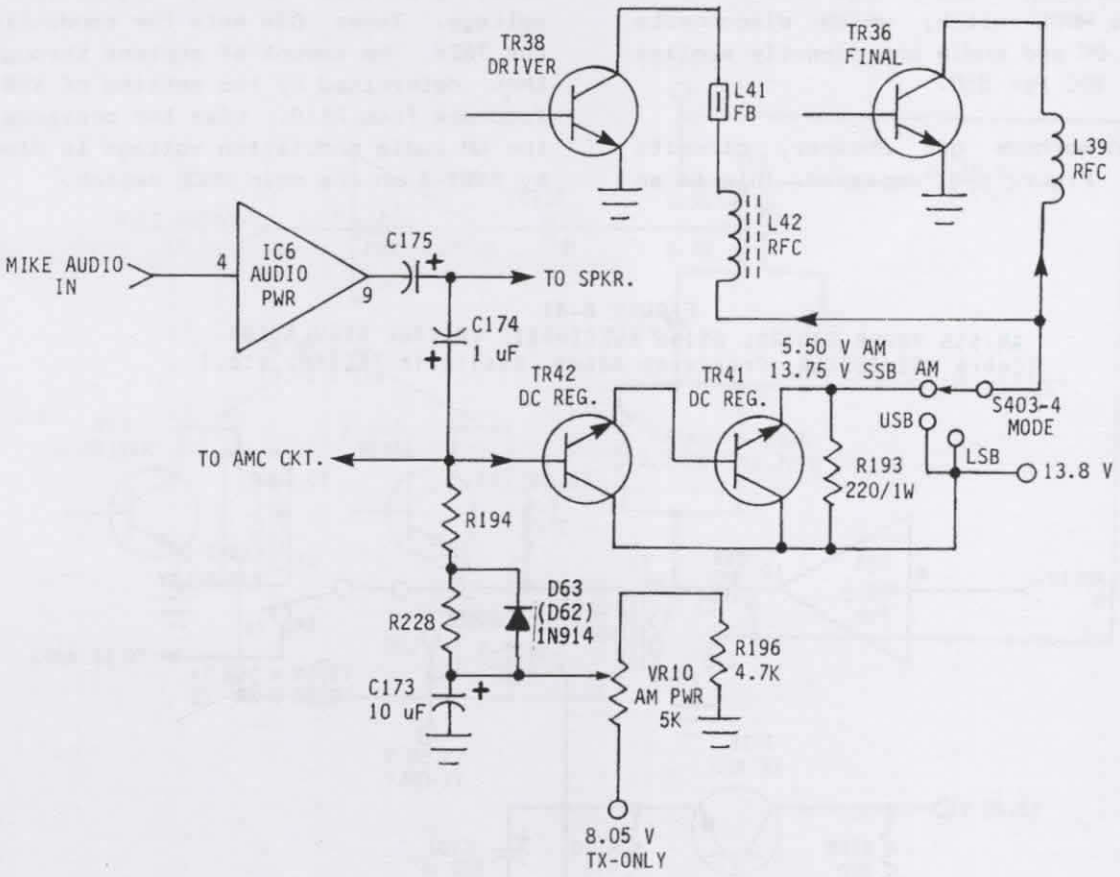


Figure 6-42 is a newer method, commonly found in the Uniden SSB radios with transformerless IC audio outputs. It uses two transistors in a Darlington circuit to control current flow and therefore voltage. The input transistor is a small-signal type and the output transistor, which passes the most current, is a heat-sinked TO-220 type. VR10 sets the base bias for TR42. The harder TR42 turns on, the more current passes through its emitter to turn on TR41. And the harder TR41 conducts, the more current it passes to the RF Driver and Final. D63 isolates RF and clamps excessive modulation peaks.

The extremely high current gain of a Darlington type amplifier can also serve a dual function as an AM modulator; a small audio input voltage at the base of TR42 produces a large output swing at the emitter of TR41. C173 bypasses audio, making it take the path through TR42 instead. With the TR38/TR36 collector voltages swinging at an audio rate, amplitude modulation results. A section of the MODE switch directs the audio path again. On AM the circuit passes both regulated DC (4.5-7 V) and audio to the Driver and Final, while on SSB it passes only the main 13.8 VDC supply.

FIGURE 6-42
AM/SSB POWER CONTROL USING DARLINGTON REGULATOR
(Cobra 148/2000GTL, Uniden Grant/Madison)



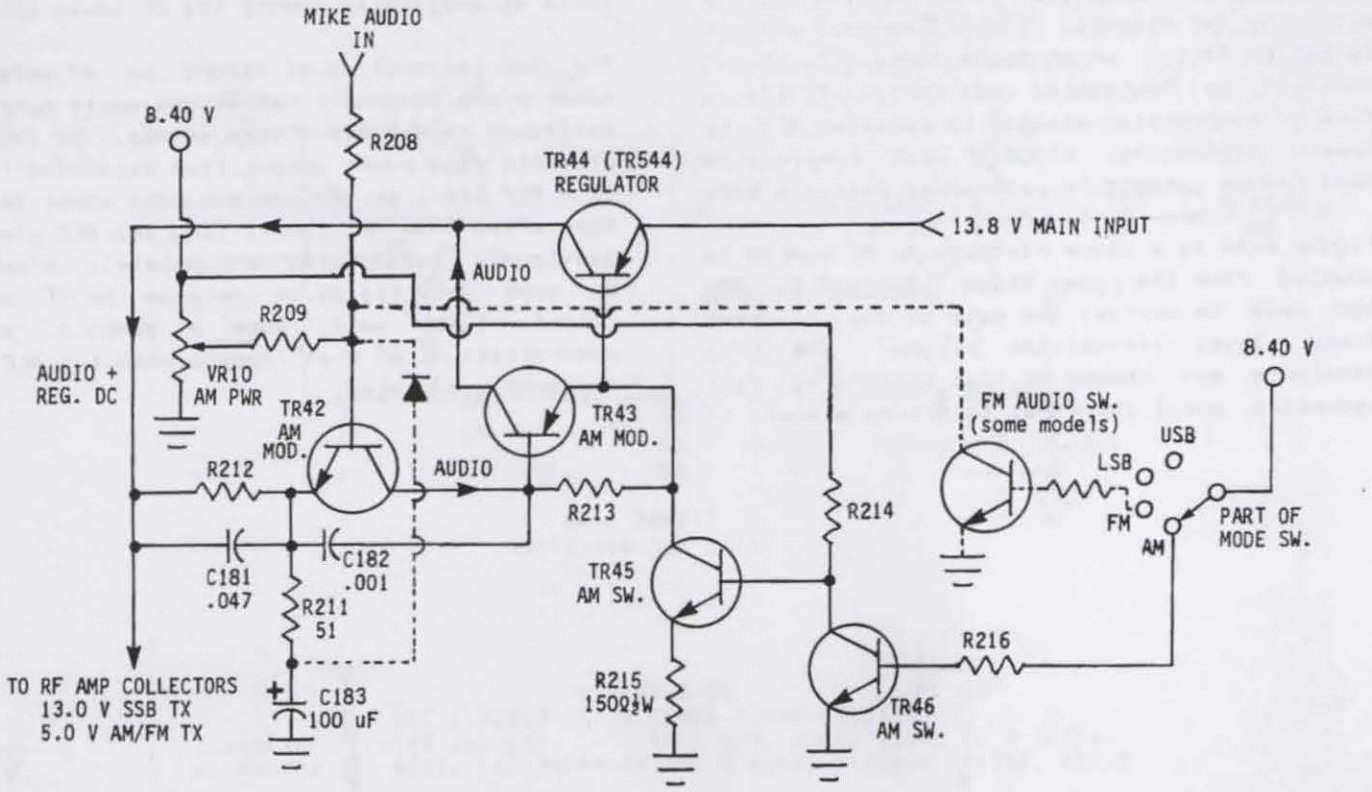
In most of the Cybernet export model chassis (PCMA0015, PTBM121D4X, PTBM133A4X, etc.) the discrete two-transistor Darlington was further simplified by using a single TO-220 plastic Darlington like the 2SD837 or 2SD1192. The schematics call this a "DC SWITCH BUFFER," but the functions are more accurately described as "DC REGULATOR/AM MODULATOR." (See Page 174.)

Switching control of the AM/SSB voltages and audio paths can be made using a section of the MODE switch, or by transistor switching typical of the newer Uniden chassis. (PB010, PB015, PB062, PB122, PC833, PC879, PC893, PC965, PC999.) Transistor switching is cheaper, since a MODE switch with fewer poles can be used. The circuit is a bit more complicated but works on exactly the same principle. The following describes this circuit, shown in Figure 6-43.

TR44 (TR544 in some models) is the main series-pass transistor, which connects to the 13.8 VDC main input and acts as a variable resistance to supply DC voltage to the RF Driver and Final collectors. The more negative its base, the harder it conducts and the more its collector voltage drops, which is the AM condition. The conduction of TR44 is controlled by TR42 and TR43, which double as AM modulators, and by switch TR45 (and TR46 in some models) which disable the regulation and audio for SSB. Base bias on TR42 is determined by VR10 and the mike audio. The audio path goes from TR42 to TR43 and out the collector of TR43 to the RF stages, being amplified along the way. Since the DC supply to the RF amp collectors will change at an audio rate, amplitude modulation results.

In the initial SSB condition TR45 is conducting via the constant base supply through R214, and R215 establishes its collector voltage (and therefore the base voltage of TR44) at about 13.0 VDC. Note R215 is a 1/2-watt type, since it's passing a fair amount of current. With the base of TR44 at 13.0 V and emitter at 13.8 V it will conduct, supplying about 13.6 V to the RF stages. The emitter of modulator TR43 is also at 13.0 VDC; its base is at about 13.2 VDC via

FIGURE 6-43
AM/SSB POWER CONTROL USING DISCRETE TRANSISTOR REGULATION
(Cobra 146GTL, President AX144, Realistic TRC451, Uniden PC244, etc.)



pullup R213. This keeps TR43 turned off so no modulated audio can pass to the RF stages.

On AM the reverse happens: TR45 turns off as its base voltage drops when TR46 conducts. TR42 conducts more and its collector goes lower, pulling down the bases of TR43 and TR44. They conduct, pulling down the DC supply to about 5.0 VDC. With TR43 now on, modulated audio can pass to the RF amps. C183 decouples audio, making it take the desired path through TR43. Note the small unbypassed emitter resistance (R211) of TR42; this increases stability by degeneration and lowering of stage gain. C182 rolls off the higher audio frequencies. In some models a diode (dotted lines) is added to clamp modulation peaks and isolate RF from the DC.

In the Uniden export models having FM, an extra NPN transistor (dotted lines) is turned on in the "FM" mode only. Its collector is across the modulated AM input and will shunt the audio to ground to prevent any simultaneous amplitude modulation. This switch is only for AM audio and has no effect on the power regulation part of the circuit, which is still needed for FM.

Because of the high current flow through the AM regulator, this circuit is a common failure. Symptoms include:

1. Blows main radio fuse.
2. No modulation on AM; SSB (and possibly FM) are OK.
3. Excess carrier power on AM (or FM).
4. Weak carrier power on AM (or FM).
5. No power adjustment possible.
6. No Transmit on AM (or FM); SSB OK.
7. Downward modulation due to poor regulation.*

*The Cybernet export models all suffer from this problem. There's no cure. I've personally tried everything from ripping out the associated wires and replacing them with heavier ones, to replacing the plastic Darlington with two discrete transistors of higher ratings. The only solution is not to exceed 4 watts maximum AM carrier power, regardless of the worthless POWER switch and its phony 7-watt "HI" position.

AUTOMATIC LEVEL CONTROL (ALC)

To prevent the splatter that results from overdriving a linear amplifier, some form of gain control must be used. This is similar to preventing overmodulation in an AM transmitter with the AMC circuit. The SSB control circuit is called "ALC," which means "Automatic Level Control" or "Automatic Load Control." It's a form of compression similar to receiver AGC or speech processing, since RF peak compression does reduce average-to-peak power ratios a bit.

Figure 6-44 is a block diagram. An RF sample is coupled from the Final stage, changed to DC, and used to control the gain of one or more lower level transmitter stages. The time constants are chosen so that there's no gain reduction until the Final is driven almost to its maximum linear capability, after which the ALC attacks rapidly to reduce gain. As shown, the ALC feedback voltage may be applied to the mike audio stage, an IF stage, or even the mixer with equal effect; lowering any of their gains automatically lowers the RF power output.

The ALC circuit must always be adjustable, since minor component variations would make it difficult to set with fixed values. The trimmer prevents the power output from exceeding the 12 W PEP limit at the maximum mike input level. More often than not you'll find the ALC circuit previously misadjusted or completely disabled by some jerk trying to increase the RF power output. Later we'll show a graphic 'scope demonstration of what happens when the ALC is improperly adjusted.

FIGURE 6-44
BASIC ALC OPERATION

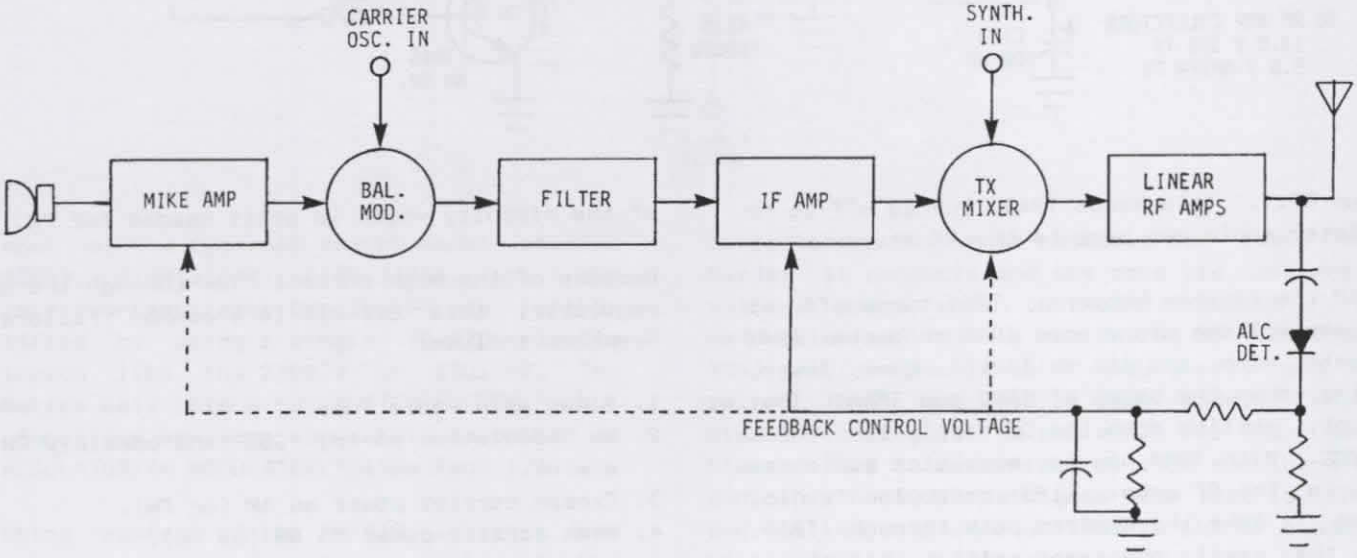


Figure 6-45 shows the simplest type of ALC circuit. In this model the sample comes from the Driver, but most circuits sample the Final. C123 couples the RF to the detector. This sampling capacitor is always very small to minimize amplifier loading and impedance changes. D37 conducts on positive RF peaks and D38 conducts on negative peaks, so the ALC voltage is negative-going and will lower the conduction of IF Amp TR13. C124, C125 and R94 form an RF filter and establish a suitable time constant for 27 MHz. VR9 sets the level at which the ALC attacks. Since TR13 is also used in the Receive mode, diode T/R switching via R95/D39/D31 is included for mode isolation.

Figure 6-46 shows how a Zener diode may also be used in an ALC circuit. Gain is controlled directly at the Transmit Mixer IC rather than at an IF amp. D8 is the ALC Detector, and RV2 sets the ALC threshold. R41, C58, C59, R172, and C901 are all part of the attack/delay time

FIGURE 6-45
ALC USING DIODE DETECTORS

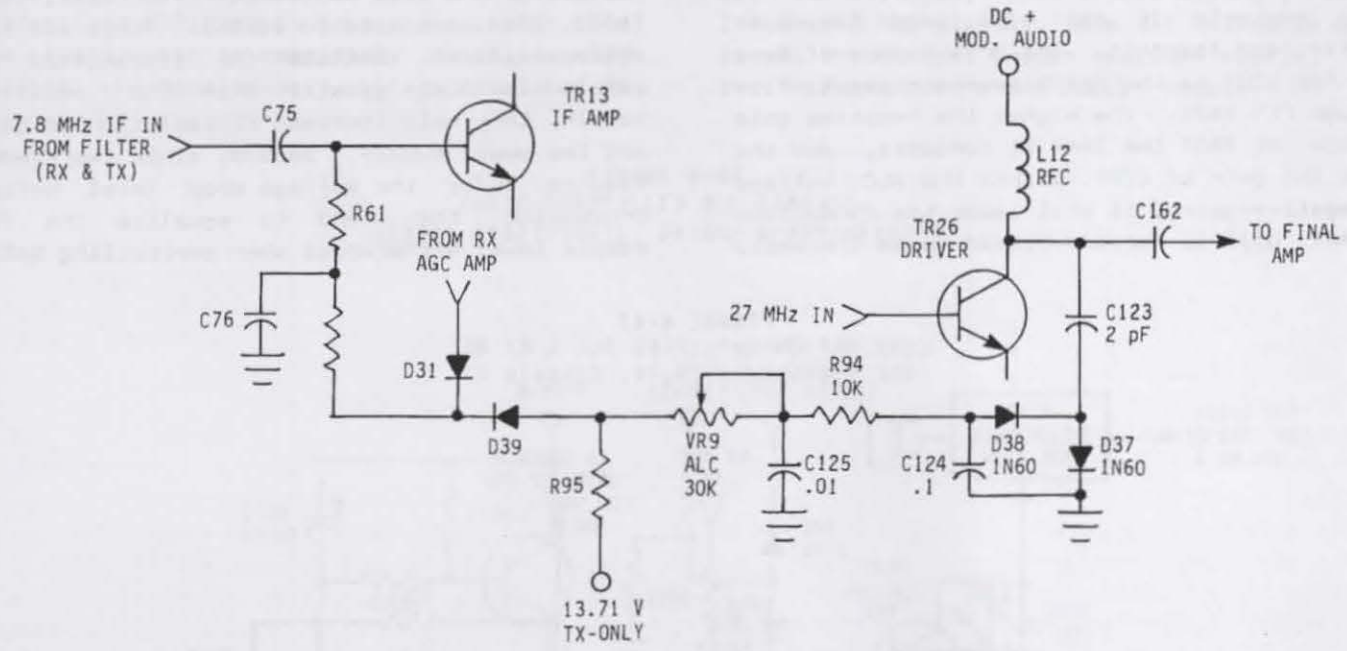
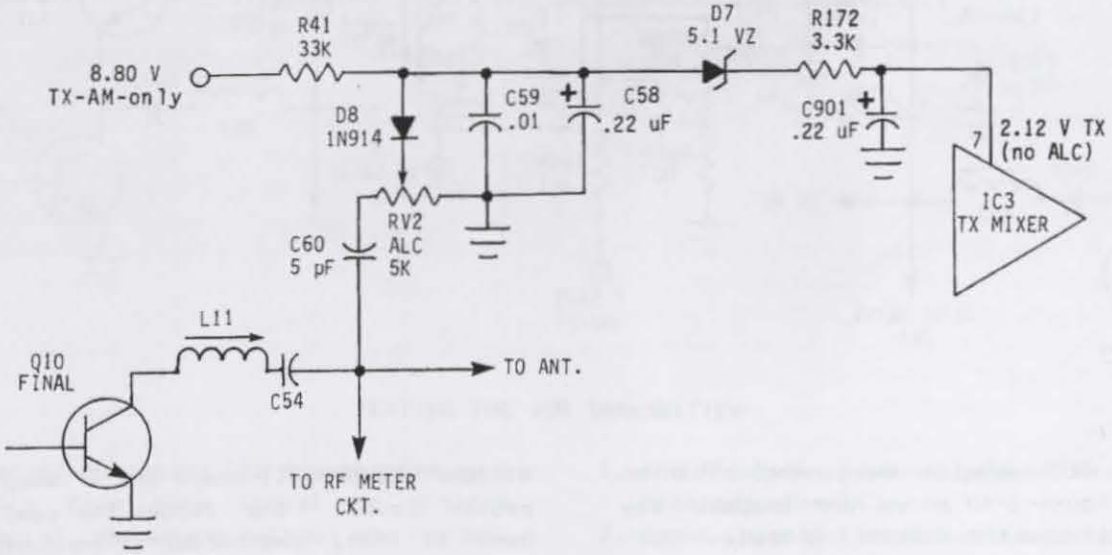


FIGURE 6-46
ALC CIRCUIT USING ZENER DIODE SENSING
(Cybernet PTBM058 chassis: Colt 480, 485, 1000, 1200, GE 3-5825A, JC Penney 981-6247, Lafayette Telsat SSB140, Midland 79-892, etc.)



constants. D7 is a 5.1 V Zener diode which is normally cut off on AM through the forward bias of the 8.80 V AM-Only Transmit source. A Zener conducts when its voltage is exceeded in the reverse-bias direction. For SSB, the conduction of D7 can be used to control IC3. When the negative RF peaks exceed 5.1 V plus the 0.6 V for D8 and the preset level, D7 and D8 conduct.

IC3 Pin 7 connects internally to the base of an output transistor, so the normal 2.12 V bias is pulled down and lowers the chip's RF gain.

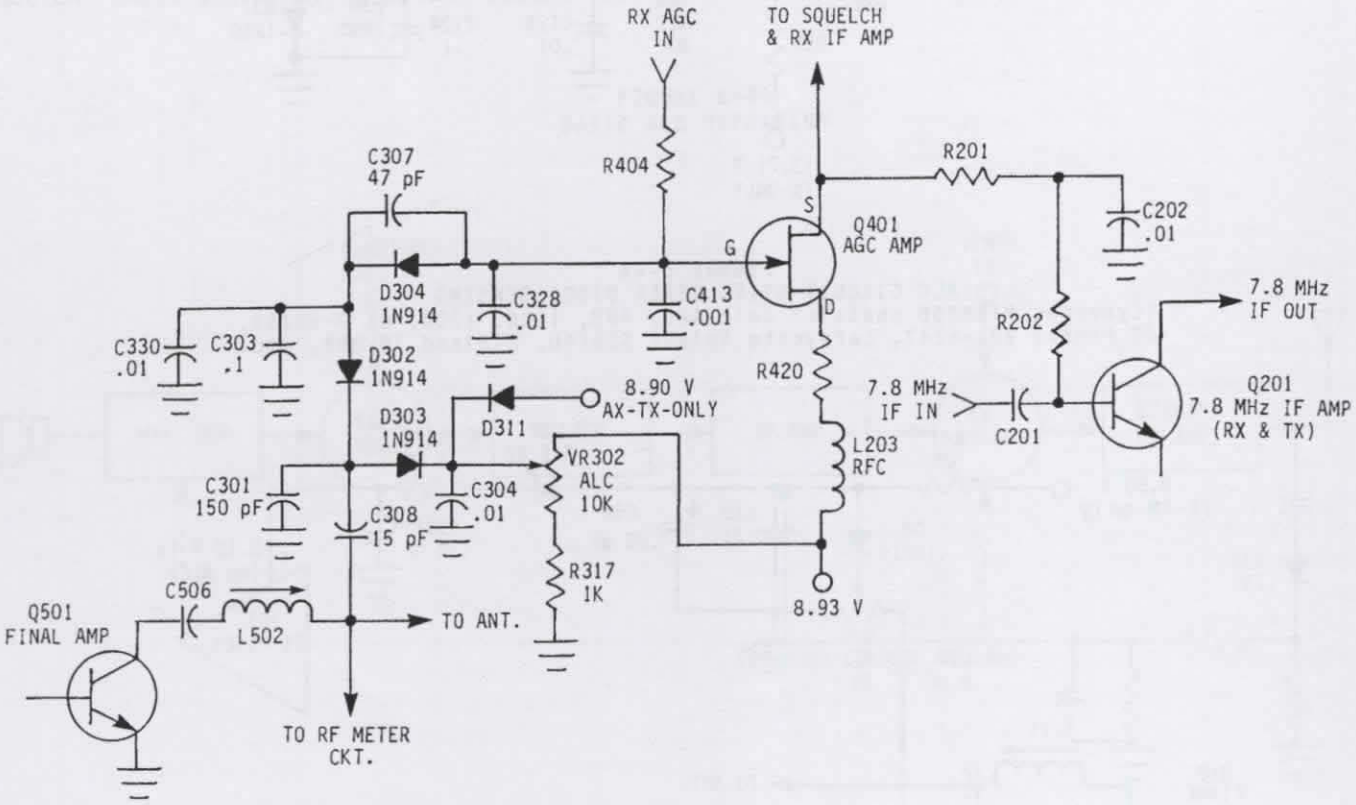
NOTE: There'a a slight difference between the Cybernet PTBM048 and PTBM058 chassis in the ALC circuit. In the PTBM048 version (Boman CB950, HyGain 2705, RCA 14T302, etc.) Zener D7 is used

to control SSB IF amp Q14 rather than IC3; both chassis types are otherwise identical.

Sometimes ALC is combined with receiver AGC, as in Figure 6-47. Q401 is the AGC amp, which in turns controls IF amp Q201 used for both Receive and Transmit. The only source of base bias for Q201 is the drain-source current flow through FET Q401. The higher the negative gate voltage at Q401 the less it conducts, and the lower the gain of Q201. Since the ALC voltage is negative-going, it will lower the conduction of Q401. D311 is forward-biased on AM Transmit, which cuts off isolation diode D303 so the circuit will only work on SSB.

The various shunt capacitors are for RF filtering and time constants. Two rectifiers (D302, D304) are used in series. There are two reasons: first, because the transmitted RF sample is much greater than the received sample, they help increase RF isolation to Q401 and the power supply. Second, since two diodes require twice the voltage drop level before conduction, they tend to equalize the T/R sample level differences when controlling Q401.

FIGURE 6-47
COMBINATION AMPLIFIED ALC & RX AGC
(SBE Sidebander IV, V, Console V)

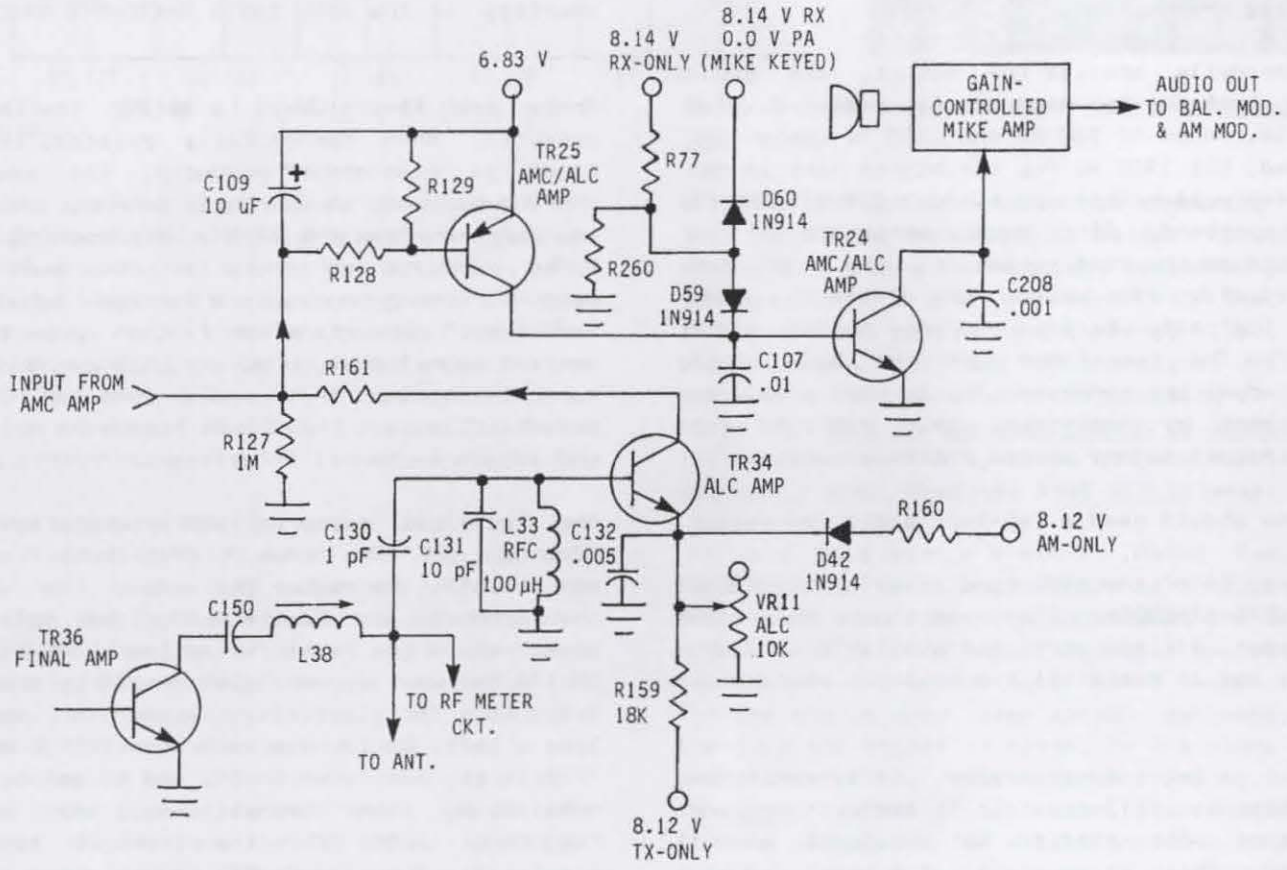


The previous ALC examples use control of IF or RF stages. Figure 6-48 shows how feedback may be used directly on the modulating audio. With SSB there's no RF output without modulation anyway, so audio control is just as effective. The ALC is shared with the AMC input, and both control the same shunt transistor across the mike line. The amplified ALC used here has much better control compared to the simpler diode detectors. TR34 is an RF amp, indicated by L33 and its lack of base bias. A 10:1 voltage divider (C130/C131) keeps the RF sample at the proper level. The larger the sample at the base of TR34, the harder it conducts and the further its collector voltage is lowered. The collector voltage swing is stretched out by the long time constant of C109/R127 to control the rest of the shunt amplifier circuit, TR25/TR24.

VR11 sets the conduction level; the lower the emitter voltage, the sooner TR34 conducts. The negative-going collector voltage of TR34 makes

TR25 conduct harder, supplying more base current to TR24. And the harder TR24 conducts, the more audio shunted to ground, reducing its level to the Balanced Modulator and therefore the RF output power. TR24 is also conducting on Receive via R77/R260 to help insure that the mike audio chain is completely disabled; D59 isolates the Receive-only voltage from the PA and mike keying circuits. Since limiting isn't required for the PA, the cathode of switch D60 is held LOW to keep TR24 inoperative in that mode. On AM, D42/R160 turn off TR34 by raising its emitter bias, thus disconnecting it from the shared AMC circuit. This ALC method is used in all the current Uniden American models, and the Uniden/Uniden clone export models.

FIGURE 6-48
AUDIO-CONTROLLED ALC CIRCUIT
(Cobra 148/2000GTL, Uniden Grant/Madison)



TESTING THE SSB TRANSMITTER

Since a properly operating SSB transmitter is a linear device from mike socket to antenna socket, special measuring methods are needed. Test equipment includes an oscilloscope, a peak-reading RF wattmeter, and if you're really lucky, a spectrum analyzer. In this section you'll learn the importance of linearity and how to test for it. There's only one reason for transmitter non-linearity: excess input signal relative to the bias level. And this in turn can only be caused by:

1. Insufficient base or grid bias. (Improper bias adjustment.)
2. Input signal level too large relative to bias level. (Improper ALC setting.)
3. Final amplifier not loaded heavily enough. (Improper tuning or alignment.)

The cures for these problems are obvious and can be easily fixed by any good, conscientious technician. If you're a true professional, don't let them leave your shop dirty.

The Two-Tone Test

The standard method for checking amplifier linearity is the "two-tone" test, where two RF frequencies of equal amplitude are applied to the linear amplifier, and the output is observed on a 'scope or spectrum analyzer for spurious products. Since an SSB transmitter has no RF output without an audio input, this means two audio tones can be applied at the mike input. For each audio frequency there should only be a single RF frequency. No amplifier is perfectly linear and some mixing will occur, but these mixing products should be much weaker than the main output.

To correctly analyze the output, the audio tones must not be harmonically related. For example, tones of 800 Hz and 1600 Hz could not be used, but 1900 Hz for the higher tone is OK. Both are well within the typical 300-2500 Hz CB audio passband. Since measurements are only as reliable as the test equipment, the tones must be very clean sine waves; any distortion would then logically be produced only in the radio itself. The two tones must also have equal amplitudes; the generator should have a balance adjustment or individual gain controls for this. Actual 'scope photos follow shortly.

If you should need a two-tone audio generator for your bench, there's a very good one in Chapter 25 of the 1986 (and later) ARRL RADIO AMATEUR'S HANDBOOK. They even show a full-size PC layout, all the parts are available at Radio Shack, and it meets all the criteria mentioned.

Without a two-tone generator, it's sometimes possible to use just a single audio tone and unbalance the carrier by an equal amount instead. This gives exactly the same result. But I find the carrier supression is so good in most IC Balanced Modulators that you can't unbalance them enough to match tone and carrier levels, limiting the use of this method to certain older SSB radios only.

The test equipment set-up is identical to that described in CHAPTER 5 (Figure 5-60), except that two audio tones are injected at the mike input instead of just one, and a peak-reading type of RF wattmeter is used. The transceiver is connected to a dummy load, and the 'scope across the RF output with a suitable coupler. The 'scope should have a 30 MHz bandwidth to view the 27 MHz RF signal directly.

Measuring Intermodulation Distortion (IMD)

The spectrum analyzer is the most accurate way to measure RF amplifier distortion. While the oscilloscope measures signal amplitude as a function of time, the spectrum analyzer measures amplitude as a function of frequency. By definition then it must have a tremendous bandwidth compared to a 'scope, which is why prices start at about $10,000! It shows a graphic display of all mixing products and their strengths relative to the carrier. Since one picture's worth a thousand words, I've reprinted some spectrum photos in this section, courtesy of the ARRL RADIO AMATEUR'S HANDBOOK.

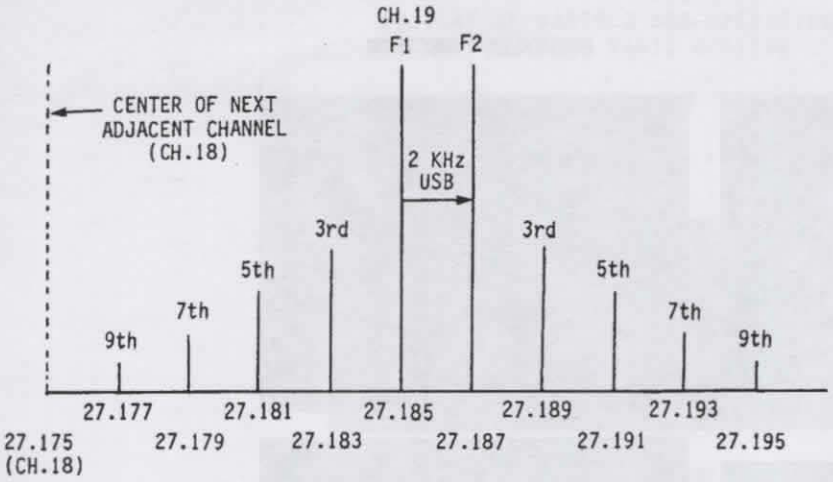
There are several ways to define the mixing products. When harmonically related, they're known as "even-order" products. For example, the 2nd harmonic of 27 MHz is 54 MHz, which is so far away from the 27 MHz fundamental that tuned circuits can remove it. Thus even-order products aren't generally a problem. But IMD or "odd-order" products often fall so close to the desired signal that tuned circuits can't always separate them, so they're also radiated. If not severely limited, they cause bleedover splatter and adjacent-channel interference.

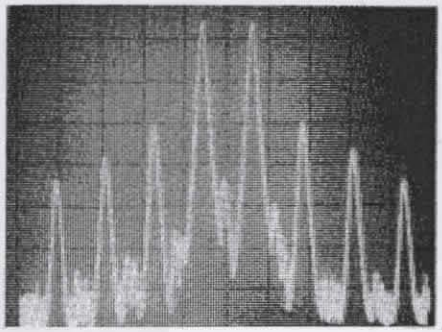
The technical names for IMD products are the "3rd Order," "5th Order," "7th Order," and so on. Usually the higher the order, the weaker the product. In Figure 6-49, the left-hand sketch shows the first few mixing products of a 27.185 MHz carrier modulated on USB by a single 2 KHz tone for simplicity; a complex waveform like a voice would have many more IMD products. "F1" is the center of Ch.19, and by temporarily unbalancing the transmitter, the second frequency ("F2") for the two-tone test is simulated. The 3rd Order products are ±2 KHz from F1 and F2, the 5th Order are ±4 KHz away, etc. While the SSB bandwidth is supposed to be limited to about 2.5 KHz, it's obvious that beyond the 5th Order, products start spilling over into the adjacent CB channel. If they're strong enough, interference results.

Good engineering specifies that 3rd Order IMD products be down at least -30 dB below one tone of a two-tone test input. Most CBs don't offer published specs. The FCC minimum specs are:

3rd & 5th Order: -25 dB or better.
7th & 9th Order: -35 dB or better.

FIGURE 6-49
IMD MIXING PRODUCTS





(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)

Now let's see what that means. In Figure 6-49, the right-hand photo shows the actual spectrum of an HF transceiver out to the 7th Order. The two large blips in the center result from the two inputs; note they're exactly the same amplitude, which is why the spec says, "one tone of a two-tone input." Spreading out from these two tones are the 3rd, 5th, and 7th Order mixing products.

Each horizontal scale division is 1 KHz, and each vertical division is 10 dB. The top edge of the photo is the 0 dB reference point, which means that the two tone peaks are actually down about -6 dB from the PEP output. (If they were in phase and combining, they'd have twice the voltage and twice the current of a single tone; a 4:1 power ratio equals 6 dB. That's why the two inputs can't be harmonically related.) The 3rd Order product is down about -30 dB, the 5th about -37 dB, and the 7th about -43 dB. So in this example, the FCC specs are easily met.

Effects of Amplifier Non-Linearity

To emphasize again the importance of proper alignment, review the photos of the test conditions in Figure 6-50. On the left are the two-tone 'scope patterns most of us would see. On the right are the graphic effects shown on a spectrum analyzer. Photo "A" shows a properly adjusted transmitter. The only noticeable IMD products are the 3rd Order, which are way down. In Photo "B" the bias was disconnected and the amplifier now approaches the Class C condition. Note the extremely strong 3rd Order products, with the 5th and 7th orders now appearing too. This particular condition is called "crossover" distortion, since the envelope crossover points are no longer a sharply-defined "X." The cure is to increase the resting current; i.e., the bias voltage. In Photo "C" the signal drive is excessive, which causes flat-topping or peak clipping. This is the most common CB condition, and you can see the spectrum has now splattered out quite wide. Readjust that ALC trimmer!

For those of you inexperienced at interpreting SSB 'scope displays, the additional photos of Figure 6-51 should help. A couple are similar to Figure 6-50, but using a faster sweep time. The top photos show voice speech patterns. On the left the signal is clean. On the right it's being overdriven, causing peak clipping. This is very typical in CB transmitters where the ALC was disabled. The slight increase in power output comes at the expense of everybody else near the frequency. Don't allow it.

Photo "A" shows proper transmitter adjustment, with a sharp "X" at the crossovers and straight envelope sides. Photo "B" is the same pattern but with hum on the signal, probably due to poor grounding in the test set-up. In Photo "C" the two tones were unequal, since they don't form a sharp "X" at the crossover points. The frequency response of some transmitters may not be flat across the whole voice range, so one tone may require a higher input level until you get the Photo "A" pattern. That's why the audio generator levels must be adjustable.

FIGURE 6-50
DISPLAY OF VARIOUS AMPLIFIER CONDITIONS VS. SPECTRAL EFFECTS
(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)

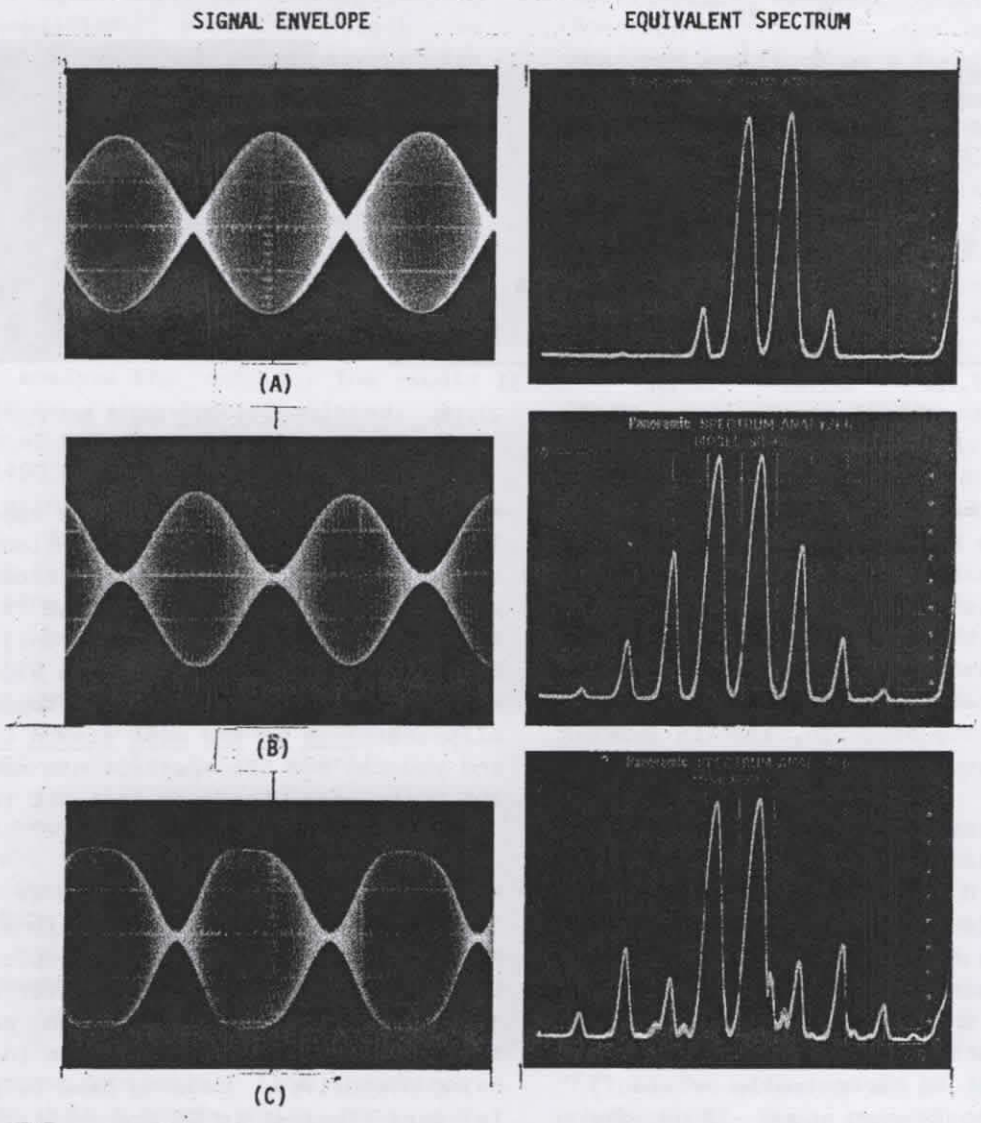
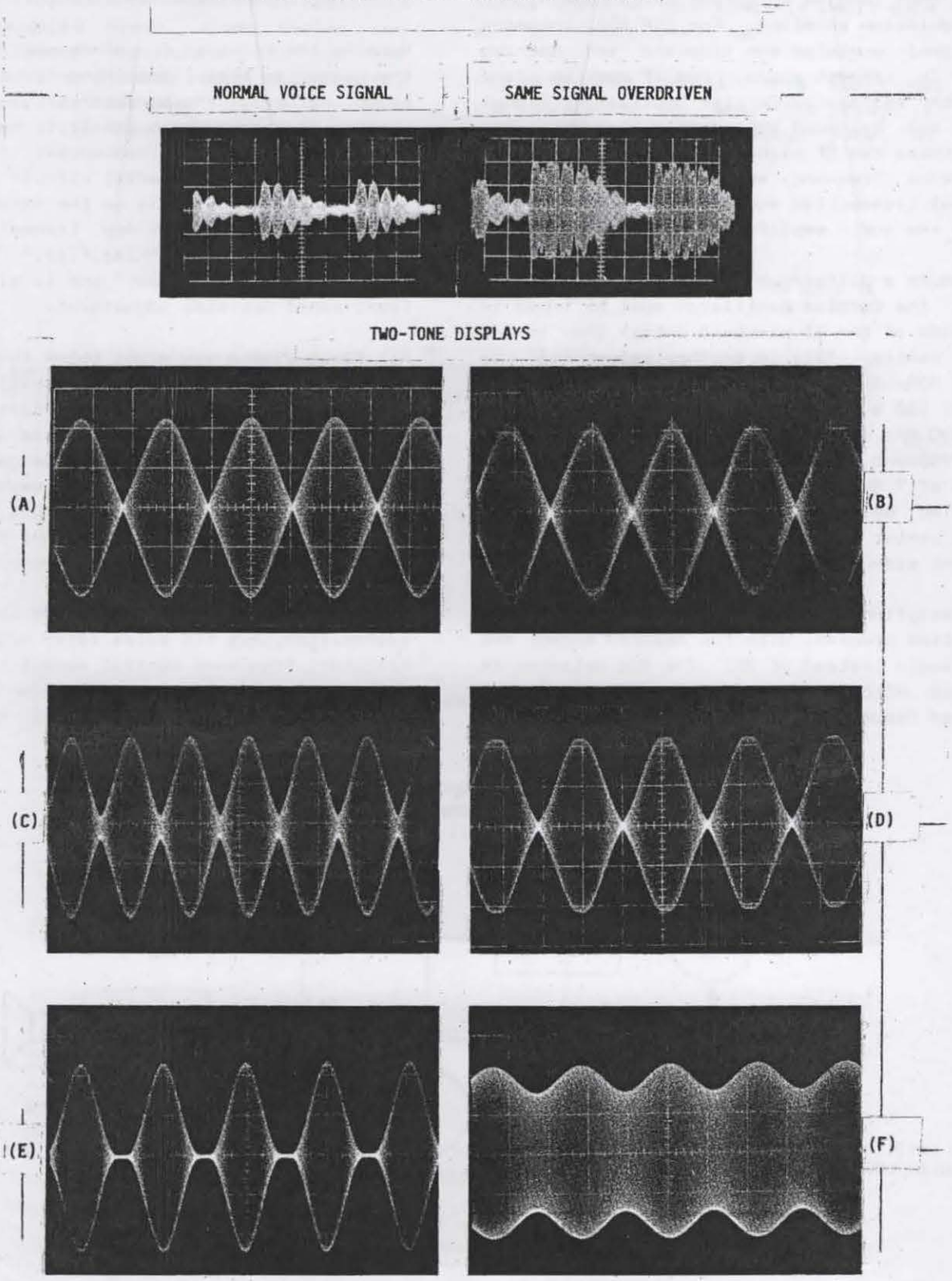


Photo "D" shows the start of flat-topping on the peaks, and the envelope sides are no longer perfectly straight. The amplifier is no longer linear and is being overdriven or underloaded; readjust the ALC or the input/output tuning of the Final, respectively. Crossover distortion appears in Photo "E," evidenced by rounding of the crossover points and the bright horizontal lines between the envelopes. The cause is insufficient bias, which should be readjusted to the manufacturer's specs. Most transistor CB Driver and Final stages idle at about 30 ma and 50 ma respectively; sometimes the adjustment's in terms of base voltages, about 0.60-0.75 VDC.

Photo "F" clearly shows undermodulation due to insufficient audio input. The level of the tone generator should be increased, or the "SSB MIC GAIN" trimmer in the radio (if present) should be adjusted. This photo could also represent a single tone modulating a partially suppressed carrier. It illustrates how a single tone might be used for SSB testing, assuming the audio and unbalanced carrier levels could be made equal.

At the end of this chapter we show a complete multimode transceiver alignment. Refer back to these 'scope photos to make sure your SSB test procedures and adjustments are done correctly.

FIGURE 6-51
DISPLAY OF VARIOUS SSB OPERATING CONDITIONS
(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)



SSB SIGNAL RECEPTION

An SSB receiver has some minor differences from AM, as shown in Figure 6-52. On AM a carrier and one or two sidebands couple from the IF amp to a diode envelope detector, which rectifies the signal to give an output corresponding to the modulation envelope. For SSB the incoming IF signal contains one sideband and nothing else. To recover audio, the IF must be mixed with the reinserted Carrier Oscillator signal which was balanced out during transmission. When these two RF signals mix, they produce a difference frequency which corresponds to the original transmitted audio. This signal is then fed to the audio amplifiers in the usual way.

To produce a difference frequency in the audio range, the Carrier Oscillator must be tuned to one side of the IF passband rather than to the exact center. This is another reason for the use of USB/LSB offsets. For example to detect a 1.5 KHz USB audio tone, the receiver might mix a 7.800 MHz IF with a USB Carrier Oscillator of 7.7985 MHz, producing the audio difference signal of 7.800 MHz - 7.7985 MHz = 1.5 KHz. AM can also be received on SSB by tuning to the exact center of the carrier or "zero-beat;" only one sideband will actually be detected.

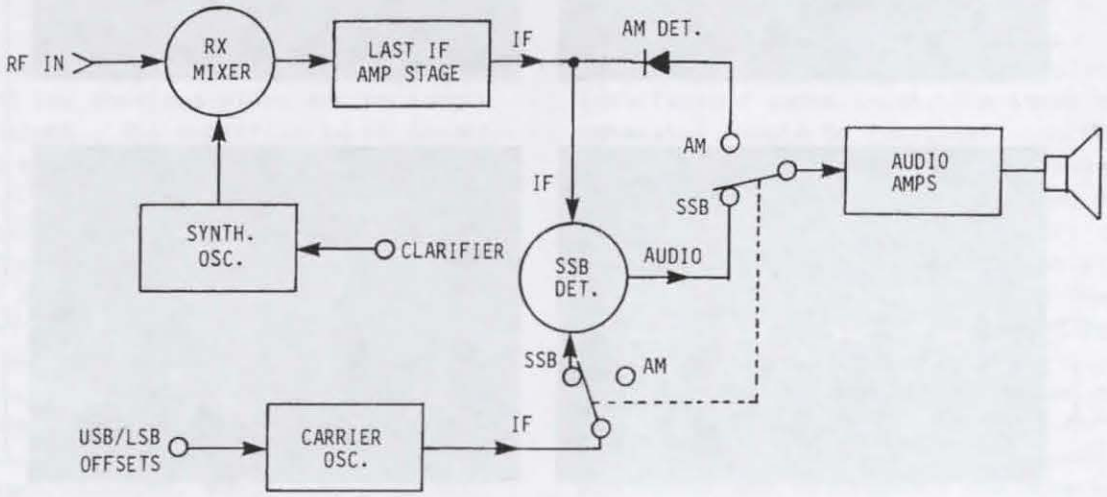
SSB reception is therefore the reverse of its modulation process, with the desired output now being audio instead of RF. The SSB Detector is a mixer circuit. The two main types are the Balanced Demodulator, and the Product Detector. (The Product Detector is also sometimes called a "synchronous" or "heterodyne" detector.) They're found about equally if you include all the older 23-channel CBs; modern radios favor just the Product Detector circuit.

Because the received frequency must be <u>exactly</u> the same as that transmitted for a voice to sound natural, and because no two SSB radios picked at random are likely to have exactly the same oscillator frequencies (within the required few Hz), a special circuit is included to shift the IF slightly so the recovered audio precisely matches what was transmitted. This circuit is called the "Clarifier," "Fine-Tune," "Slider," or "Voice Lock," and is always made a front-panel operator adjustment.

At first glance you might think the Clarifier should be tied to the Carrier Oscillator, since that is what reinserts the carrier; but this oscillator is crystal-controlled and is only shifted by a fixed amount to change sidebands. Instead the Clarifier circuit always shifts the crystal or PLL <u>synthesizer</u> output, which is what provides the mixer injection; this in turn shifts the received IF to be demodulated.

Originally the Clarifier was also locked to the transmitter, but FCC rules later prohibited any operator frequency control except the Channel Selector itself. Current (American) CBs have a Clarifier that's only functional on Receive.

FIGURE 6-52
AM & SSB RECEIVER DIFFERENCES



You'll find the Clarifier circuit to be a major CB repair headache, as countless amateurs keep trying to modify it back to the old way!

Balanced Demodulators

This type of SSB detector circuit is basically a double-balanced diode mixer having two slightly different IF inputs. It has the advantages of wide dynamic range, low noise, and good separation between inputs. Because it's balanced, the carrier and a lot of the harmonic products resulting from the strong L.O. injection are highly suppressed. Diode mixers do have loss though, about 8 dB for the ring, so you'll find radios using this circuit also tend to have more audio amplifier stages. These are generally the older, pre-IC models using three or four discrete audio amps and a push-pull audio power amp.

Figure 6-53 is typical. This works just like the transmitter BM, where the bridge is being unbalanced at the modulation rate. An input

FIGURE 6-53
BALANCED DEMODULATOR SSB DETECTOR
(Pearce-Simpson Bengal SSB)

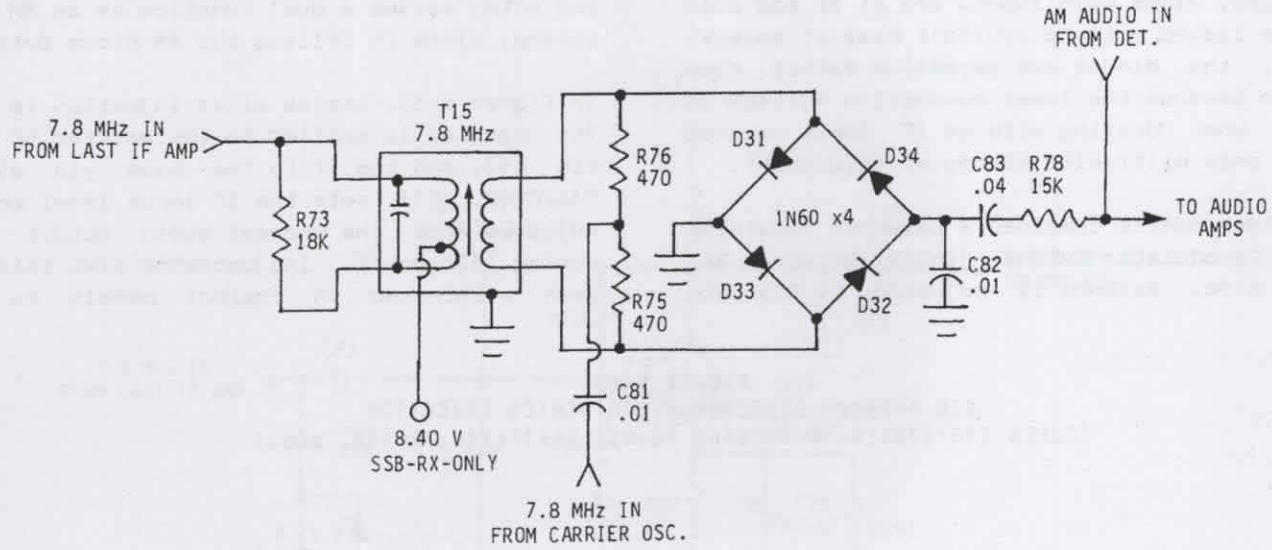
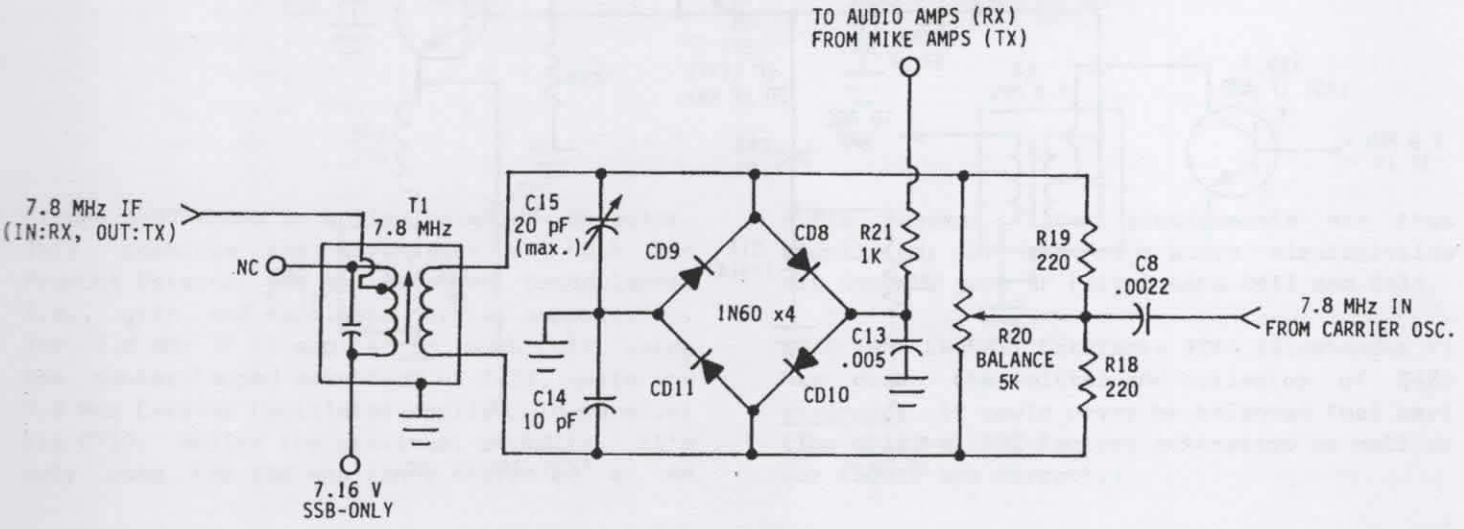


FIGURE 6-54
COMBINATION BALANCED MODULATOR/DETECTOR
(Browning LTD, Cobra 132/135, 132A, Tram D60)



transformer (T15) is used to make the IF operate in push-pull; the Carrier Oscillator is applied in parallel via C81 and is removed by the push-pull configuration. R73 lowers the Q of T15 to help maintain stability. The Carrier Oscillator has the strongest input signal, so it controls diode conduction. Matched resistors R75 and R76 balance the carrier input. As the modulated IF is applied, the bridge becomes unbalanced at a rate that corresponds to the modulated intelligence. Audio is coupled out through C83. C82 shunts any residual RF so the output is pure audio. AM audio joins it at R78, since both modes share common audio power amps.

There are two notable differences from the transmitter version. First, no BALANCE control is needed, since both inputs are at RF and even if some leaked out you couldn't hear it anyway. Second, the diodes are germanium rather than silicon because the lower conduction voltage is needed when dealing with an IF input signal that's only millivolts strong at this point.

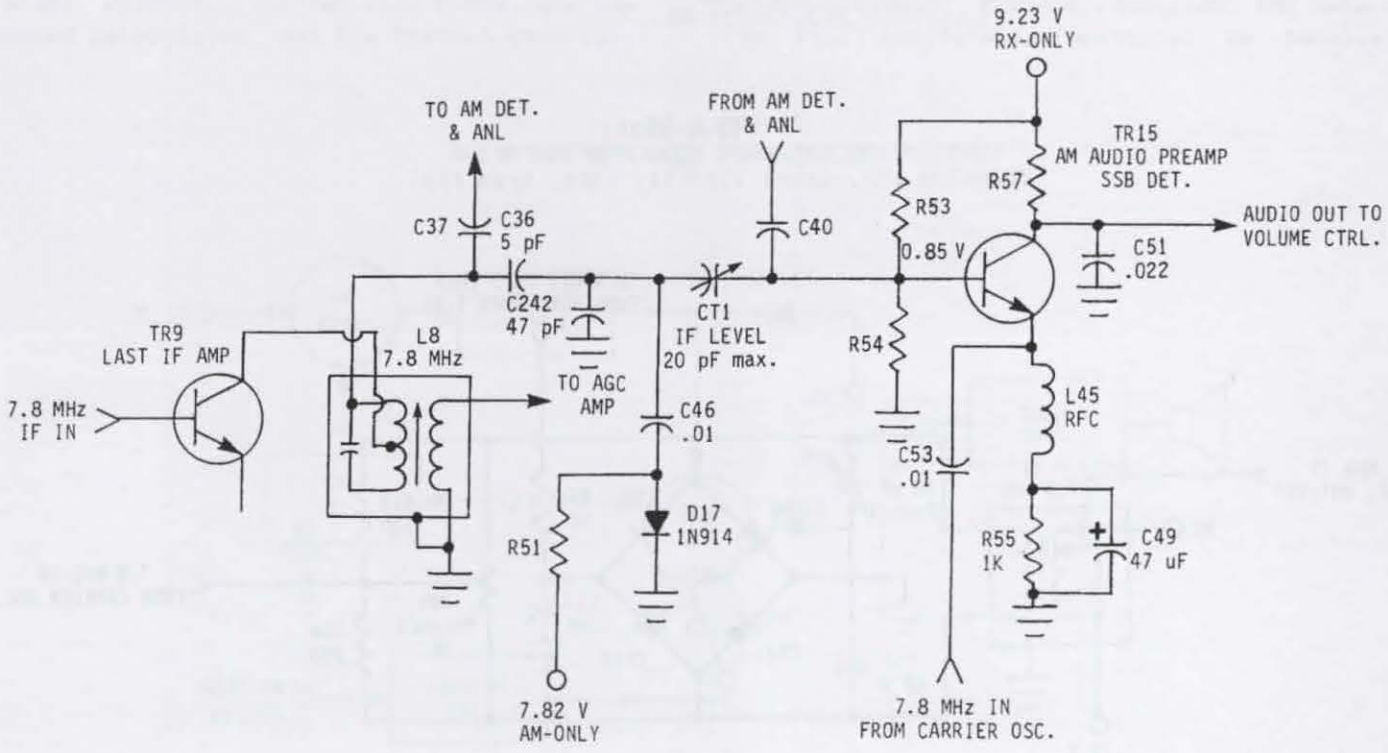
Some older models combined a Balanced Modulator and a Demodulator into a single bridge. See Figure 6-54. Balance is adjusted by C15 and R20. Both the mike audio input and the receiver audio output are coupled via R21, which when combined with C13 forms an RF filter to insure there's only audio at this point. The diodes are germanium again for maximum sensitivity.

Product Detectors

The Product Detector is the modern SSB method, since it offers some voltage gain which can be followed by simpler audio chains using audio power ICs. Because of its high gain less L.O. injection is needed, which reduces IMD in the audio output. In this circuit the Carrier Oscillator is added to the incoming IF, and the product of mixing them together is the audio difference. The stage uses an NPN transistor and often serves a dual function as an AM audio preamp, since it follows the AM diode detector.

In Figure 6-55, series mixer injection is used. The carrier is applied to the emitter of TR15 via C53, and the IF to the base via divider C36/C242. CT1 sets the IF input level and is adjusted for the correct audio output level during alignment. (Adjustments like this have been eliminated in current models to save

FIGURE 6-55
SSB PRODUCT DETECTOR USING SERIES INJECTION
(Cobra 138/139XLR, President Adams, Realistic TRC458, etc.)



costs.) TR15 is lightly biased (0.85 VDC) to perform as a mixer on SSB. L45 keeps the carrier injection point well above RF ground for mixing purposes, while R55/C49 bias TR15 for audio amplification on AM. C51 removes RF from the output. On AM, R51 turns on D17 and shunts the SSB IF path to ground through C46.

Figure 6-56 uses shunt mixer injection. Both inputs are applied to the base of TR13, because the emitter is being used for the squelch circuit; when enough positive squelch control voltage develops at the emitter it turns off TR13. Otherwise its operation is the same as in Figure 6-55. C24/R30 bias TR13 for AM audio amplification, and C25 removes residual RF. Note how D10 was added in series with AM shunt switch D11 for better power supply isolation.

FIGURE 6-56
SSB PRODUCT DETECTOR USING SHUNT INJECTION
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)

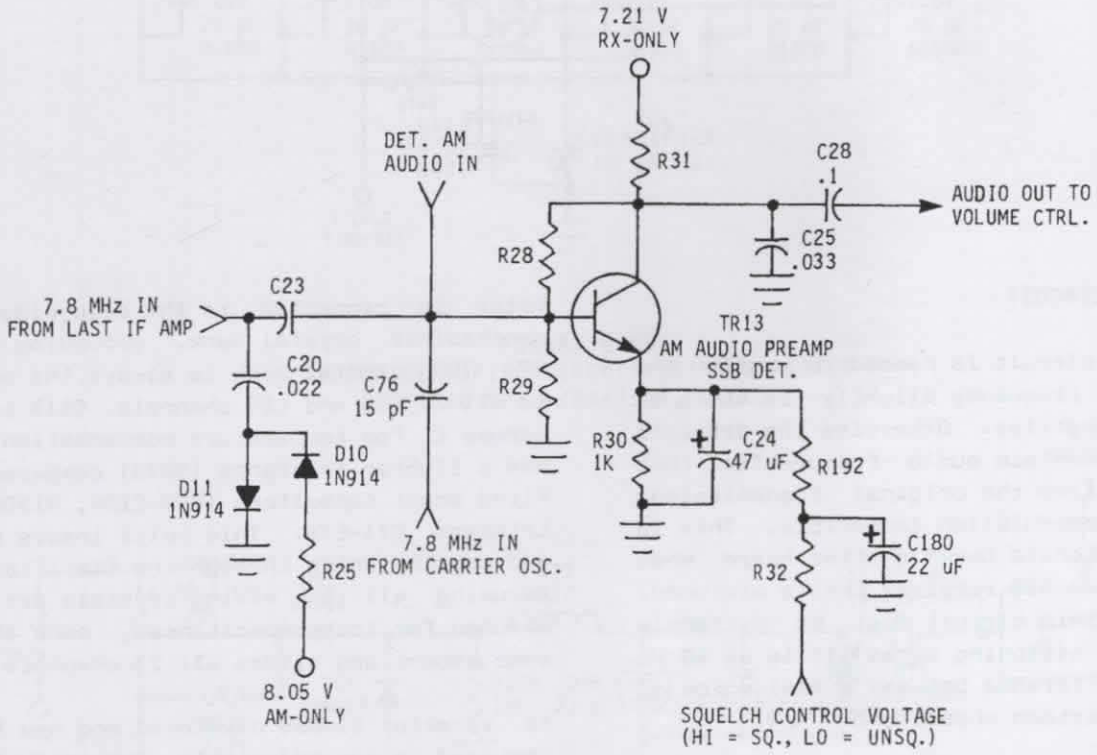
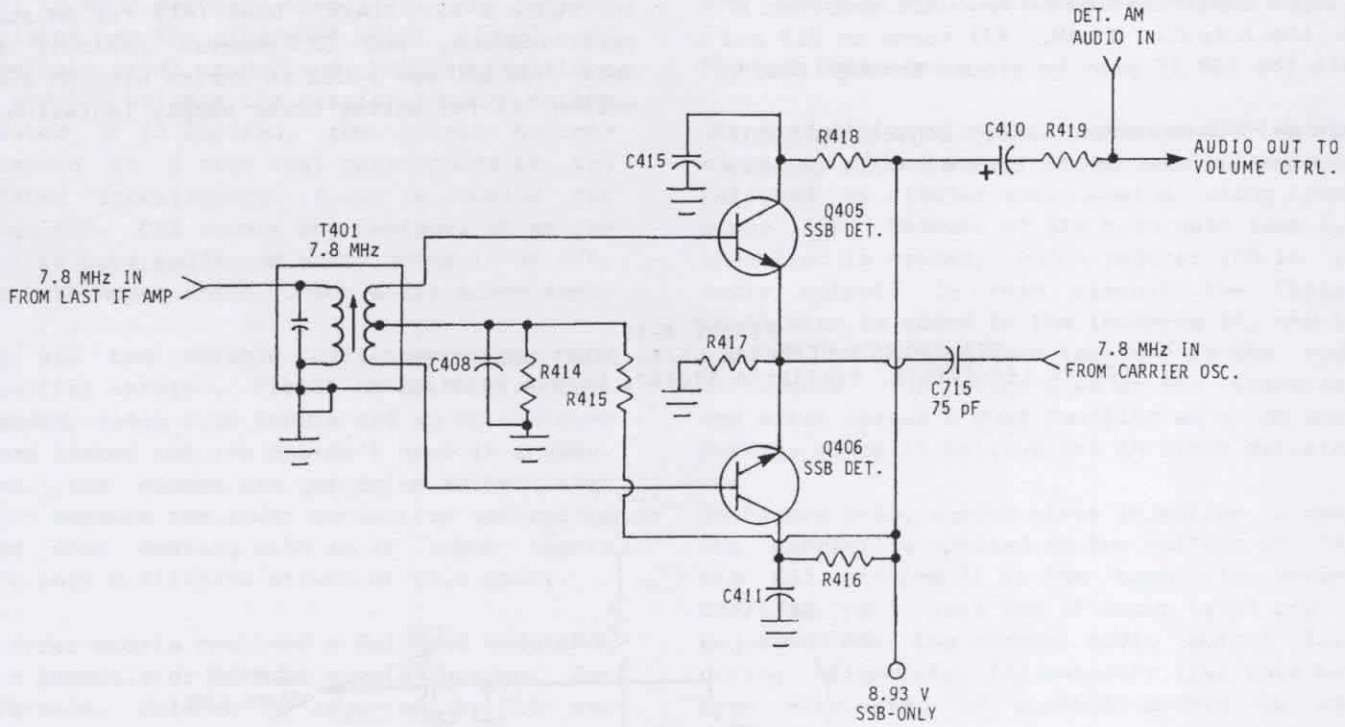


Figure 6-57 shows an active balanced detector. This combines the advantages of both the Product Detector and the Balanced Demodulator; i.e., gain and excellent carrier suppression. The 7.8 MHz IF is applied in push-pull using the center-tapped secondary of T401, with the 7.8 MHz Carrier Oscillator applied in parallel via C715. Unlike the previous circuits, it's only used for SSB and isn't shared as an AM audio preamp. Filter requirements are thus simplified; no expensive audio electrolytics are needed, just RF filter caps C411 and C415.

NOTE SAMS ERROR: Fotofacts #264 (Sidebander V) has drawn the emitter and collector of Q405 reversed; it could never be balanced that way! (The original SBE factory schematics as well as our figure are correct.)

FIGURE 6-57
BALANCED SSB PRODUCT DETECTOR
(SBE Sidebander IV, V, Console V)



THE CLARIFIER CIRCUIT

The Clarifier circuit is needed to shift the L.O. injection frequency slightly relative to the reinserted carrier. Otherwise the detector output would contain audio frequencies that were different from the original transmission, making proper demodulation impossible. This is the familiar "Donald Duck" chatter heard when you listen to an SSB receiver that's mistuned. By definition this circuit must be extremely stable, since mistuning by as little as 40 Hz can make the difference between a real voice or your favorite cartoon character!

The Clarifier shifts the receiver IF just enough to match the correct audio. It's always associated with the main synthesizer circuit, since that's what determines the exact IF developed at the mixer(s). In PLL circuits it's connected to the same stage as the AM/USB/LSB offsets and in fact the only difference is that the Clarifier is continuously adjustable over a small range, while the mode offsets are shifted by fixed amounts.

Figure 6-58 is an example from the 23-channel era using an air-variable capacitor. The stator of CL is bolted to the front panel, while its rotor is connected to the cold side of one synthesizer crystal bank, grounding them for RF. This crystal bank is always the one common to all 23 USB and LSB channels. C113 is shunted across CL for temperature compensation; note it has a tighter tolerance (N470) compared to the fixed shunt capacitors (C99-C104, N1500) across trimmers CT1-CT6. This helps insure stability and smooth tuning through the Clarifier range. Assuming all six mixing crystals are closely matched for load capacitances, each shifts the same amount and slides all 23 channels equally.

As varactor diodes developed and new FCC rules required a non-adjustable Transmit Clarifier, the circuit of Figure 6-59 appeared. This is the standard method now used for all CB crystal oscillators and has many variations, always working on the same basic principle. Recall the varactor diode changes its capacitance as the reverse bias changes. The greater this bias the smaller the capacitance, and vice-versa. When used with a standard Colpitts oscillator, this changing capacitance also shifts the oscillator frequency slightly.

Crystal X3 can be shifted by both varactor D35 and CT1. (CT1 is the fixed USB offset.) D51 and D52 are steering diodes used to isolate T/R

FIGURE 6-58
EARLY 23-CH. CLARIFIER USING AIR-VARIABLE CAPACITOR
(Courier Spartan SSB)

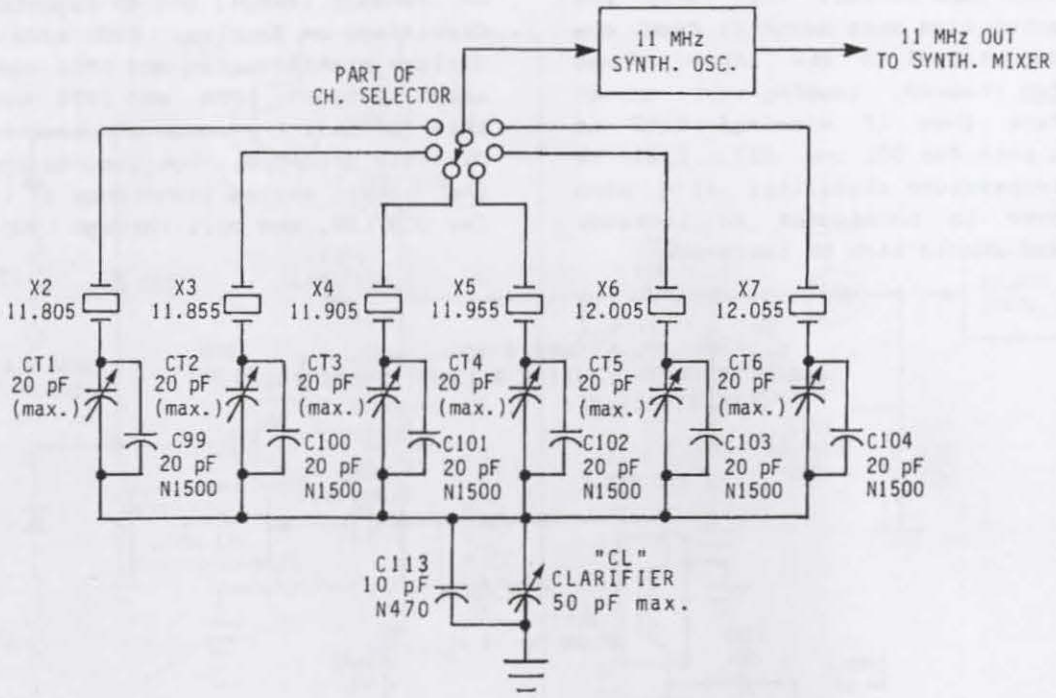
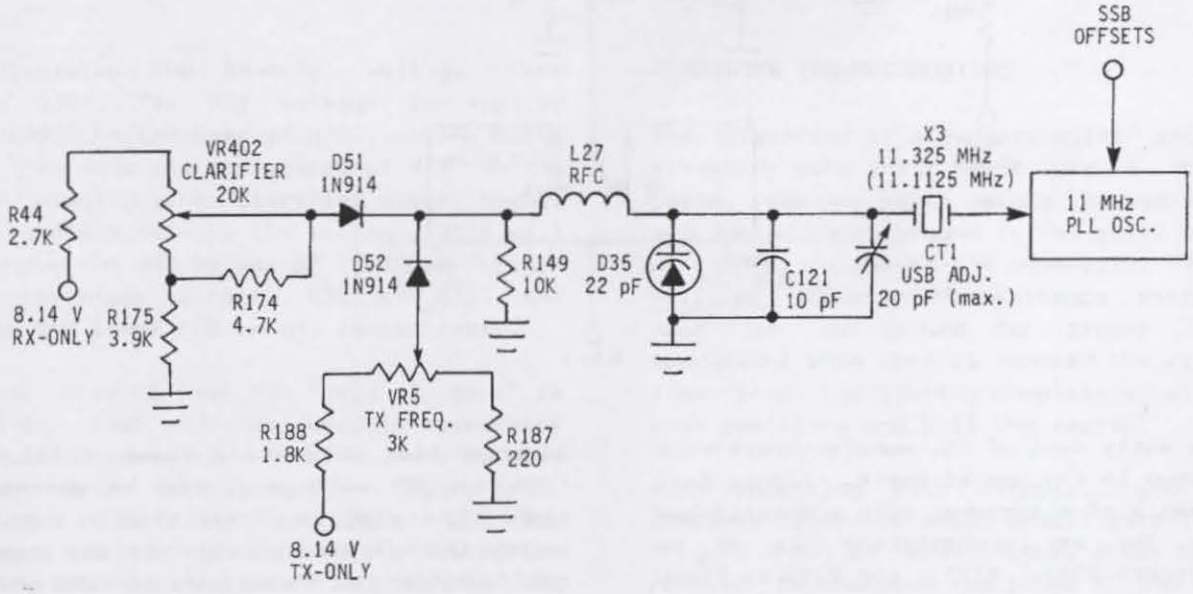


FIGURE 6-59
MODERN CLARIFIER CIRCUIT USING VARACTOR
(Uniden Grant/Madison, etc.)



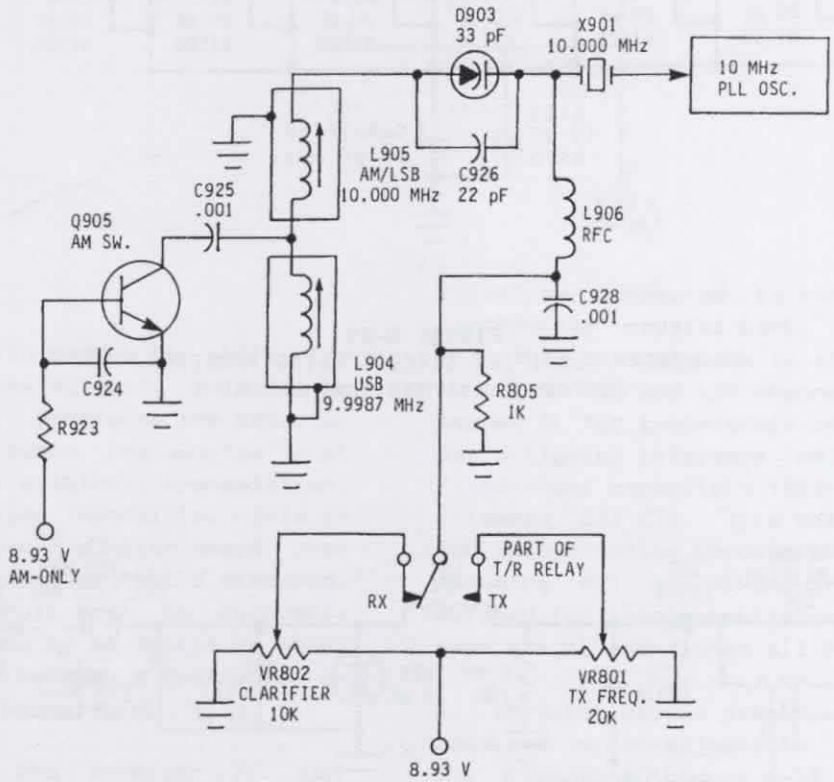
functions; the Clarifier control only has a DC voltage applied in the Receive mode via R44. On Transmit the fixed internal trimmer VR5 sets the frequency, being supplied with Transmit-only voltage via R188. Thus on Receive, D51 applies operator-controlled varactor bias while simultaneously cutting off D52.

On Transmit, D52 applies the preset bias and cuts off D51 and the front panel control. L27

is an RF choke which isolates the DC supply and keeps RF on the crystal side of the circuit. Parts R44/R174/R175 and R187/R188 form voltage dividers for each mode which help to keep the Clarifier action more linear; they taper the changing varactor bias more smoothly from one end of the knob travel to the other. These parts are often removed, causing very uneven tuning. Replace them if missing! R149 is the grounding path for D51 and D52. C121 is crucial for temperature stability; it's also commonly removed in an attmept to increase slide range, and should also be restored.

Figure 6-60 shows a circuit using relay rather than electronic Clarifier control switching. Instead of diodes a set of relay poles controls the varactor voltage. A preset bias is applied on Transmit (VR801) and an adjustable bias (the Clarifier) on Receive. R805 adds some voltage-divider stabilization and C926 adds temperature stabilization. L906 and C928 decouple RF. In this circuit the anode of varactor D903 isn't directly grounded, but grounds instead through the total series inductance of L905 and L904 for USB/LSB, and only through L905/C925 for AM.

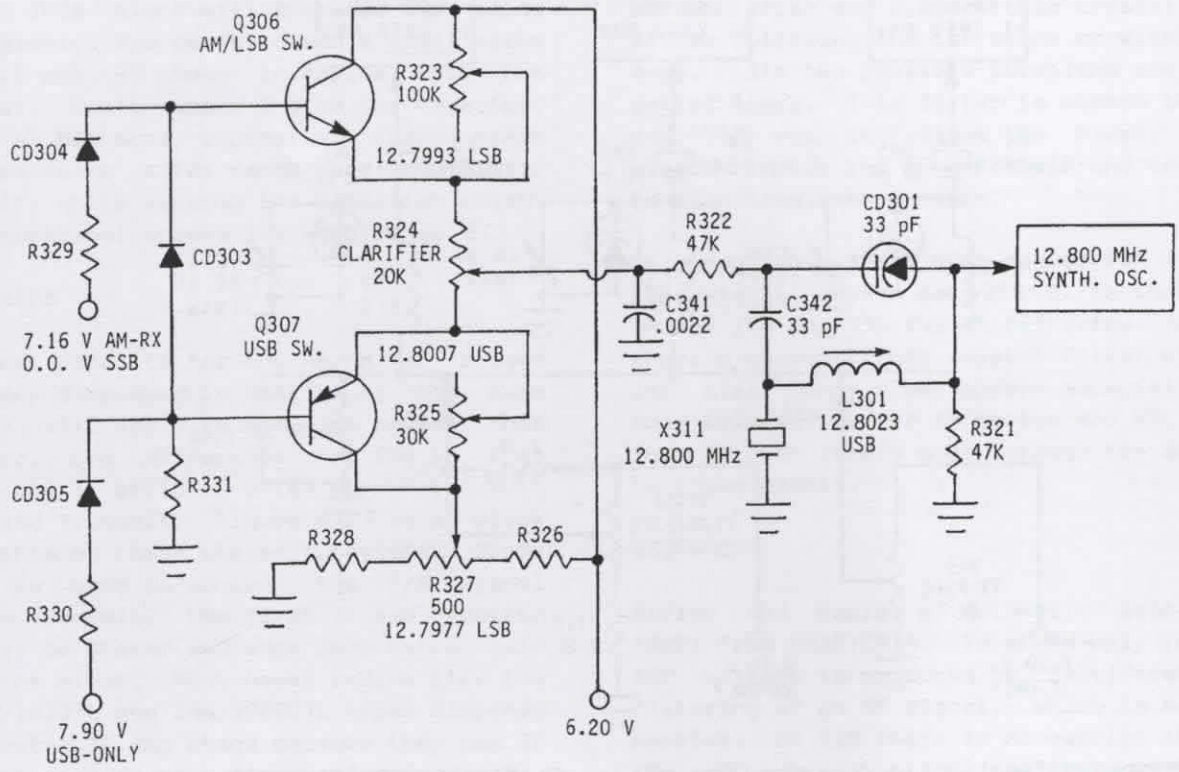
FIGURE 6-60
CLARIFIER CONTROL USING RELAY T/R SWITCHING
(SBE Sidebander IV, V, Console V)



During the early days of CB, manufacturers were more generous in the use of parts. Figure 6-61 is an example of a somewhat more sophisticated Clarifier. The way to understand this is to first consider R323, R325, and R327 as fixed resistors. All are in series with the Clarifier pot to form voltage dividers. Depending upon the mode, this means the wiper of the Clarifier will be more or less above ground potential. The higher the wiper above ground, the higher the varactor bias and therefore the higher the crystal frequency. Thus USB needs the most varactor bias and LSB the least. CD301 and C342 form an RF voltage divider to increase the stability. They're in series with the crystal rather than in shunt, which is the more common configuration. L301 adjusts the USB offset and R321 lowers its Q for better stability.

On AM and LSB, Q307 is conducting and shorting out R325. This places the Clarifier wiper closer to ground, lowering its voltage and the crystal frequency. On AM Q306 turns on and shorts out R323, raising the wiper voltage.

FIGURE 6-61
TRANSISTOR-SWITCH CLARIFIER MODE CONTROL
(Browning LTD, Cobra 132/135, 132A, Tram D60)



CD303 isolates the AM-only voltage from reaching Q307. For USB voltage is applied through CD305 to the base of Q307, which turns it off. This adds the resistance of R325 to the circuit, placing the Clarifier wiper higher above ground and raising its voltage. Q306 will also conduct on USB by way of CD303, further raising the wiper voltage. R323 and R327 set the upper and lower LSB range, respectively.

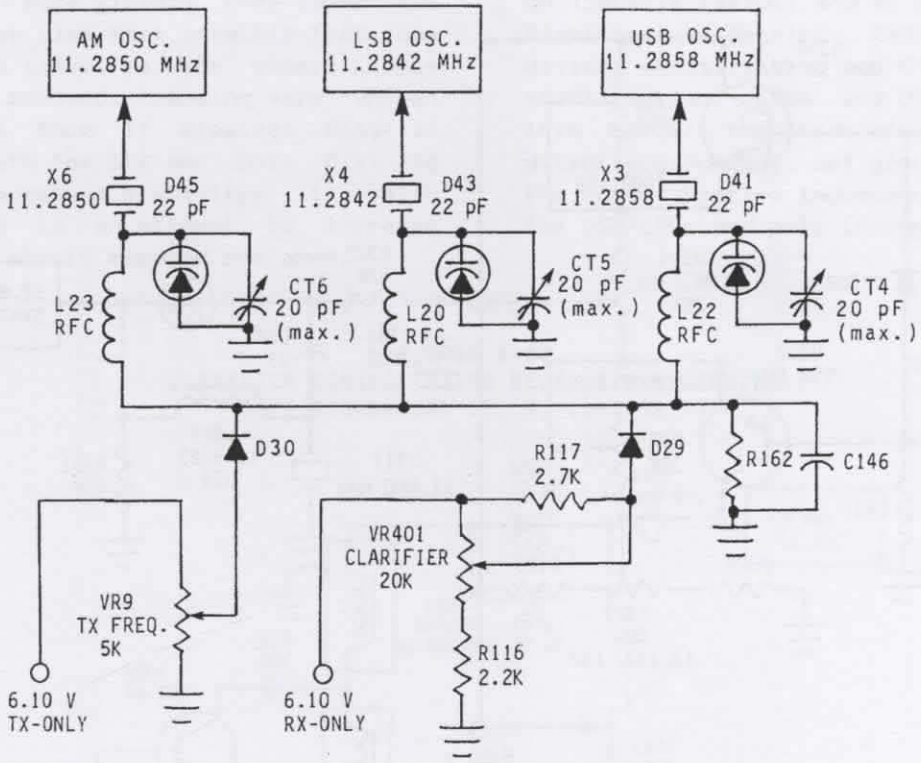
One final circuit from the "good old days" is Figure 6-62. Each mode has separate transistor oscillators, crystals, varactors, and related parts; otherwise it's just like Figure 6-59. The cathodes of D45, D43, and D41 are all tied to a common bus that connects to the Clarifier and Transmit frequency trimmer adjustment. The Clarifier is powered by a 6.1 V Receive-only source, while VR9 uses a 6.1 V Transmit-only supply. D30 and D29 isolate each source from the other. R116 and R117 are part of the Clarifier's voltage divider to insure smooth knob action; replace them when missing!

CLARIFIER TROUBLESHOOTING

The Clarifier is a major problem area, since everybody gets their hands into it. They remove parts, change parts values indiscriminately, and jumper wires around to the point where it's no longer close to the schematic. There's a critical inductance/capacitance ratio which must be maintained for proper Clarifier operation! When this is ignored the circuit may even stop oscillating completely at certain knob positions and kill the radio.

When repairing this circuit, you'll often discover that the shunt stabilizers like C121 (Figure 6-59) or C926 (Figure 6-60) have been removed to increase the range of the Clarifier circuit. It's true that without having to divide the capacitance between the varactor and its shunt, the varactor has a greater effect. But it does this at the cost of a very touchy, unstable, and non-linear Clarifier control that tends to drift.

FIGURE 6-62
CLARIFIER USING SEPARATE OSCILLATORS FOR EACH MODE
(Cobra 138/139XLR, President Adams, Realistic TRC458, etc.)



Another common modification is the shorting of any or all voltage divider resistors around the Clarifier pot. This does have the effect of increasing the varactor bias, but at the cost of lost knob symmetry; the shift becomes logarithmic at one end of the knob range and crams a huge amount of up or down slide into a tiny amount of knob travel. And it leaves no significant series resistance except the Clarifier pot itself to limit power supply current, sometimes causing sudden regulator failure. (The MB3756 is often prone to this.)

When the complaint is "No Clarifier Control," first check for a changing DC bias voltage at the varactor's anode when the knob is turned through its range. If it's missing, or there's a fixed voltage that doesn't change at all, trace the DC path back to its source to locate the problem. You'll often find the cause to be an improper modification by some amateur. Most of the customer complaints about poor Clarifier operation will be traced to previous meddling rather than an outright component failure. When gross circuit and component changes are found, restore them to normal!

CLARIFIER SERVICE NOTES:

1. Always replace ceramic disc capacitors in critical circuits with the proper type. For temperature compensation or offsets, use "NPO" types rather than the general purpose "Z5U" type. The NPO version has a superior dielectric which is much more stable with changing temperatures. When the capacitor has an "N" number, like "N220," this refers to the maximum capacitance change, specified in parts-per-million (ppm) per °C. and is negative (N); the higher the temperature, the lower the capacitance. In this example, the downward drift is only 220 ppm per °C. rise in temperature.

2. Crystal load capacitance (C_L) has a direct effect on the amount of frequency shift. The smaller the C_L, the greater the effect of any external capacitors and inductors on frequency shift. For American CBs, the crystal associated with the Clarifier will generally have a 20 pF C_L rather than the standard 32 pF synthesizer crystal. Replace faulty crystals with those having similar characteristics. (See #3 for exceptions.)

3. Since most people will continue to modify Clarifiers, the smart way to do it and avoid the headaches is to copy the export radio method. Replace the crystal in the Clarifier circuit with one having a C_L of only 10 pF and the highest accuracy available, usually .001%. This alone will increase the slide considerably. You can also add a small value (2.2-4.7 µH) RF choke in series with the varactor. Don't exceed 8 V on the varactor. While a bit more expensive, these steps will maximize slide range and oscillator stability while keeping the Clarifier smooth and symmetrical across its knob range.

IF AMPLIFIERS

Theory and circuits for the AM/FM IF stages were already discussed in CHAPTER 4; the same principles will apply to SSB, so review that section too. One difference for SSB is that part of the IF strip is often common to both Receive and Transmit. Figure 6-63 is a block diagram showing these shared functions. Diode steering is used to control the T/R signal paths. On Transmit, the first IF amp (dotted lines) may be shared and adds some extra gain ahead of the mixer. Most newer radios like the Cobra 140/142GTL and 148/2000GTL types dispense with the extra IF amp stage because they use IC mixers that already have plenty of gain.

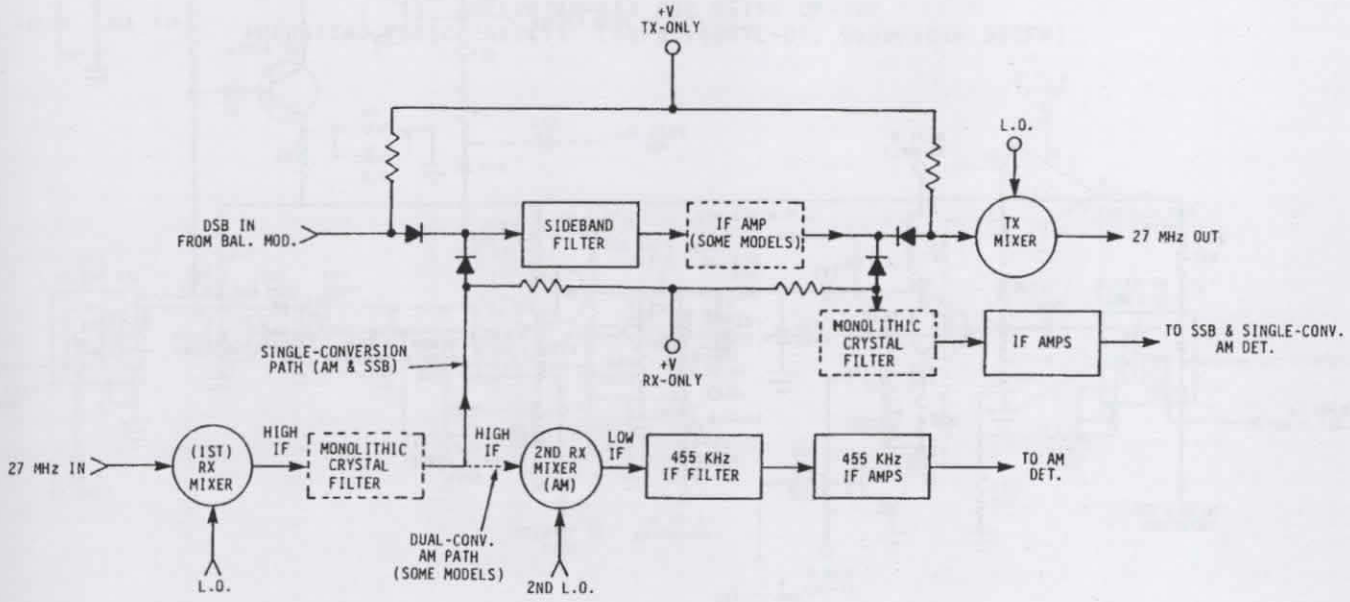
On Receive, the main sideband filter is placed in the SSB signal path to provide selectivity as well as removing the unwanted sideband. In many older models it's often the only way to establish selectivity, since nearly all SSB reception is single-conversion. The newer models often add a monolithic crystal filter, either following the 1st mixer or within the IF amps. Its two possible locations are shown in dotted lines. This filter is common to both AM and SSB when it follows the mixer, or when placed inside the IF amp chain and the AM mode is also single-conversion.

As shown, when AM is dual-conversion it takes a separate IF path. A second L.O. is included and AM has its own 455 KHz IF filtering. In fact if there's no monolithic crystal filter after the 1st mixer (many older models especially), the only selectivity for AM is the 455 KHz filter. The AM path rarely goes through the SSB filter in these models.

SSB AGC

Review the basics of Automatic Gain Control (AGC) from CHAPTER 4. In an AM-only radio, the AGC voltage is produced by rectification and filtering of an RF signal, which is mainly the carrier. On SSB there is no carrier to develop the AGC voltage. And you couldn't use the

FIGURE 6-63
SSB T/R SIGNAL PATHS
(SINGLE- & DUAL-CONVERSION)



reinserted carrier from the Carrier Oscillator, because it's constant and doesn't vary in strength with the received SSB signal.

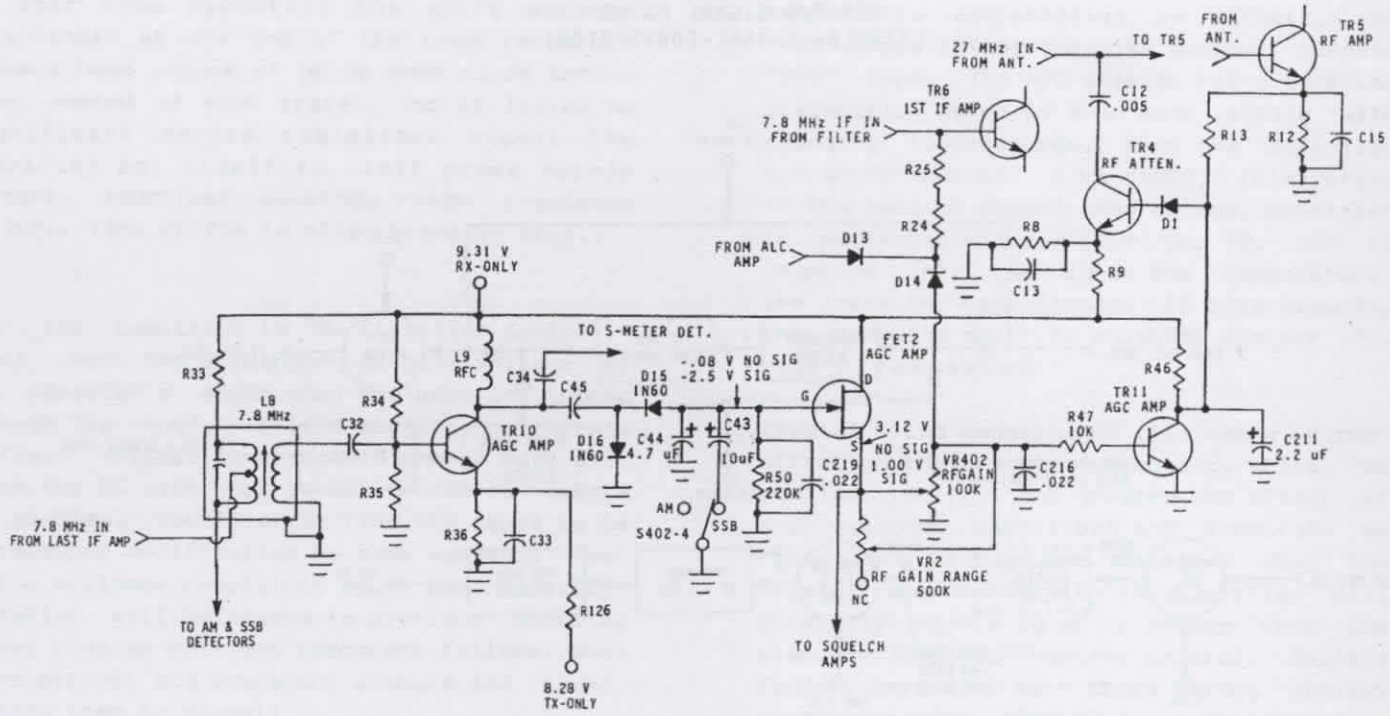
Instead, "RF-derived" AGC is used. The sample comes from the last IF stage before detection, where the incoming signal strength does change. Furthermore since there's no SSB audio until a signal is received, and since signals of very different strengths may be received at the same time, good AGC is especially important. More complex circuits with DC amplifiers for greater sensitivity and different AM/SSB time constants are used. This superior AGC control voltage is also used for the S-Meter and squelch circuits, where it improves AM performance too.

Virtually all SSB CB radios use either an FET or an op-amp to generate the amplified AGC control voltage. That's because both devices have extremely high input impedances to prevent loading of the sampled IF, and because they handle strong signals with less distortion than bipolar transistors. The FET AGC circuits are usually fed to a second, bipolar DC amplifier.

Analysis of Typical AGC Circuit

Every SSB model using discrete AGC transistors works basically the same way. Figure 6-64 shows one popular AGC system and the stages it controls. This circuit is sophisticated and typical of the better SSB equipment, but not very difficult to understand when approached logically. It's powered by a single AM/SSB Receive-only source. TR10 is actually an IF amplifier. In SAMS it's called an "AGC/S-Meter" amplifier, since it only controls those two functions. R126 disables it on Transmit so that IF amp TR6 (which is also used on SSB-Transmit) will be controlled only by the ALC circuit. The IF signal is amplified by TR10 and applied to D15 and D16. D16 clamps on positive signal peaks and D15 conducts on negative peaks, resulting in a gate voltage on FET2 that's negative-going with increasing signal strength. C219 has a low impedance at RF and charges very quickly to establish the fast attack time. C44 has a low impedance to audio, and discharges slowly to establish the basic AM time delay. Both charge and discharge through R50. C43 is switched in only for SSB, adding another 10 µF

FIGURE 6-64
AMPLIFIED SSB AGC USING DISCRETE TRANSISTORS
(Cobra 138/139XLR, President Adams, Realistic TRC458, etc.)



to lengthen the decay time more. (SSB requires a slower AGC decay than AM so it can follow the normal syllabic changes in speech before acting to control gain.) The attack time must be fast enough to prevent strong signals from blasting through too loudly at first. In this particular circuit you'd calculate about 5 mS attack time and 3.3 seconds delay, typical SSB values.

Current flows through FET2 from the drain to the source. (Remember, this is conventional current, not the actual electron movement.) Voltage divider VR2 (internal trimmer) and VR402 (panel control) set the desired gain. As the incoming signal gets stronger more negative gate voltage develops, moving the FET towards pinchoff. This decreases its current flow and therefore its source voltage, which controls several other circuits. It drives the squelch directly, which has its own DC amplifiers.

FET2 also controls TR6, the 1st IF amp. FET2's source voltage provides the only bias for TR6 on Receive, while the ALC provides its only bias on Transmit. As the signal strength increases, the base bias on TR6 decreases, reducing its gain. Another controlled circuit is front-end gain via TR11, TR4, and TR5. TR11 is an additional DC amp stage used to improve the dynamic range of the RF amp.

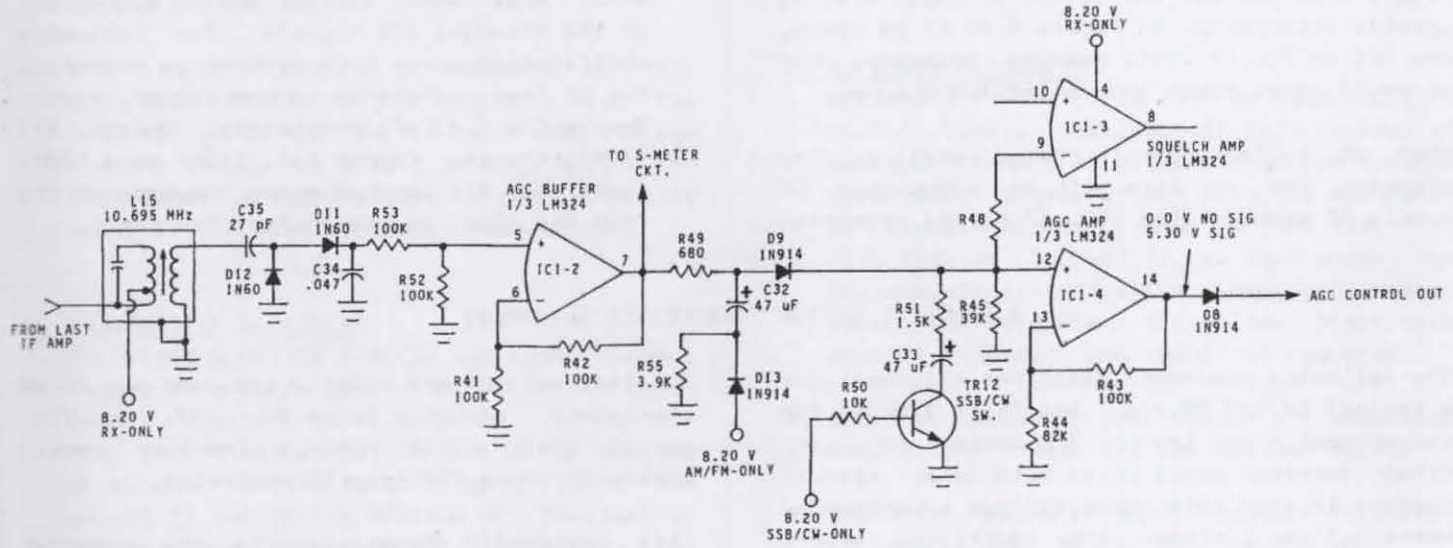
As the signal strength increases, FET2's source voltage and therefore the base voltage of TR11 decreases. TR11 conducts less so its collector pulls up higher via R46. TR11 controls TR4 and therefore makes it conduct harder. Since TR4 is shunted directly across the antenna input, it grounds more 27 MHz RF via C12/R8/C13. At the same time the emitter voltage of RF amp TR5 increases, which lowers its gain. C216 and C211 filter the remaining RF and audio respectively. D13 and D14 isolate the AGC and ALC. D1 clamps on extremely strong signals to protect TR4.

AGC Using Op-Amps

Another amplified AGC method uses op-amps. The newer Uniden radios in particular favor this method. Figure 6-65 shows this circuit, redrawn from the Japanese schematic for simplicity. IC1 is a quad op-amp. Two sections are used for AGC and one for squelch; the fourth amp isn't used. The 10.695 MHz IF signal is sampled from the last IF stage at L15's secondary and coupled via C35 to a voltage doubler detector, D11/D12. C35 is a small value to avoid loading down L15. C34 provides RF decoupling. The positive AGC voltage is applied to the non-inverting input of IC1 Pin 5. This IC section actually has no gain because R41, R42, R52, and R53 are all equal; it's used as a buffer/voltage follower to help protect against the loading effects of the diode detectors across the IF stage at L15.

The output from Pin 7 is coupled through R49/D9 to Pin 12, the input to the high-gain voltage amplifier section. Separate AM/FM and SSB/CW delay values are used, and are controlled by appropriate voltage sources. For AM/FM, D13/R55 will shunt C32 across the AGC line. For SSB/CW,

FIGURE 6-65
AMPLIFIED SSB AGC USING OP-AMP
(Uniden PB010 chassis: Cobra 148GTL-DX, Superstar 360FM)



TR12 shunts C33 and R51; note the extra 1.5 KΩ lengthens the capacitor discharge time for the slower decay needed on SSB. D9 isolates the two switches. The S-Meter and squelch amp inputs (Pin 9) are also being driven from this line.

The amplified AGC at Pin 14 is coupled through isolation diode D8 to the controlled circuits, which are like the previous example. A very large AGC voltage range is possible with this circuit. In a test I measured 0.0 V at Pin 14, no signal input, up to 5.30 V with an extremely strong input signal. Note how the non-inverting inputs of both amps are used, since in this case the AGC voltage must change in direct proportion to signal strength. This is one of those circuits where AGC is positive-going and will increase with stronger signals.

AGC TROUBLESHOOTING

While SSB AGC circuits are more sophisticated, fault-finding is still very logical. Like AM radios, the problems fall into two general categories. When there's no AGC at all, signals come blasting through, usually distorted. The other problem is just the opposite: excessive gain reduction that produces a "No Receive" or a "Weak Receive" symptom.

Using your signal generator and DC voltmeter, measure the AGC bus with different signal input levels to see if the voltage is changing. In those circuits like Figure 6-64 the voltage is negative-going, while in those like Figure 6-65 it's positive-going. If the voltage is changing as it should, then troubleshoot the associated gain-reduction circuits. For example if TR4 in Figure 6-64 shorts, the 27 MHz RF input will be greatly attenuated. In Figure 6-65 if D8 opens, the AGC on Pin 14 would measure normally, but it would never reach the controlled stages.

When AGC voltage doesn't change normally, try clamping the AGC line with an adjustable DC supply of perhaps ±0-5 VDC. If normal reception is restored, you've isolated the problem to the AGC loop itself. The most likely suspects are the active devices. Trace the voltage from the sampling point through each stage until it's lost. Since the amplified AGC also drives the S-Meter and squelch, a faulty AGC stage could simultaneously affect these circuits.

SERVICE TIPS:

1. Figure 6-65 illustrated the PB010 chassis, but all the following Uniden SSB chassis use exactly the same AGC circuit.

   PB010: Cobra 148GTL-DX late, Superstar 360FM
   PB015: Midland 7001 (new American version)
   PB042: President Jackson
   PC833: Cobra 146GTL, Midland 6001 (late), 79-260, President AR-144 and AX-144, Sears 663.3810, Uniden PC244
   PC879: Cobra 148GTL-DX (early version)
   PC893: President McKinley (export model), Stalker 9-FDX
   PC965: Realistic TRC451, new Pearce-Simpson "Super Cheetah" (Australian)
   PC999: President Grant (export)
   Also Uniden copies and clones: Galaxy 2100, Super Galaxy, Excalibur Samurai and base, Superstar 3600, 3900, Ranger AR3300, etc.

2. The TA75902/TA6324/NJM2902 AGC/Squelch chip is a common failure. Exactly the same chip, different manufacturers. It can be directly replaced with an LM324. (Such as Radio Shack #276-1711.) I strongly suggest installing a 14-pin DIP socket if replacement is needed!

3. The Uniden Jackson (PB042) has an AGC design error that causes extreme audio distortion on the stronger SSB signals. The following modification cures this problem by restoring the RC time constants to the proper values: Remove C31 (.47 µF) completely. Change R43 (10K) to a 1K. Change R41 (150K) to a 270K. These are all located along the back of the 2902 AGC chip, as viewed from the front.

A COMPLETE AM/SSB TRANSCEIVER ALIGNMENT

The following procedure describes alignment for a typical AM/SSB CB rig. See Pages 270-271 for the schematic and layout. The chassis is a very common American model which with minor circuit changes is also sold under various export model names. I've included the additional export adjustments to demonstrate their similarities.

The test set-ups are exactly the same as those previously shown on Pages 80, 139, and 204, except that you'll need a two-tone audio generator and a PEP type RF wattmeter.

This particular chassis type is the Cybernet PTBM048AOX (also PTBM058COX), found under many

models like the G.E. 3-5825A, HyGain 2705 (V), J.C. Penney 981-6247, JIL Citizen SSB-M6/MPL-5, Lafayette Telsat SSB-120/140, Midland 78-976 or 79-892, or RCA 14T302. Export versions include the Colt 485DX, which is an 80-channel model. I chose the Colt 485DX schematic and procedure because it uses a separate oscillator PC board with two loop mixing crystals (40 channels per crystal) instead of the single-crystal American version. The alignment parts layout is for the American version, which is all I had available to print; the only real difference is that CT1 and CT2 shown on the main chassis would be on the separate oscillator board (TC1-4) instead.

A. SYNTHESIZER ALIGNMENT

1. REFERENCE OSC.: Set to Ch.40 USB LOW Band, Clarifier midrange. Frequency counter to TP2. (IC1 Pin 3.) Adjust CT3 for 10.240 MHz ±50 Hz.

2. 'Scope to TP3 (IC2 Pin 4.) Adjust T1 on the PTOSOO3AOX board for maximum RF voltage.

3. LOW BAND OSC.: Frequency counter to TP3 as above. Adjust trimmer TC2 on PTOSOO3AOX board for 20.105 MHz ±40 Hz. Switch to LSB; adjust TC1 for 20.1035 MHz ±40 Hz.

4. HIGH BAND OSC.: Switch to HIGH Band and USB. Adjust trimmer TC3 on PTOSOO3AOX board for 20.330 MHz ±40 Hz. Switch to LSB; adjust TC4 for 20.3285 MHz ±40 Hz.

5. CARRIER OSC.: Return to LOW Band, Ch.1 USB. Move frequency counter to TP5. (Junction of L15/C70/C71.) Adjust CT5 for 10.695 MHz ±50 Hz. Switch to LSB and adjust CT4 for 10.692 MHz ±50 Hz.

6. VCO: Input of Digital DC Voltmeter to TP1. (Junction R1/R2.) Adjust VCO core slug for 3.60 VDC ±0.10 VDC. Switch to Ch.40; voltage reading should be 1.40-2.30 VDC. Switch to HIGH Band; reading should be proportionally lower at the higher channel frequencies.

B. TRANSMITTER ALIGNMENT

1. PREDRIVER & DRIVER STAGES: USB mode. Connect 'scope to antenna jack. Return to LOW Band. Inject single tone of 2400 Hz, 2.5 mV into MIKE jack. Adjust T2, T5 and T6 for maximum RF output. Switch to HIGH Band, Ch.40 and adjust T1 and T4 for maximum RF. Readjust or stagger-tune transformers if necessary for an even power spread across all 80 channels.

2. FINAL BIAS: Remove audio input. Insert DC Ammeter between emitter of Q10 and ground. Adjust RV1 for 35 ma ±10 ma.

3. Connect 'scope to emitter of Q7. Reinject 2400 Hz, 10 mV audio tone into MIKE jack. Adjust T11 for maximum RF output.

4. Inject two-tone, 10 mV audio signal at MIKE jack. Adjust RV11 (SSB MIKE GAIN control) for 12 watts PEP. (Or for 68 V P-P on 'scope at the ANT. jack.)

5. Reconnect 'scope and wattmeter to ANT. jack. Disable ALC circuit by turning RV2 full counterclockwise. Adjust T6, L7, L11, and L13 for maximum RF output.

6. CARRIER BALANCE: Remove audio input tone. Adjust RV4 and RV5 for minimum RF indication at ANT. jack. Recheck carrier suppression on LSB, which should be the same.

7. ALC: Inject a two-tone, 25 mV audio signal. Adjust RV2 for 12 watts PEP. 'Scope pattern should look like earlier photos; i.e., no distortion with correct two-tone test input.

8. AM CARRIER POWER: Remove audio tone input. Switch to AM, Ch.40, LOW Band. Adjust VR4 for 3.7 watts carrier output.

9. AMC: Inject a 2400 Hz, 25 mV audio signal. Adjust RV12 for maximum modulation of 95%.

10. RF POWER METER: Adjust RV3 so panel meter agrees with external wattmeter reading.

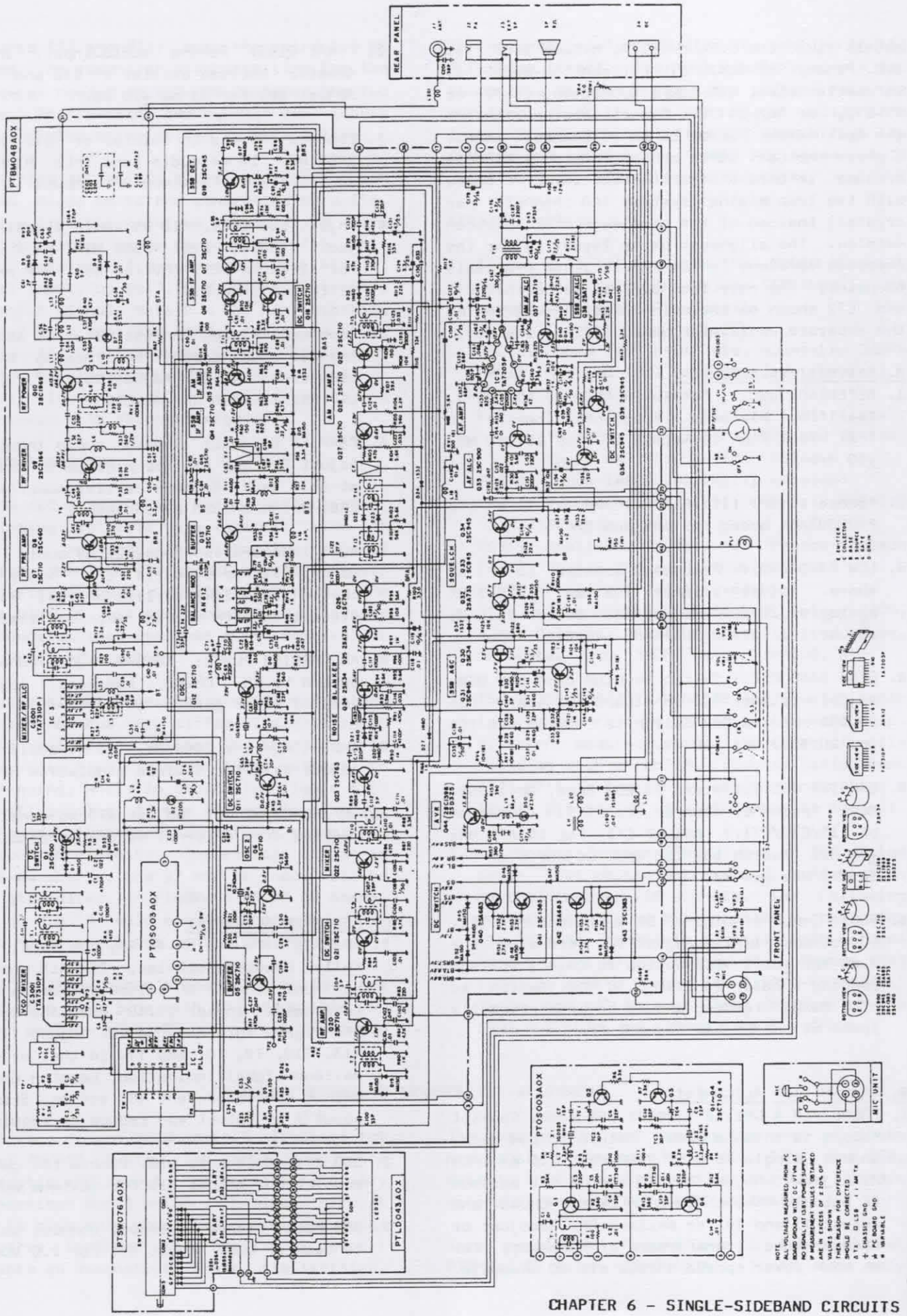
C. RECEIVER ALIGNMENT

1. RF/IF STRIP: Set Ch.40 AM, LOW Band, SQUELCH fully counterclockwise, RF GAIN control at maximum. Connect AC voltmeter across speaker terminals. Inject 27.405 MHz, 30% modulated RF signal into ANT. jack. Adjust T15, T14, T13, T10, T9, T8, and T7, in that order, for maximum signal indication, keeping generator output low to prevent AGC action. Start with about 1 µV output and reduce as required.

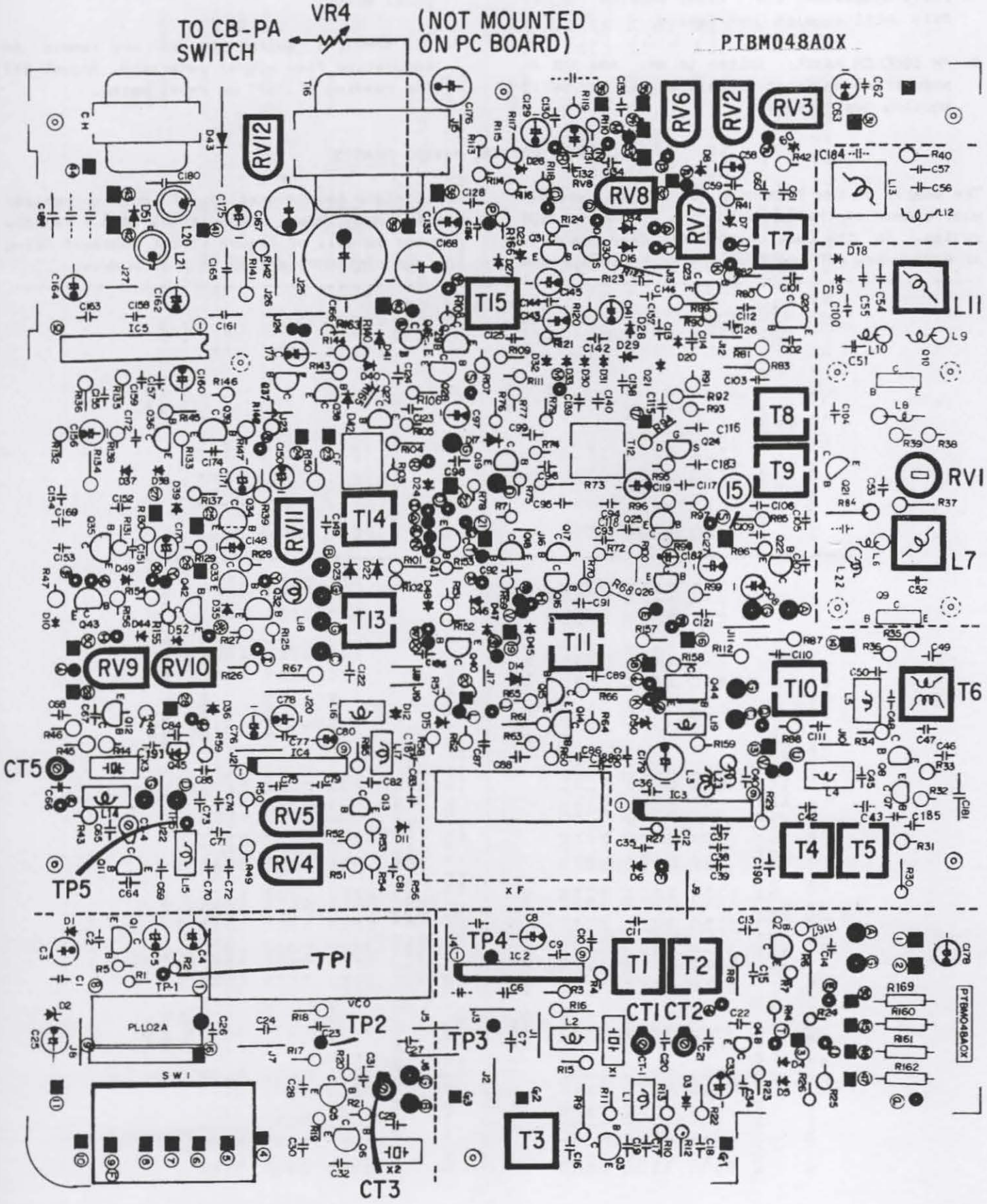
2. SSB IF: Switch to USB. Remove the generator modulation. Adjust T12 for maximum output.

3. SSB AGC: Remove RF input. Connect Voltmeter to base of Q20. Adjust RV8 for 2.0 VDC.

SCHEMATIC DIAGRAM FOR TRANSCEIVER DESCRIBED IN TEXT
(Courtesy the manufacturer.)



ALIGNMENT LOCATIONS FOR TRANSCEIVER DESCRIBED IN TEXT
(Courtesy the manufacturer.)



4. SSB SQUELCH RANGE: Inject a 500 µV RF signal at ANT. jack, no modulation. SQUELCH control fully clockwise; i.e., tight squelch. Adjust RV10 until squelch just breaks.

5. AM SQUELCH RANGE: Switch to AM. Add 30% AM modulation to input signal. Adjust RV9 until squelch just breaks.

6. AM S-METER: Reduce RF generator output to 100 µV. Adjust RV6 for reading of "S9" on panel meter.

7. SSB S-METER: Switch to USB and remove AM modulation from signal generator. Adjust RV7 for reading of "S9" on panel meter.

23-CHANNEL CRYSTAL MIXING CHARTS

The charts on the following four pages show the most common synthesizers for the 23-channel SSB radios. In the case of specific dead channels or modes, you can use the charts to locate the appropriate bad crystal(s). If your synthesizer isn't among these, consult the SAMS, factory service manual, or figure it out yourself using the descriptions earlier in this chapter.

NOTES

	BOTH RX&TX	AM/USB	LSB		BOTH RX&TX	AM/USB	LSB
	"A"	"B"	"C"		"A"	"B"	"C"
Ch. 1 (26.965)	7.779166	14.907	14.904	Ch.13 (27.115)	7.829166	14.907	14.904
Ch. 2 (26.975)	"	14.917	14.914	Ch.14 (27.125)	"	14.917	14.914
Ch. 3 (26.985)	"	14.927	14.924	Ch.15 (27.135)	"	14.927	14.924
Ch. 4 (27.005)	"	14.947	14.944	Ch.16 (27.155)	"	14.947	14.944
Ch. 5 (27.015)	7.795833	14.907	14.904	Ch.17 (27.165)	7.845833	14.907	14.904
Ch. 6 (27.025)	"	14.917	14.914	Ch.18 (27.175)	"	14.917	14.914
Ch. 7 (27.035)	"	14.927	14.924	Ch.19 (27.185)	"	14.927	14.924
Ch. 8 (27.055)	"	14.947	14.944	Ch.20 (27.205)	"	14.947	14.944
Ch. 9 (27.065)	7.812500	14.907	14.904	Ch.21 (27.215)	7.862500	14.907	14.904
Ch.10 (27.075)	"	14.917	14.914	Ch.22 (27.225)	"	14.917	14.914
Ch.11 (27.085)	"	14.927	14.924	Ch.23 (27.255)	"	14.947	14.944
Ch.12 (27.105)	"	14.947	14.944				

Additional Crystals: 11.730 MHz AM RX Oscillator;
11.275 MHz AM/USB Carrier Oscillator;
11.272 MHz LSB Carrier Oscillator

Synthesis: (3 x "A") + "B" - 11.275 MHz = AM/USB carrier frequency;
(3 x "A") + "C" - 11.272 MHz = LSB carrier frequency.

	BOTH RX&TX	AM/USB	LSB		BOTH RX&TX	AM/USB	LSB
	"A"	"B"	"C"		"A"	"B"	"C"
Ch. 1 (26.965)	7.7766	14.907	14.904	Ch.13 (27.115)	7.8266	14.907	14.904
Ch. 2 (26.975)	"	14.917	14.914	Ch.14 (27.125)	"	14.917	14.914
Ch. 3 (26.985)	"	14.927	14.924	Ch.15 (27.135)	"	14.927	14.924
Ch. 4 (27.005)	"	14.947	14.944	Ch.16 (27.155)	"	14.947	14.944
Ch. 5 (27.015)	7.7933	14.907	14.904	Ch.17 (27.165)	7.8433	14.907	14.904
Ch. 6 (27.025)	"	14.917	14.914	Ch.18 (27.175)	"	14.917	14.914
Ch. 7 (27.035)	"	14.927	14.924	Ch.19 (27.185)	"	14.927	14.924
Ch. 8 (27.055)	"	14.947	14.944	Ch.20 (27.205)	"	14.947	14.944
Ch. 9 (27.065)	7.8100	14.907	14.904	Ch.21 (27.215)	7.8600	14.907	14.904
Ch.10 (27.075)	"	14.917	14.914	Ch.22 (27.225)	"	14.917	14.914
Ch.11 (27.085)	"	14.927	14.924	Ch.23 (27.255)	"	14.947	14.944
Ch.12 (27.105)	"	14.947	14.944				

Additional Crystals: 11.730 MHz AM RX Oscillator;
11.275 MHz AM/USB Carrier Oscillator;
11.272 MHz LSB Carrier Oscillator

Synthesis: (3 x "A") + "B" - 11.275 MHz = AM/USB carrier frequency;
(3 x "A") + "C" - 11.272 MHz = LSB carrier frequency.

	BOTH RX&TX	LSB	AM/USB		BOTH RX&TX	LSB	AM/USB
	"A"	"B"	"C"		"A"	"B"	"C"
Ch. 1 (26.965)	23.330	14.907	14.910	Ch.13 (27.115)	23.480	14.907	14.910
Ch. 2 (26.975)	"	14.917	14.920	Ch.14 (27.125)	"	14.917	14.920
Ch. 3 (26.985)	"	14.927	14.930	Ch.15 (27.135)	"	14.927	14.930
Ch. 4 (27.005)	"	14.947	14.950	Ch.16 (27.155)	"	14.947	14.950
Ch. 5 (27.015)	23.380	14.907	14.910	Ch.17 (27.165)	23.530	14.907	14.910
Ch. 6 (27.025)	"	14.917	14.920	Ch.18 (27.175)	"	14.917	14.920
Ch. 7 (27.035)	"	14.927	14.930	Ch.19 (27.185)	"	14.927	14.930
Ch. 8 (27.055)	"	14.947	14.950	Ch.20 (27.205)	"	14.947	14.950
Ch. 9 (27.065)	23.430	14.907	14.910	Ch.21 (27.215)	23.580	14.907	14.910
Ch.10 (27.075)	"	14.917	14.920	Ch.22 (27.225)	"	14.917	14.920
Ch.11 (27.085)	"	14.927	14.930	Ch.23 (27.255)	"	14.947	14.950
Ch.12 (27.105)	"	14.947	14.950				

Additional Crystals: 11.730 MHz AM RX Oscillator;
11.275 MHz AM/USB Carrier Oscillator;
11.272 MHz LSB Carrier Oscillator

Synthesis: "A" + "B" - 11.272 MHz = LSB carrier frequency;
"A" + "C" - 11.275 MHz = AM/USB carrier frequency.

	BOTH RX&TX	AM/USB	LSB		BOTH RX&TX	AM/USB	LSB
	"A"	"B"	"C"		"A"	"B"	"C"
Ch. 1 (26.965)	23.330	14.907	14.904	Ch.13 (27.115)	23.480	14.907	14.904
Ch. 2 (26.975)	"	14.917	14.914	Ch.14 (27.125)	"	14.917	14.914
Ch. 3 (26.985)	"	14.927	14.924	Ch.15 (27.135)	"	14.927	14.924
Ch. 4 (27.005)	"	14.947	14.944	Ch.16 (27.155)	"	14.947	14.944
Ch. 5 (27.015)	23.380	14.907	14.904	Ch.17 (27.165)	23.530	14.907	14.904
Ch. 6 (27.025)	"	14.917	14.914	Ch.18 (27.175)	"	14.917	14.914
Ch. 7 (27.035)	"	14.927	14.924	Ch.19 (27.185)	"	14.927	14.924
Ch. 8 (27.055)	"	14.947	14.944	Ch.20 (27.205)	"	14.947	14.944
Ch. 9 (27.065)	23.430	14.907	14.904	Ch.21 (27.215)	23.580	14.907	14.904
Ch.10 (27.075)	"	14.917	14.914	Ch.22 (27.225)	"	14.917	14.914
Ch.11 (27.085)	"	14.927	14.924	Ch.23 (27.255)	"	14.947	14.944
Ch.12 (27.105)	"	14.947	14.944				

Additional Crystals: 11.730 MHz AM RX Oscillator;
11.275 MHz AM/USB Carrier Oscillator;
11.272 MHz LSB Carrier Oscillator

Synthesis: "A" + "B" - 11.275 MHz = AM/USB carrier frequency;
"A" + "C" - 11.272 MHz = LSB carrier frequency.

	RX&TX "A"	RX&TX "B"	RX&TX "C"		RX&TX "A"	RX&TX "B"	RX&TX "C"
Ch. 1 (26.965)	12.800	15.965	6.000	Ch.13 (27.115)	12.800	16.115	6.000
Ch. 2 (26.975)	"	"	6.010	Ch.14 (27.125)	"	"	6.010
Ch. 3 (26.985)	"	"	6.020	Ch.15 (27.135)	"	"	6.020
Ch. 4 (27.005)	"	"	6.040	Ch.16 (27.155)	"	"	6.040
Ch. 5 (27.015)	12.800	16.015	6.000	Ch.17 (27.165)	12.800	16.165	6.000
Ch. 6 (27.025)	"	"	6.010	Ch.18 (27.175)	"	"	6.010
Ch. 7 (27.035)	"	"	6.020	Ch.19 (27.185)	"	"	6.020
Ch. 8 (27.055)	"	"	6.040	Ch.20 (27.205)	"	"	6.040
Ch. 9 (27.065)	12.800	16.065	6.000	Ch.21 (27.215)	12.800	16.215	6.000
Ch.10 (27.075)	"	"	6.010	Ch.22 (27.225)	"	"	6.010
Ch.11 (27.085)	"	"	6.020	Ch.23 (27.255)	"	"	6.040
Ch.12 (27.105)	"	"	6.040				

Additional Crystals: 7.7975 MHz LSB Carrier Oscillator
7.8015 MHz AM/USB Carrier Oscillator

Synthesis: "A" + "B" + "C" - 7.8 MHz = direct channel frequency.

	BOTH RX&TX "A"	AM/USB "B"	LSB "C"		BOTH RX&TX "A"	AM/USB "B"	LSB "C"
Ch. 1 (26.965)	11.000	8.1665	8.1635	Ch.13 (27.115)	11.150	8.1665	8.1635
Ch. 2 (26.975)	"	8.1765	8.1735	Ch.14 (27.125)	"	8.1765	8.1735
Ch. 3 (26.985)	"	8.1885	8.1835	Ch.15 (27.135)	"	8.1865	8.1835
Ch. 4 (27.005)	"	8.2065	8.2035	Ch.16 (27.155)	"	8.2065	8.2035
Ch. 5 (27.015)	11.050	8.1665	8.1635	Ch.17 (27.165)	11.200	8.1665	8.1635
Ch. 6 (27.025)	"	8.1765	8.1735	Ch.18 (27.175)	"	8.1765	8.1735
Ch. 7 (27.035)	"	8.1865	8.1835	Ch.19 (27.185)	"	8.1865	8.1835
Ch. 8 (27.055)	"	8.2065	8.2035	Ch.20 (27.205)	"	8.2065	8.2035
Ch. 9 (27.065)	11.100	8.1665	8.1635	Ch.21 (27.215)	11.250	8.1665	8.1635
Ch.10 (27.075)	"	8.1765	8.1735	Ch.22 (27.225)	"	8.1765	8.1735
Ch.11 (27.085)	"	8.1865	8.1835	Ch.23 (27.255)	"	8.2065	8.2035
Ch.12 (27.105)	"	8.2065	8.2035				

Additional Crystals: 7.3435 MHz AM RX Oscillator;
7.7985 MHz AM/USB Carrier Oscillator;
7.8015 MHz LSB Carrier Oscillator

Synthesis: "A" + "B" + 7.7985 MHz = AM/USB carrier frequency;
"A" + "C" + 7.8015 MHz = LSB carrier frequency.

	BOTH RX&TX "A"	AM/USB "B"	LSB "C"		BOTH RX&TX "A"	AM/USB "B"	LSB "C"
Ch. 1 (26.965)	11.705	7.4615	7.4585	Ch.13 (27.115)	11.855	7.4615	7.4585
Ch. 2 (26.975)	"	7.4715	7.4685	Ch.14 (27.125)	"	7.4715	7.4685
Ch. 3 (26.985)	"	7.4815	7.4785	Ch.15 (27.135)	"	7.4815	7.4785
Ch. 4 (27.005)	"	7.5015	7.4985	Ch.16 (27.155)	"	7.5015	7.4985
Ch. 5 (27.015)	11.755	7.4615	7.4585	Ch.17 (27.165)	11.905	7.4615	7.4585
Ch. 6 (27.025)	"	7.4715	7.4685	Ch.18 (27.175)	"	7.4715	7.4685
Ch. 7 (27.035)	"	7.4815	7.4785	Ch.19 (27.185)	"	7.4815	7.4785
Ch. 8 (27.055)	"	7.5015	7.4985	Ch.20 (27.205)	"	7.5015	7.4985
Ch. 9 (27.065)	11.805	7.4615	7.4585	Ch.21 (27.215)	11.955	7.4615	7.4585
Ch.10 (27.075)	"	7.4715	7.4685	Ch.22 (27.225)	"	7.4715	7.4685
Ch.11 (27.085)	"	7.4815	7.4785	Ch.23 (27.255)	"	7.5015	7.4985
Ch.12 (27.105)	"	7.5015	7.4985				

Additional Crystals: 7.3435 MHz AM RX Oscillator;
7.7985 MHz AM/USB Carrier Oscillator;
7.8015 MHz LSB Carrier Oscillator

Synthesis: "A" + "B" + 7.7985 MHz = AM/USB carrier frequency;
"A" + "C" + 7.8015 MHz = LSB carrier frequency.

	BOTH RX&TX "A"	AM/USB "B"	LSB "C"		BOTH RX&TX "A"	AM/USB "B"	LSB "C"
Ch. 1 (26.965)	11.805	7.3615	7.3585	Ch.13 (27.115)	11.955	7.3615	7.3585
Ch. 2 (26.975)	"	7.3715	7.3685	Ch.14 (27.125)	"	7.3715	7.3685
Ch. 3 (26.985)	"	7.3815	7.3785	Ch.15 (27.135)	"	7.3815	7.3785
Ch. 4 (27.005)	"	7.4015	7.3985	Ch.16 (27.155)	"	7.4015	7.3985
Ch. 5 (27.015)	11.855	7.3615	7.3585	Ch.17 (27.165)	12.005	7.3615	7.3585
Ch. 6 (27.025)	"	7.3715	7.3685	Ch.18 (27.175)	"	7.3715	7.3685
Ch. 7 (27.035)	"	7.3815	7.3785	Ch.19 (27.185)	"	7.3815	7.3785
Ch. 8 (27.055)	"	7.4015	7.3985	Ch.20 (27.205)	"	7.4015	7.3985
Ch. 9 (27.065)	11.905	7.3615	7.3585	Ch.21 (27.215)	12.055	7.3615	7.3585
Ch.10 (27.075)	"	7.3715	7.3685	Ch.22 (27.225)	"	7.3715	7.3685
Ch.11 (27.085)	"	7.3815	7.3785	Ch.23 (27.255)	"	7.4015	7.3985
Ch.12 (27.105)	"	7.4015	7.3985				

Additional Crystals: 7.3435 MHz AM RX Oscillator;
7.7985 MHz AM/USB Carrier Oscillator;
7.8015 MHz LSB Carrier Oscillator

Synthesis: "A" + "B" + 7.7985 MHz = AM/USB carrier frequency;
"A" + "C" + 7.8015 MHz = LSB carrier frequency.

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	8.1590	11.0035	Ch.13 (27.115)	8.3090	11.0035
Ch. 2 (26.975)	"	11.0135	Ch.14 (27.125	"	11.0135
Ch. 3 (26.985)	"	11.0235	Ch.15 (27.135)	"	11.0235
Ch. 4 (27.005)	"	11.0435	Ch.16 (27.155)	"	11.0435
Ch. 5 (27.015)	8.2090	11.0035	Ch.17 (27.165)	8.3590	11.0035
Ch. 6 (27.025)	"	11.0135	Ch.18 (27.175)	"	11.0135
Ch. 7 (27.035)	"	11.0235	Ch.19 (27.185)	"	11.0235
Ch. 8 (27.055)	"	11.0435	Ch.20 (27.205)	"	11.0435
Ch. 9 (27.065)	8.2590	11.0035	Ch.21 (27.215)	8.4090	11.0035
Ch.10 (27.075)	"	11.0135	Ch.22 (27.225)	"	11.0135
Ch.11 (27.085)	"	11.0235	Ch.23 (27.255)	"	11.0435
Ch.12 (27.105)	"	11.0435			

Additional Crystals Used: 7.8025 MHz Carrier Oscillator, all 23 channels, RX & TX.

Synthesis: "A" + "B" + 7.8025 MHz = channel frequency. (Plus mode offsets as required.)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	23.330	14.907	Ch.13 (27.115)	23.480	14.907
Ch. 2 (26.975)	"	14.917	Ch.14 (27.125)	"	14.917
Ch. 3 (26.985)	"	14.927	Ch.15 (27.135)	"	14.927
Ch. 4 (27.005)	"	14.947	Ch.16 (27.155)	"	14.947
Ch. 5 (27.015)	23.380	14.907	Ch.17 (27.165)	23.530	14.907
Ch. 6 (27.025)	"	14.917	Ch.18 (27.175)	"	14.917
Ch. 7 (27.035)	"	14.927	Ch.19 (27.185)	"	14.927
Ch. 8 (27.055)	"	14.947	Ch.20 (27.205)	"	14.947
Ch. 9 (27.065)	23.430	14.907	Ch.21 (27.215)	23.580	14.907
Ch.10 (27.075)	"	14.917	Ch.22 (27.225)	"	14.917
Ch.11 (27.085)	"	14.927	Ch.23 (27.255)	"	14.947
Ch.12 (27.105)	"	14.947			

Additional Crystals Used: 11.275 MHz Carrier Oscillator, all channels and modes.

Synthesis: "A" + "B" - 11.275 MHz = channel frequency. (Plus mode offsets as required.)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	11.740	7.4225	Ch.13 (27.115)	11.890	7.4225
Ch. 2 (26.975)	"	7.4325	Ch.14 (27.125)	"	7.4325
Ch. 3 (26.985)	"	7.4425	Ch.15 (27.135)	"	7.4425
Ch. 4 (27.005)	"	7.4625	Ch.16 (27.155)	"	7.4625
Ch. 5 (27.015)	11.790	7.4225	Ch.17 (27.165)	11.940	7.4225
Ch. 6 (27.025)	"	7.4325	Ch.18 (27.175)	"	7.4325
Ch. 7 (27.035)	"	7.4425	Ch.19 (27.185)	"	7.4425
Ch. 8 (27.055)	"	7.4625	Ch.20 (27.205)	"	7.4625
Ch. 9 (27.065)	11.840	7.4225	Ch.21 (27.215)	11.990	7.4225
Ch.10 (27.075)	"	7.4325	Ch.22 (27.225)	"	7.4325
Ch.11 (27.085)	"	7.4425	Ch.23 (27.255)	"	7.4625
Ch.12 (27.105)	"	7.4625			

Additional Crystals Used: 7.8025 MHz Carrier Oscillator.

Synthesis: "A" + "B" + 7.8025 MHz = channel frequency. (Plus mode offsets as required.)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	11.700	7.4625	Ch.13 (27.115)	11.850	7.4625
Ch. 2 (26.975)	"	7.4725	Ch.14 (27.125)	"	7.4725
Ch. 3 (26.985)	"	7.4825	Ch.15 (27.135)	"	7.4825
Ch. 4 (27.005)	"	7.5025	Ch.16 (27.155)	"	7.5025
Ch. 5 (27.015)	11.750	7.4625	Ch.17 (27.165)	11.900	7.4625
Ch. 6 (27.025)	"	7.4725	Ch.18 (27.175)	"	7.4725
Ch. 7 (27.035)	"	7.4825	Ch.19 (27.185)	"	7.4825
Ch. 8 (27.055)	"	7.5025	Ch.20 (27.205)	"	7.5025
Ch. 9 (27.065)	11.800	7.4625	Ch.21 (27.215)	11.950	7.4625
Ch.10 (27.075)	"	7.4725	Ch.22 (27.225)	"	7.4725
Ch.11 (27.085)	"	7.4825	Ch.23 (27.255)	"	7.5025
Ch.12 (27.105)	"	7.5025			

Additional Crystals Used: 7.8025 MHz Carrier Oscillator, all 23 channels, RX & TX.

Synthesis: "A"+ "B" + 7.8025 MHz = channel frequency. (Plus mode offsets as required.)

	BOTH RX&TX	AM/LSB	USB		BOTH RX&TX	AM/LSB	USB
	"A"	"B"	"C"		"A"	"B"	"C"
Ch. 1 (26.965)	37.600	10.1815	11.0885	Ch.13 (27.115)	37.750	10.1815	11.0885
Ch. 2 (26.975)	"	10.1715	11.0785	Ch.14 (27.125)	"	10.1715	11.0785
Ch. 3 (26.985)	"	10.1615	11.0685	Ch.15 (27.135)	"	10.1615	11.0685
Ch. 4 (27.005)	"	10.1415	11.0485	Ch.16 (27.155)	"	10.1415	11.0485
Ch. 5 (27.015)	37.650	10.1815	11.0885	Ch.17 (27.165)	37.800	10.1815	11.0885
Ch. 6 (27.025)	"	10.1715	11.0785	Ch.18 (27.175)	"	10.1715	11.0785
Ch. 7 (27.035)	"	10.1615	11.0685	Ch.19 (27.185)	"	10.1615	11.0685
Ch. 8 (27.055)	"	10.1415	11.0485	Ch.20 (27.205)	"	10.1415	11.0485
Ch. 9 (27.065)	37.700	10.1815	11.0885	Ch.21 (27.215)	37.850	10.1815	11.0885
Ch.10 (27.075)	"	10.1715	11.0785	Ch.22 (27.225)	"	10.1715	11.0785
Ch.11 (27.085)	"	10.1615	11.0685	Ch.23 (27.255)	"	10.1415	11.0485
Ch.12 (27.105)	"	10.1415	11.0485				

Synthesis: "A" - "B" - 453.5 KHz = AM/LSB carrier frequency;
"A" - "C" + 453.5 KHz = USB carrier frequency.

Browning Golden Eagle Mark III

	ALL MODES		ALL MODES		ALL MODES
Ch. 1 (26.965)	16.270	Ch. 9 (27.065)	16.370	Ch.17 (27.165)	16.470
Ch. 2 (26.975)	16.280	Ch.10 (27.075)	16.380	Ch.18 (27.175)	16.480
Ch. 3 (26.985)	16.290	Ch.11 (27.085)	16.390	Ch.19 (27.185)	16.490
Ch. 4 (27.005)	16.310	Ch.12 (27.105)	16.410	Ch.20 (27.205)	16.510
Ch. 5 (27.015)	16.320	Ch.13 (27.115)	16.420	Ch.21 (27.215)	16.520
Ch. 6 (27.025)	16.330	Ch.14 (27.125)	16.430	Ch.22 (27.225)	16.530
Ch. 7 (27.035)	16.340	Ch.15 (27.135)	16.440	Ch.23 (27.255)	16.560
Ch. 8 (27.055)	16.360	Ch.16 (27.155)	16.460		

Additional Crystals Used:

31.400 MHz RX oscillator all 23 channels.

5.6465 MHz AM Carrier Oscillator.
5.6480 MHz LSB Carrier Oscillator.
5.6450 MHz USB Carrier Oscillator.

5.0485 MHz AM Synth. Osc. all 23 channels
5.0470 MHz LSB Synth. Osc. all 23 channels.
5.0500 MHz USB Synth. Osc. all 23 channels.

Synthesis: The 16 MHz channel crystal + both the 5 MHz crystals (each mode) = the on-channel frequency. Example: For Ch. 1 AM, it is 16.270 MHz + 5.6465 MHz + 5.0485 MHz = 26.965 MHz.

Tram D201 & D201A

The D201A is simply an expanded version of the D201, with extra mixing crystals added to get 40 channels. Otherwise both models are exactly the same in all other circuitry.

	BOTH RX&TX	AM/LSB	USB		BOTH RX&TX	AM/LSB	USB
	"A"	"B"	"C"		"A"	"B"	"C"
Ch. 1 (26.965)	4.400	16.3085	16.3115	Ch.21 (27.215)	4.400	16.5585	16.5615
Ch. 2 (26.975)	4.410	"	"	Ch.22 (27.225)	4.410	"	"
Ch. 3 (26.985)	4.420	"	"	Ch.23 (27.255)	4.440	"	"
Ch. 4 (27.005)	4.440	"	"	Ch.24 (27.235)	4.420	"	"
Ch. 5 (27.015)	4.400	16.3585	16.3615	Ch.25 (27.245)	4.430	16.5585	16.5615
Ch. 6 (27.025)	4.410	"	"	Ch.26 (27.265)	4.400	16.6085	16.6115
Ch. 7 (27.035)	4.420	"	"	Ch.27 (27.275)	4.410	"	"
Ch. 8 (27.055)	4.440	"	"	Ch.28 (27.285)	4.420	"	"
Ch. 9 (27.065)	4.400	16.4085	16.4115	Ch.29 (27.295)	4.430	"	"
Ch.10 (27.075)	4.410	"	"	Ch.30 (27.305)	4.440	"	"
Ch.11 (27.085)	4.420	"	"	Ch.31 (27.315)	4.400	16.6585	16.6615
Ch.12 (27.105)	4.440	"	"	Ch.32(27.325)	4.410	"	"
Ch.13 (27.115)	4.400	16.4585	16.4615	Ch.33 (27.335)	4.420	"	"
Ch.14 (27.125)	4.410	"	"	Ch.34 (27.345)	4.430	"	"
Ch.15 (27.135)	4.420	"	"	Ch.35 (27.355)	4.440	"	"
Ch.16 (27.155)	4.440	"	"	Ch.36 (27.365)	4.400	16.7085	16.7115
Ch.17 (27.165)	4.400	16.5085	16.5115	Ch.37 (27.375)	4.410	"	"
Ch.18 (27.175)	4.410	"	"	Ch.38 (27.385)	4.420	"	"
Ch.19 (27.185)	4.420	"	"	Ch.39 (27.395)	4.430	"	"
Ch.20 (27.205)	4.440	"	"	Ch.40 (27.405)	4.440	"	"

Additional Crystals: 5.8015 MHz AM RX Oscillator;
6.2565 MHz AM/LSB Carrier Oscillator;
6.2535 MHz USB Carrier Oscillator

Synthesis: "A" + "B" + 6.2565 MHz = AM/LSB carrier frequency;
"A" + "C" + 6.2535 MHz = USB carrier frequency.
IF = 6.2565 MHz SSB & 1st AM; 455 KHz 2nd AM.

7 POWER SUPPLIES & T/R SWITCHING

All modern CB equipment operates from a 12 VDC main power supply input. In mobiles this comes directly from the vehicle battery and charging system. The CB is normally connected to a fused vehicle circuit rather than directly to the battery; otherwise the operator must remember to turn the radio on and off each time. The automotive charging system normally outputs about 13.8 VDC to maintain the battery, which is why this figure is commonly specified.

Transistorized base radios operate on exactly the same 13.8 VDC as mobiles, but they include additional circuits to change the AC mains of 110/220 VAC to 13.8 VDC. This extra circuitry is normally located on a small PC board on the frame of the main chassis. Most manufacturers use exactly the same main chassis for their base and mobile models having similar features.

Tube-type radios require various positive and negative DC voltages, as well as filament voltages to light the tubes. These voltages come from a transformer-based AC power supply connected to the 110/220 VAC mains. Some radios use hybrid circuits combining both tubes and transistors, and will require a number of low and high DC output voltages.

Since there are still many repairable tube CBs (at least in the U.S.), you should understand their operation too. Judging by the requests I get, tube rigs will be around for a long time. It's especially hard for those whose only electronics experience is with solid-state equipment. For one thing, a different way of thinking and a lot more caution is needed. Secondly, there are very few remaining electronics textbooks or references to help the newcomer with vacuum tube theory. Not to mention schematics or SAMS Fotofacts!

Regardless of what's used for the main DC supply, it will be further divided into a number of branch circuits that power specific functions in the radio. These branches may be simple or complex, depending upon factors like the degree of regulation, 23- vs. 40-channel, or AM vs. multimode. In this chapter we'll explore how these various operating voltages are generated in tube and transistorized CBs. In addition T/R control circuits are also analyzed, since problems often occur in only one mode and are usually related to specific branch circuits. I'm grateful to the Howard W. Sams Publishing Co. for permission to reprint some of their more complicated schematics here.

THE MOBILE DC POWER SUPPLY

The simplest DC power supply is found in AM and FM radios. The radio ties to the main 13.8 VDC vehicle supply through a pair of wires, usually colored RED and BLACK to indicate positive and negative inputs, respectively. The RED wire is usually fused at 2.0 amps using an in-line or chassis-mounted fuseholder. (SSB and export models are often fused at 3.0 A or more.) Most radios use a plug & socket arrangement for the DC power, although some cheaper models have the wires entering the frame directly through a plastic strain relief with no socket.

Positive Vs. Negative Grounds

Some large trucks and foreign cars use a positive-ground electrical system, which means the vehicle frame is the [+] connection and the [-] is the hot side. Partly because of this, most CBs have a "floating" chassis which is electrically insulated from the metal frame to work with either system. You'll notice the PC board mounting screws don't actually touch any foil on the main board; they pass through holes having either no pads, or isolated foil pads. On floating chassis the frame is <u>not</u> the ground return for DC or signals; the ground return is the chassis common tie point. This is the large foil area running all around the PC board. The large foil surface forms a ground plane to help break up stray ground loops, and offers a low impedance at CB frequencies and higher.

In positive-ground systems, the BLACK [-] wire should always be fused to protect the radio! Most people don't even realize this, since

manufacturers didn't bother with the extra expense of fusing both power leads for such a relatively small percentage of vehicles. You can't connect a negative-ground radio to a positive-ground vehicle without using a special inverter. (Radio Shack still sells these, Cat. #22-129.) The odds of seeing such radios are small though. Some 23-channel models like the Johnson Messenger 123B had a polarity-reversing switch for the RED and BLACK DC input wires.

Ground Loops

If the frame ground is at one DC potential and the chassis common point at another, sparks may fly with careless handling of tools and test probes. The radio is also more likely to show self-oscillation or increased TVI/RFI problems. These are the result of "ground loops," which are small currents generated when physically grounding a circuit at more than one place. That's why you see two separate ground symbols on the schematics: the little fork symbol means frame ground, and the symbol with the tapering horizontal lines means signal/DC ground.

Refer to the following sketch. "A" shows three circuits that each have different wire lengths running to the ground point. The boxes can represent separate circuits within one radio, or separate pieces of station equipment. The ground of Circuit #3 is tied to the ground of Circuit #2, which is tied to the ground of Circuit #1. The problem is that real wire lengths may have slightly different impedances, indicated by Z1, Z2, Z3. As shown by R1, R2, R3 and the arrows, these may create unequal ground currents, especially where RF is circulating. They're known as "common mode" currents.

An arrangement that improves this situation is shown in "B" and is called a "star" ground. This is the usual CB chassis grounding method. Note Circuit #1, #2, and #3 are tied only to a single common ground connection, and don't rely on each other for grounding. One advantage of printed circuit boards is that the large common foil surface allows a single short, direct ground connection to be used for every circuit. Ground loops in CBs can be caused by open bypass capacitors that normally tie the frame to the common PC foil. Or in base stations, by using more than one grounding point for all the various station accessories.

Because of ground loops, you can't make meaningful DC voltage measurements from any ground reference except the common circuit tie point. On older tube-type equipment this was the same as the metal frame; newer tube radios using PC boards have the same circuit common points as transistorized chassis. Never assume the signal/DC ground and the cabinet ground are the same; they may not be! On radios having floating chassis (virtually all modern radios), they're different. Only a few older solid-state CBs used the same ground for chassis and frame, generally the negative-ground-only models.

Since the metal shields of tuning coils and transformers are always soldered to the common circuit ground, you can use them for a [-] voltmeter reference when unsure. For 'scope or relative RF measurements the probe's ground can be clipped to the frame though, because it's AC-coupled in numerous places to the circuit common point via capacitors. These bridging capacitors prevent ground loops and unwanted oscillations, particularly from stray RF.

GENERATING GROUND LOOPS
(Courtesy Gernsback Publications Inc.)

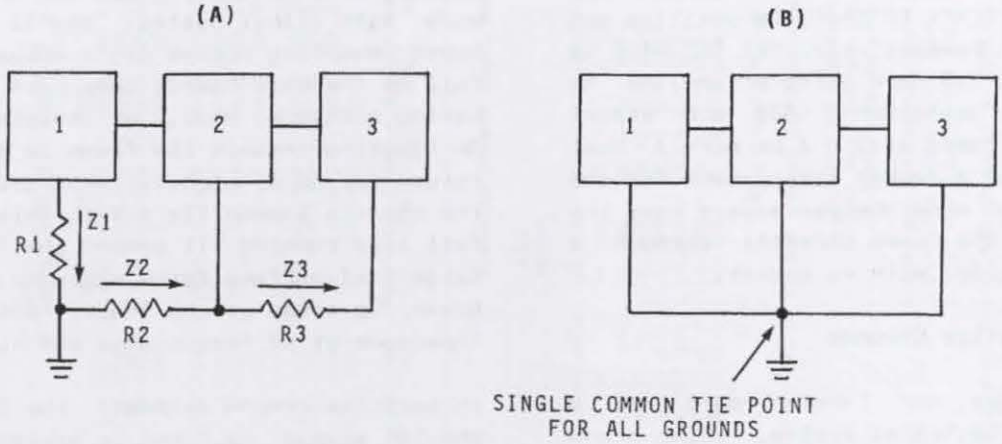


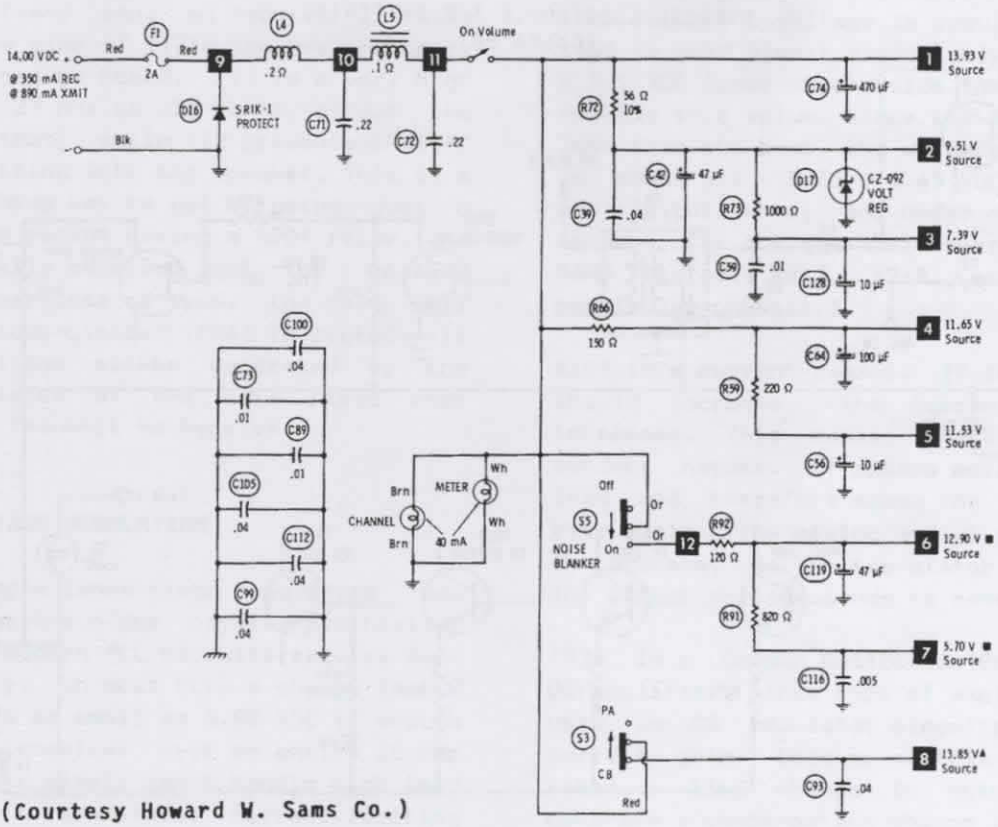
Figure 7-1 shows the simplest 13.8 VDC power system. D16 protects against accidental reverse-polarity connections, and when shorted is the most common cause for the "Blows Fuses" symptom. If the positive supply were connected to the BLACK wire and the return to the RED, the diode would conduct. With no series resistance to limit current flow, the fuse would theoretically blow. I say "theoretically" because more often than not the diode blows first! And CB operators also have a bad habit of replacing the correct fuse with something huge, like 10 A! Once the diode does short, a new fuse will blow every time the radio is reconnected to the DC source and turned on.

This diode should always be replaced with one having a forward current rating greater than the fuse, or it will blow again if the leads are accidentally reversed. Unfortunately even the manufacturers tend to use a 1 A diode here, which is why it's such a common failure. If a 2 A fuse is normal, use the heavier 2.5 A or 3.0 A replacement diode like an ECG125/SK3081 or ECG156/SK3051. Never use a 1N4001/ECG116 type here, since they're only rated at 1 A. (Note that SAMS Fotofacts almost always lists them as replacements though; they simply copied what the manufacturer specified on the original schematic, which was also wrong!)

After replacing a shorted diode, inspect the 13.8 VDC PC foil too; the excess current may have split it with a hairline crack, or done something more obvious like curling the foil right off the board. A few older radios don't even have the protection diode; if you see this on your bench, do the customer a favor and put one across the DC power entry point.

L4, L5, C71 and C72 in Figure 7-1 are for RF and spike suppression. Any ignition noise (which is broadband RF) is filtered before it can enter the radio via the power line. L5 is an iron core choke, which prevents voltage spikes from damaging other components. After the 13.8 VDC passes the ON/OFF switch part of the VOLUME control, it branches off into eight different directions. Source #1 is always used to supply the RF power amps via the modulation

FIGURE 7-1
EARLY MOBILE DC DISTRIBUTION SYSTEM
(Cobra 29)



(Courtesy Howard W. Sams Co.)

transformer, and the audio power amp stage. Note there's virtually nothing to limit current on this source except the series resistance of the coil windings. Thus a shorted RF Driver, RF Final, or push-pull audio power transistor can easily (and very often does) cause the "Dead Radio" or "Blows Fuses" symptom.

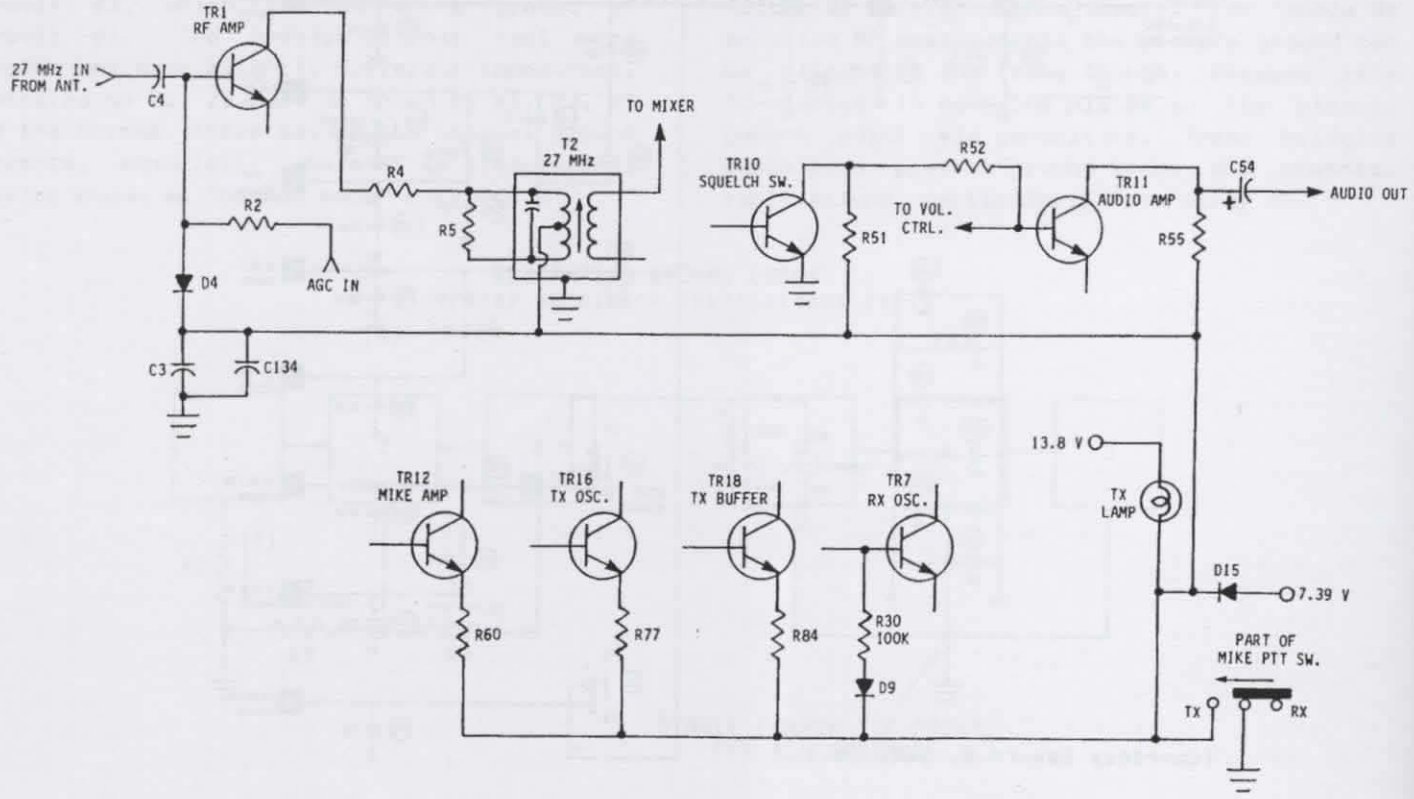
Each branch circuit is established using series resistors and shunt filter capacitors. R72 limits current to Source #2, R73 to Source #3, etc. Source #2 is the only one with fixed regulation from Zener diode D17 because it powers the oscillators, where better stability is needed. Sources #6 and #7 power the optional Noise Blanker circuit. Source #8 is a constant Transmit voltage used to power the entire transmitter oscillator/RF amplifier chain. It's disconnected in the "PA" position so only the mike and audio chain will function.

Electronic T/R Switching

The power supply in Figure 7-1 was an example of "electronic" T/R switching, in contrast to "relay" switching. The names refer to how the various T/R supply voltages and signal paths are controlled; i.e., by conduction of active devices, or by hard make/break relay contacts. Electronic switching is much more common and gives many techs difficulty due to the large number of functions being controlled. But it's easy to understand when you consider each switched stage individually. In Figure 7-2, the required switching in this particular radio is summarized.

When the PTT button is pushed, eight different changes occur. The emitters of Mike Amp TR12, Transmit Oscillator TR16 and Transmit Buffer TR18 are grounded so they'll operate. Source #3 from Figure 7-1 is pulled down to ground by D15, effectively shorting it out. This voltage has enough series resistance (not shown) to limit the short-circuit current to a safe value. D15 also isolates Source #3 from the 13.8 VDC which will simultaneously light the Transmit lamp. Grounding Source #3 removes the collector supply to Squelch Switch TR10, Audio Preamp TR11, and Receive RF Amp TR1 to disable the receiver. It also kills the base bias on Receive Oscillator TR7 when D9 switches. The high RF impedance of R30 insures T/R isolation.

FIGURE 7-2
TYPICAL ELECTRONIC T/R SWITCHING
(Cobra 29)



Grounding Source #3 also makes D4 conduct, which kills TR1's base voltage too. This extra function is needed to make absolutely sure the b-e junction of front-end amp TR1 is protected from transmitted RF. Like all electronically-switched CBs, the receiver input is connected directly to the RF power amps on Transmit, since they share a common antenna coupling network; there's no hard T/R antenna routing like that used in relay switching.

Relay T/R Switching

Since relays are much more expensive than diodes, they were limited to a handful of older CB models. The relay may be a DPDT or 4PDT type, depending upon how many T/R voltages and signals are switched on a set of poles. One set is always used to switch the antenna between the receiver front end and the transmitter RF power amps. The coil works on 13.8 VDC from the main input; a standard 12 VDC relay is used.

In Figure 7-3 a DPDT relay is used. One set of poles supplies Sources #5, #6, and #7 on Receive, and Sources #8, #9 and #10 on Transmit. The other set switches the antenna and speaker. Besides routing the antenna between the transmitter RF power amp and the receiver front-end amp, on Receive it also grounds the low side of T17's speaker secondary via L13 so it can be heard. L13 is a very high impedance to 27 MHz so it won't affect the transmitter output, while L12 prevents that RF output from getting into the speaker. This is a simple and cheap way to get by using just a DPDT relay. (In radios having a 4PDT relay, one pole is normally reserved just for speaker grounding.) Regardless of type, the relay coil is normally diode-clamped (CR6) to protect it from high-voltage spikes generated by the inductive collapse of the coil field when switching from Transmit to Receive.

TRANSISTOR VOLTAGE REGULATION

The use of simple Zener diode regulators was good enough for the older crystal-synthesized CB radios, but modern PLL circuits require much better stability. In most PLLs a change in VCO control voltage as small as 0.02 VDC is enough to shift the synthesizer over an entire 10 KHz channel! A Zener simply can't handle high load currents, and its associated current-limiting resistor is wasteful.

Instead, electronic voltage regulation offers superior stability by using one or more transistors. A transistor is connected as a variable resistance in series between the supply and the load, and feedback from the load side adjusts this resistance to keep the output voltage steady. The advantage is that the transistor handles all the load current, with a Zener diode used only as a low-current voltage reference in the transistor's base circuit.

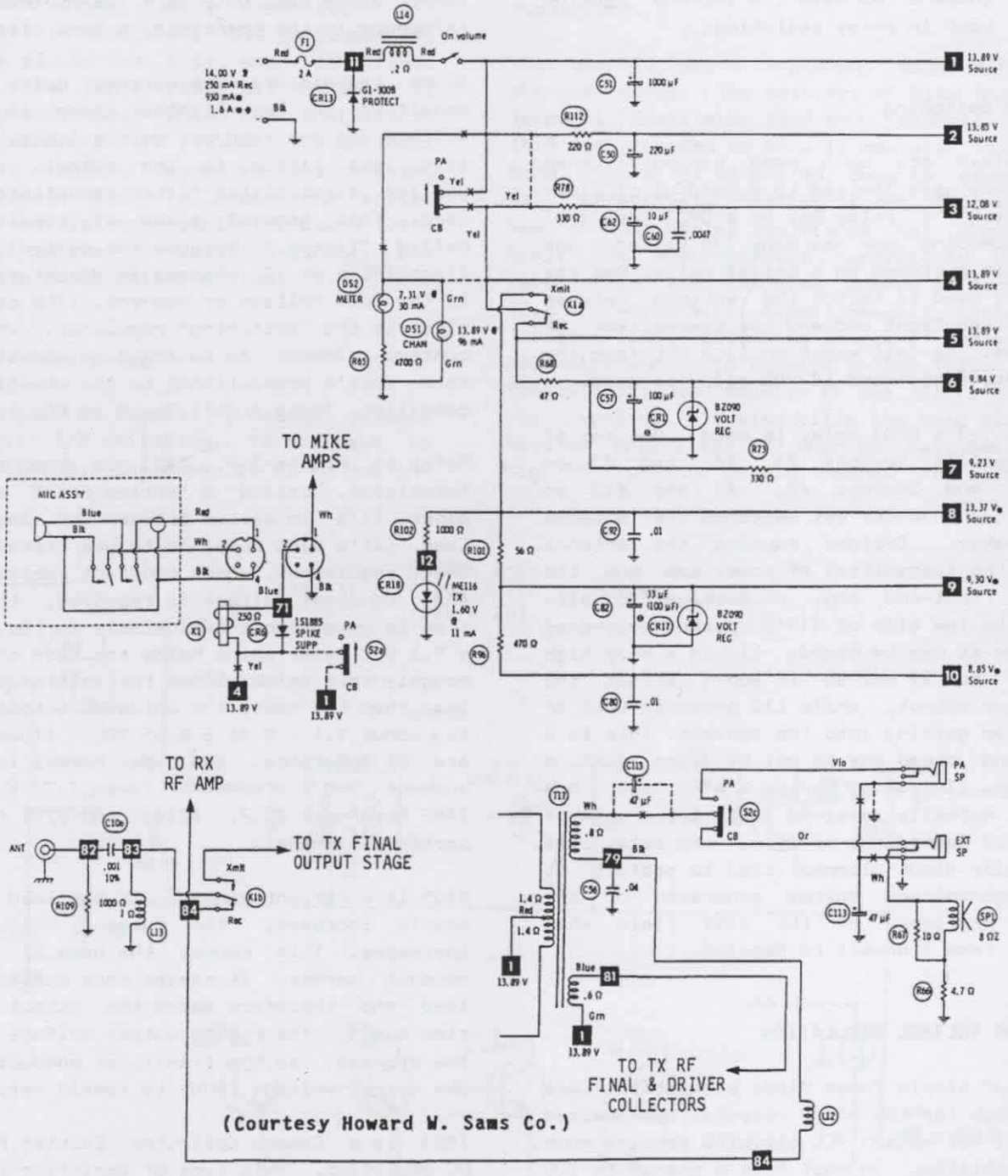
Since transistors have current gain, they're sensitive to the slightest change in output voltage and can readjust very quickly. There's also less ripple in the output, allowing smaller electrolytic filter capacitors to be used. This general class of regulators is called "linear," because the control element (transistor or IC) changes in direct proportion to the load voltage or current. (The other main class is the "switching" regulator, where the control element is switched on and off at a rate that's proportional to the changing load condition. These aren't found in CBs.)

Refer to Figure 7-4. TR23 is the regulator transistor, called a "series-pass" regulator since it's in series between the source and load. (It's also possible to use transistors as shunt regulators, where constant current rather than constant voltage is required; the series type is used almost exclusively in CBs.) D22 is a 9.1 VDC Zener which holds the base of TR23 at roughly this value. Since the emitter is 0.65 V less than the base, the unloaded output voltage is about 9.1 - 0.65 = 8.45 VDC. (These Zeners are 5% tolerance, and under normal load will account for the somewhat lower 7.79 V shown in SAMS Fotofacts #217, #218, and #281 for this particular chassis.)

R105 is a current sensor. If the load current should increase, the current through R105 increases. This causes the base of TR23 to conduct harder. It passes more current to the load and therefore makes the output voltage rise again. The rising output voltage reverses the process, so the transistor conducts less. The output voltage tends to remain very steady.

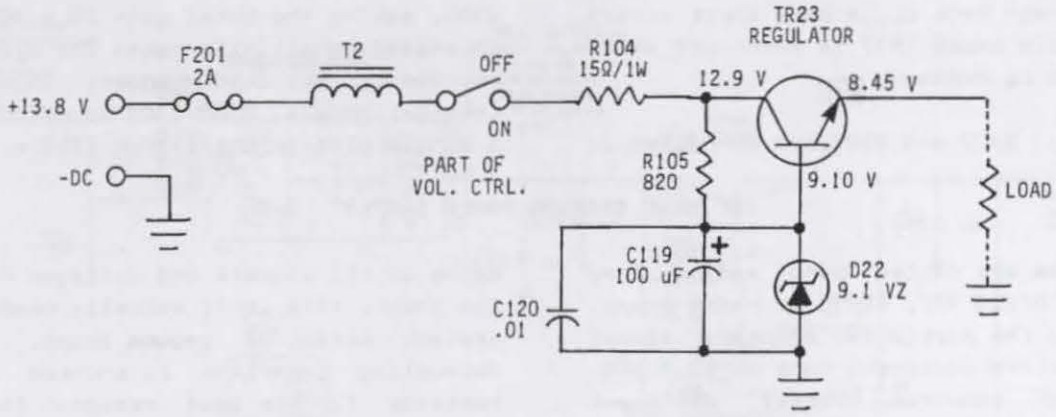
TR23 is a Common Collector (Emitter Follower) DC amplifier. This type of amplifier is widely used in CB regulator circuits and has high current gain. Because of this gain, it only takes a tiny change in output voltage to generate a compensating change in base current and maintain the regulation.

FIGURE 7-3
TYPICAL RELAY T/R SWITCHING
(Pace CB144)



(Courtesy Howard W. Sams Co.)

FIGURE 7-4
SERIES-PASS VOLTAGE REGULATION
Cobra 29GTL, 29LTD, etc.)



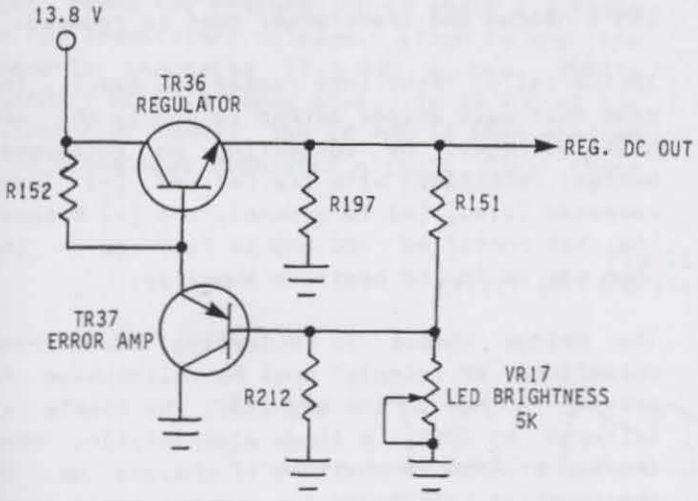
Depending upon its normal current demand the pass transistor may be heat-sinked, although nowadays most are the plastic TO-220 types standing up vertically on the PC board. The main disadvantage of this circuit is its lack of short-circuit protection. With a short across the load, the fuse wouldn't blow fast enough to protect TR23. This limitation results in another common CB power supply failure, and can be solved by current limiting circuits.

Improved Regulator Circuits

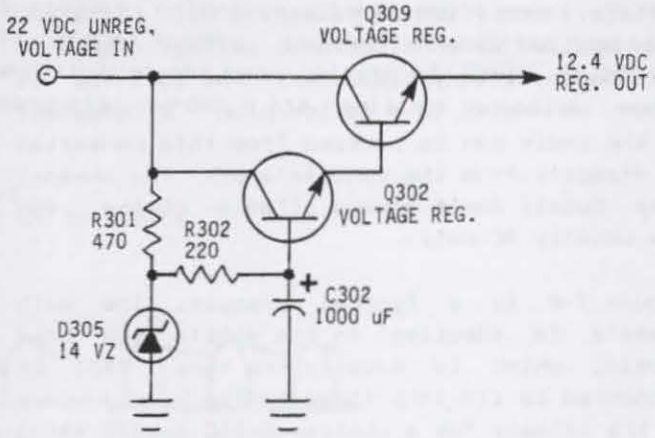
The basic series-pass regulator can be improved by adding an amplified feedback loop on the load side of the pass transistor. This not only increases its sensitivity to changes in output, but adds a current-limiting safety factor. Figure 7-5A shows how a second transistor, TR37, is used to control the conduction of pass transistor TR36 which drives the LED display.

FIGURE 7-5
ELECTRONIC VOLTAGE REGULATION

(A)
IMPROVED SERIES-PASS REGULATOR WITH ERROR AMP
(Realistic TRC457, etc.)



(B)
DARLINGTON SERIES-PASS REGULATOR
(Dak Mark X)



As the current demand to the load increases, less base current is available at TR37 from R151/VR17/R212, lowering its conduction and raising its emitter voltage. This makes TR36 conduct more, passing more current and raising the output voltage back up. A dead short across the output would cause TR37 to turn off TR36 before it could be damaged.

In Figure 7-5B, Q302 and Q309 are connected in a Darlington circuit. This is similar to the basic regulator of Figure 7-4, except current gain is now the product of both transistor gains and is therefore much higher. Typical gains (H_{fe}) are about 20 for Q309 and 40 for Q302, making the total gain 20 x 40 = 800. This increased sensitivity makes the circuit respond to the tiniest load changes. In many similar Cybernet models, Q302/Q309 is often replaced by a single plastic Darlington like a 2SD837.

THE BASE STATION POWER SUPPLY

CBs for home use are called "base" radios. They operate from 110/220 VAC, 60/50 Hz mains power, depending upon the particular country. Almost all transistorized equipment runs on 13.8 VDC. Tube equipment requires several different voltages: high-voltage DC of 200-450 VDC for the plates and screens, 6.3 VAC for the tube filaments, and a negative grid bias voltage for various amplifier functions. The purpose of any base power supply is to convert the 110/220 VAC mains to all these required operating voltages.

THE AC/DC SOLID-STATE POWER SUPPLY

The modern base radio consists of a main transceiver chassis that's virtually identical to its mobile cousin, and a mains power supply. Because the base radio is physically large and has plenty of room on its frame, the mains supply is contained on a separate PC board on the frame. The power transformer is also bolted to the frame, as well as any optional goodies like a clock, frequency counter, scanner, etc.

The mains power supply has exactly the same kind of circuitry as the AC-to-DC converters or "power packs" commonly used to operate mobiles as base stations in a building. The 110/220 VAC input is first transformed down to a lower AC voltage, rectified to pulsating DC, filtered, and applied to an electronic voltage regulator like those already discussed. The 13.8 VDC is often connected to a switch/plug arrangement so the radio can be powered from this converter or directly from the vehicle's DC. The cheaper base models don't always offer a choice, and are usually AC-only.

Figure 7-6 is a typical example. The main chassis is identical in the mobile and base models, which is usually the case. T401 is connected to 110 VAC. (Some radios have jumpers on the primary for a choice of 110 or 220 VAC.) R424 provides a DC ground reference for the AC mains so all signals and voltages have a common tie point; this isn't actually needed but helps prevent potential ground loops. Sometimes a decoupling capacitor is shunted across this resistor for the same reason. The secondary output is about 18 VAC. C412 and C413 are for voltage spike suppression. In this particular model the secondary is fused, but primary fusing is used equally.

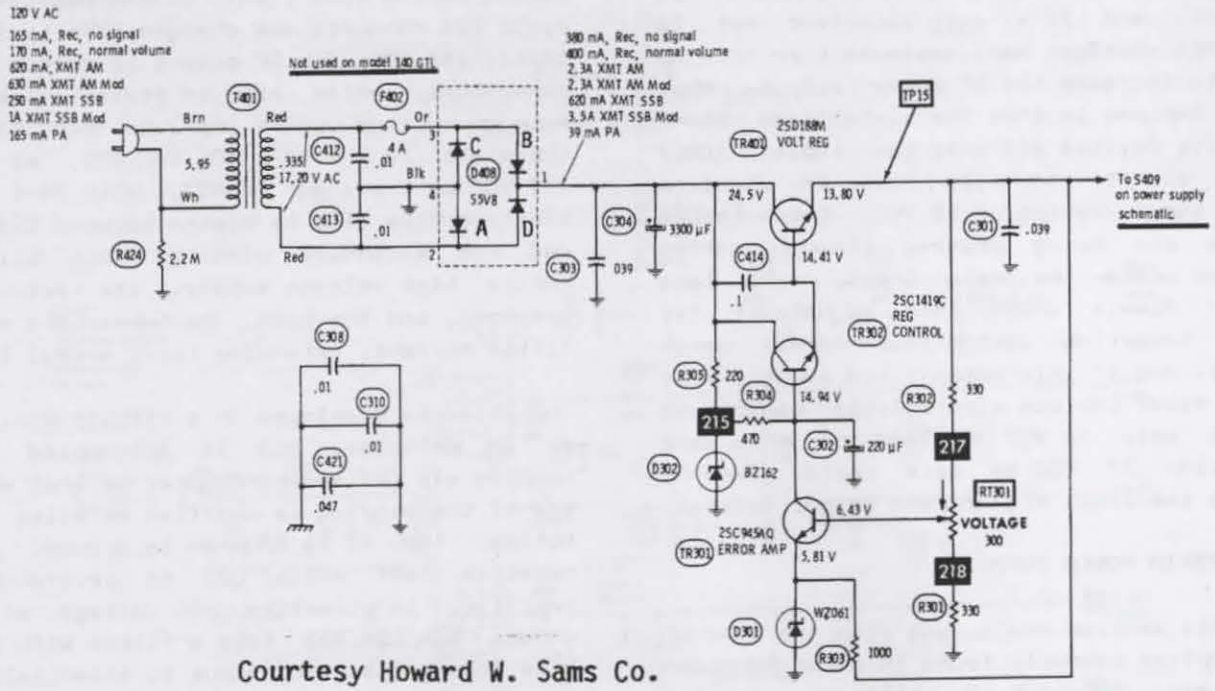
The 18 VAC secondary goes to a full-wave bridge rectifier. The bridge may consist of four discrete diodes of the 1N4006 type, or a single integrated 4-lead device. In either case they must have suitable current ratings: discrete diodes are at least 2 A, integrated bridges at least 8 A. Like the reverse-polarity diodes, they're often underrated and common failures.

The bridge rectifier consists of a pair of diodes operating on alternate halves of the AC input cycle. In this circuit, when the top of T401's secondary is positive with respect to the bottom, diodes "A" and "B" conduct; on the next half of the input cycle, diodes "C" and "D" conduct. Because a full-wave bridge is already balanced, a center-tapped secondary isn't needed and transformer cost is reduced.

Incidentally, many tube radios use exactly the same full-wave bridge method to supply the -DC bias voltages. By connecting an integrated bridge rectifier with its [+] and [-] leads reversed (i.e., [+] to ground), the [-] becomes the hot rectified -DC and is filtered in the same way as in the positive supplies.

The bridge output is pulsating DC. These pulsations or "ripple" must be eliminated to prevent AC hum on the signals. The ripple is filtered by C304, a large electrolytic. When the top of C304 is positive it charges up. On the negative half cycle the current can't force itself back through the rectifier so the

FIGURE 7-6
BASIC AC-TO-DC POWER CIRCUIT
(Cobra 142GTL, Realistic TRC490, Uniden Washington)



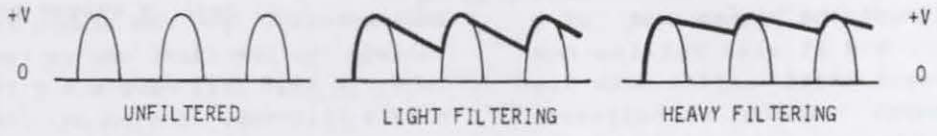
Courtesy Howard W. Sams Co.

capacitor, if large enough, retains most of its charge. Some current however will start discharging through the load resistance, but another positive half cycle will come along and recharge it before it has a chance to fully discharge. This is illustrated graphically in Figure 7-7. It shows voltage amplitude vs. time for two different capacitances; note how the larger value has the greater smoothing effect.

Rectifiers using silicon diodes always have capacitive input filters. In such filters the input capacitor charges up to about 1.4 times the RMS transformer voltage, which is why the schematic indicates 17.2 VAC across T401's secondary but 1.4 times that, or 24 VDC at the collector of TR401. The 24 VDC is then applied to a transistor regulator circuit like those described earlier; three transistors are used here for greater current gain and sensitivity. The output has now been made adjustable too.

Again feedback controls the conduction of pass transistor TR401. This time the error amp, TR301, compares the feedback of R301/R302/RT301 with a fixed reference voltage from Zener D301. Any difference is fed to another DC error amp, TR302, which also has a fixed base reference via Zener D302. Suppose a heavy load caused the output voltage to drop. This would cause the base voltage of TR301 to drop, turning it off more and raising its collector voltage. This increased collector voltage would cause TR302 to conduct harder, raising its emitter voltage and in turn the base voltage of TR401. As TR401 conducts harder, its emitter supplies more

FIGURE 7-7
EFFECT OF CAPACITANCE ON DC RIPPLE



current so the output voltage rises. A lighter load will cause just the reverse to happen.

RT301 adjusts the regulated output to exactly 13.8 VDC. All similar base models include this adjustment, and it's very important not to exceed this voltage! Many amateurs turn this up trying to increase the RF power output. What usually happens is that the overvoltage blows out active devices all over the radio! (CMOS ICs for example normally have an absolute maximum supply rating of 12 VDC. Even though such ICs are being powered through series resistance from the main input, why take chances?) Always check this adjustment for previous tampering during your normal bench alignment. And if this weren't bad enough, most of the newer CBs use electrolytic capacitors rated at only 16 VDC instead of the more conservative 25 VDC to save costs. They're pushed to the limit with excess output voltage.

TUBE & HYBRID POWER SUPPLIES

(NOTE: This section deals just with the type of power supplies commonly found in older American models, many of which are still very popular here. Technicians and foreign readers expecting to service only the transistor CB equipment may want to skip over this material.)

Tubes need high DC operating voltages, which are normally supplied by a step-up AC power transformer. The high-voltage pulsating DC that results is filtered and applied to the tubes. Separate secondary windings supply the negative bias voltages and AC filament voltages. In the case of hybrid tube/transistor equipment (Eg., Tram D201/201A, Browning Mark 4/4A, Dak Mark X, etc.), an additional low-voltage AC winding is included to power the solid-state circuits using methods already discussed. Many tube-type mobiles from the early CB days used switching oscillators to produce the high-voltage DC.

Figure 7-8 shows a typical base power supply for an older 23-channel hybrid transceiver. C31 and C32 are for transient suppression. The top secondary of T1 supplies 106 VAC which is used for both the high-voltage and bias supplies. D26 and D27 form a voltage doubler. This is a very common method in tube CBs to get high voltage without the higher cost of a bigger transformer. And it also retains the advantages of full-wave rectification with its higher ripple frequency compared to half-wave rectifiers; smaller electrolytics can be used.

Assume "STANDY" switch S4-1 is closed. On the positive half of the AC cycle D27 conducts and charges C28 to 1.4 times the RMS secondary voltage, or about 148 VDC. D26 is reverse-biased during this time. On the negative half cycle D26 conducts and charges C29c to the same level, 148 VDC. The DC output is across the two capacitors, which are in series. The total output voltage under no-load conditions is therefore (2 x 1.4) x 106 VAC RMS, or roughly 297 VDC at the input to R27. With S4-1 opened, electron flow will be broken between C28, C29c and the secondary winding. This kills the entire high voltage supply, its various load branches, and the bias. The tubes idle and draw little current, extending their useful lives.

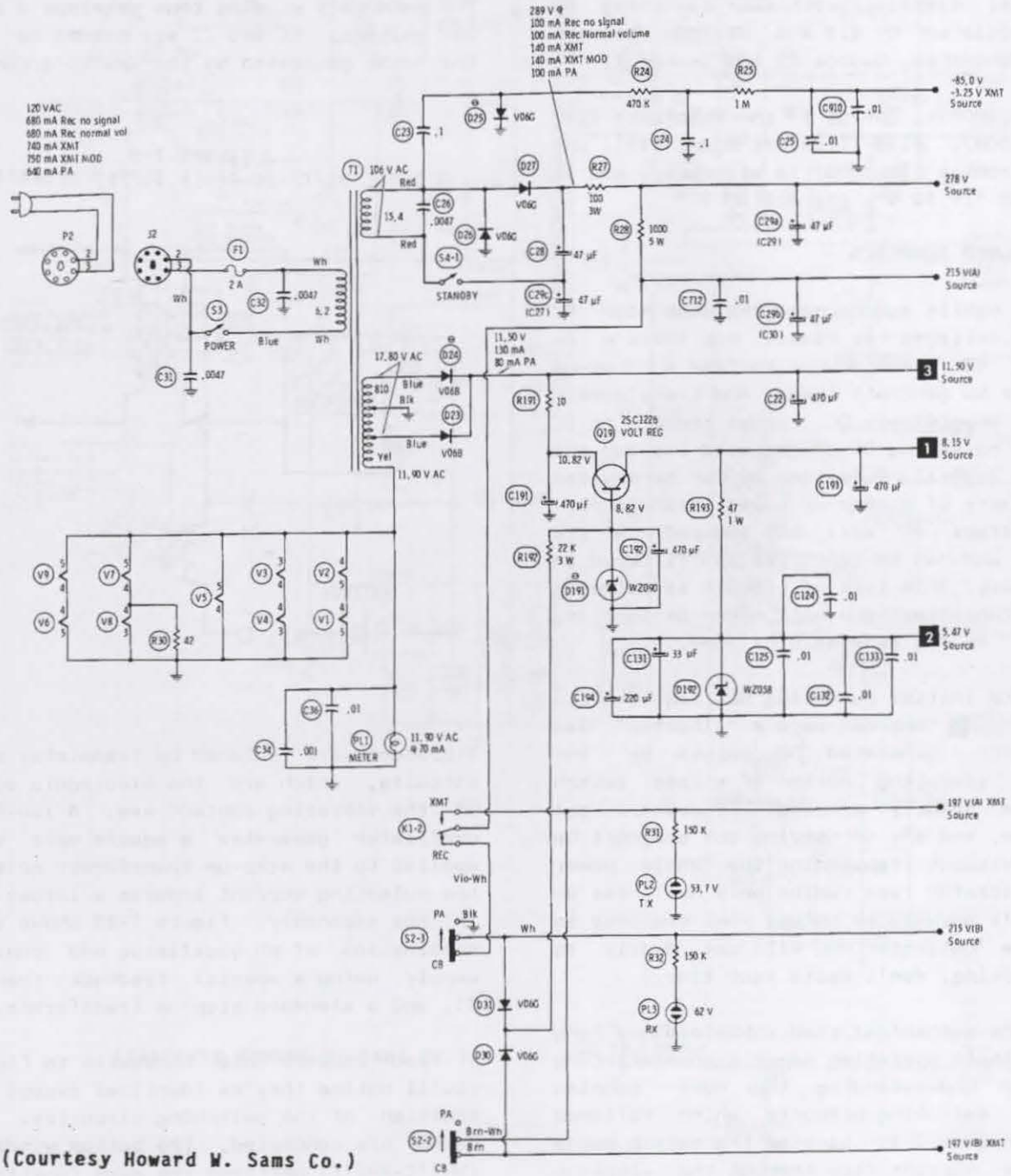
The bias is developed in a circuit similar to an AM detector. D25 is AC-coupled to the winding via C23 and configured so that when the top of the winding is positive relative to the bottom, the AC is shunted to ground. On the negative half cycle D25 is reverse-biased, resulting in pulsating -DC voltage at D25's anode. R24/C24/R25 form a filter with a long time constant so the output is essentially pure DC. C25 and C910 are for transient suppression and RF filtering. In some radios an integrated bridge rectifier supplies the -DC bias instead of discrete diodes, but is otherwise the same.

The lower secondary winding also serves a dual function. It's tapped at the 11.90 VAC point to provide the filament voltages, and center-tapped to supply 17.80 VAC for the low-voltage transistor supply. Since all the tubes in this radio use indirectly-heated cathodes (i.e., cathode and filament are electrically separate but thermally close to each other), AC hum pickup isn't a problem and the simpler AC power can be used to heat the filaments.

Note all tube filaments except V5 are part of a series pair. V5 is a 12 V filament tube, but all the others are 6 V types. (Actually, 6.3 V and 12.6 V.) Two series-connected filaments across a 12 V supply drop 6 volts across each; V5 is across the full 12 V winding. This is a standard method used in tube power supplies. When only 6 V filaments are used, the power transformer has a winding just for them.

Incidentally, you can always tell the filament voltage by the first one or two numbers of the tube: a 6BQ5 will have a 6 V filament, a 12AX7 a 12 V filament, and so on. This goes back to the old days of radio when batteries powered

FIGURE 7-8
TYPICAL HYBRID POWER SUPPLY
(Teaberry Model "T")



(Courtesy Howard W. Sams Co.)

everything; if a radio required say, a 90 V "B" battery, it would choose tubes such that their total series filament voltage drops equal 90 V.

This radio's transistor DC power is supplied by the full-wave rectifier D23/D24. This works like the full-wave bridge described earlier, except that only two diodes and a grounded center-tap are needed. C22 is the filter capacitor. The 15.5 VDC (Source #3) drives the LED channel display, with the remaining DC output regulated by Q19 and divided between two other branches, Source #1 and Source #2.

NOTE SAMS ERRORS: Source #3 in Fotofacts #187 (Robyn T-240D), #198 (Teaberry Model "T"), and #202 (Gemtronics GTX-5000) is mismarked, and it should read "15.50 V", not "11.50 V."

DC-TO-DC POWER SUPPLIES

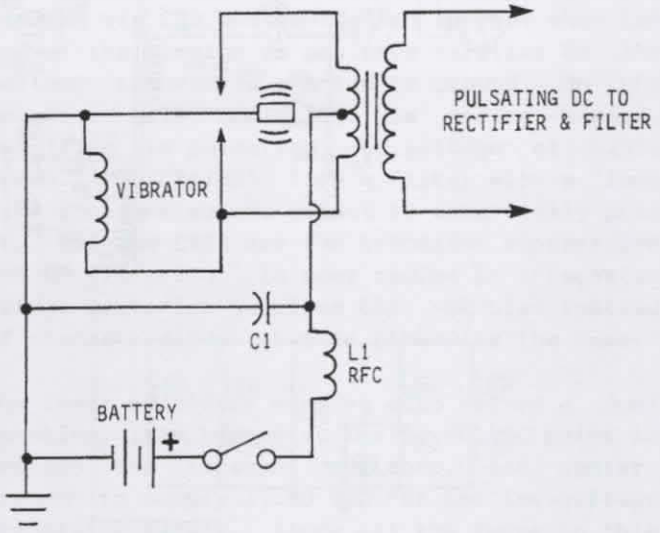
Tube-type mobile radios need the same high DC operating voltages as bases, but there's no convenient AC mains source to feed a step-up transformer to generate them. And transformers won't work on ordinary DC. Since there's no AC available, pulsating DC can be used instead and works just as well. Pulsating DC can be applied to the primary of a step-up power transformer. A high-voltage AC will be induced in its secondary, and can be rectified and filtered in the usual way. This type of circuit is called a "DC-to-DC Converter" and will often be labelled "POWER OSC" on the schematic or SAMS.

To get the initial pulsating DC requires an oscillator. In the old days a "vibrator" was used, which generated DC pulses by the mechanical vibrating action of a reed switch across the primary winding. Vibrators are extinct now, and any CB needing one couldn't be repaired without rebuilding the whole power supply. Vibrator type radios only had three or six channels anyway, so unless your customer is an antique collector who will pay dearly to keep it working, don't waste your time.

Although the mechanical reed vibrators are long obsolete, their operation makes a good starting point for understanding the more complex electronic switching circuits which followed them. In Figure 7-9, closing the switch makes DC battery current flow through the vibrator coil, pulling the center contact down. Once it hits the bottom contact, the coil is shorted out and a surge of DC current flows through the bottom half of the transformer's primary. This induces a voltage in its secondary winding.

The center contact is springy and with no more coil voltage to hold it down, it springs back and hits the upper contact. This feeds a DC pulse to the top half of the primary now, inducing an equal but opposite-phase voltage in the secondary. This combination of mechanical and electromagnetic action makes it continue to vibrate, just like that of a bell or a buzzer. The secondary winding thus develops a pulsating DC voltage. L1 and C1 are needed to suppress the noise generated by the sparking contacts.

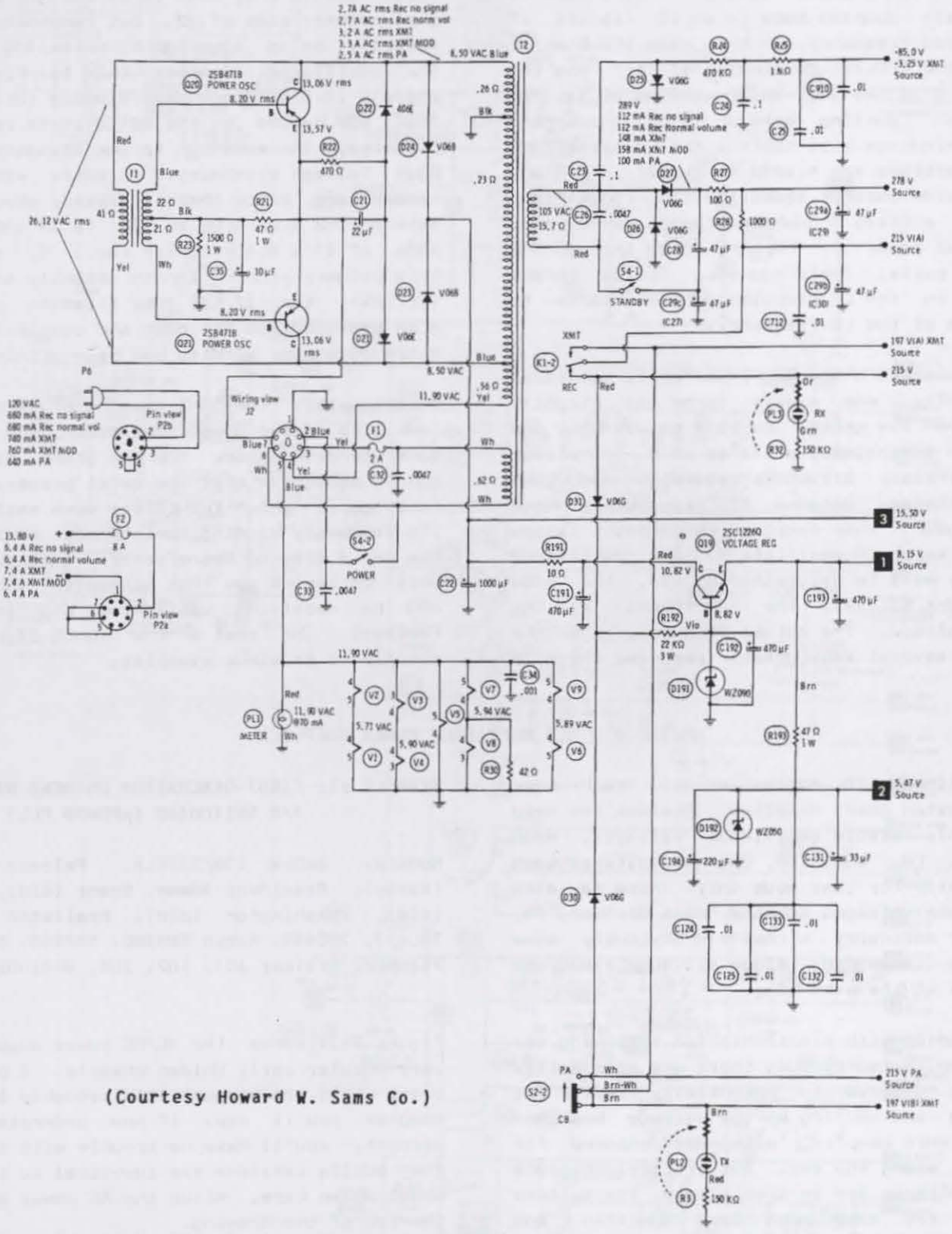
FIGURE 7-9
BASIC DC-TO-DC POWER SUPPLY OPERATION



Vibrators were replaced by transistor switching circuits, which are the electronic equivalent of the vibrating contact arm. A low-frequency oscillator generates a square wave which is applied to the step-up transformer primary, and the pulsating current induces a larger voltage in the secondary. Figure 7-10 shows a clever combination of an oscillator and conventional supply using a special feedback transformer, T1, and a standard step-up transformer, T2.

If you compare this schematic to Figure 7-8, you'll notice they're identical except for the addition of the switching circuitry. When AC mains are connected, the bottom winding here (WHITE-WHITE) performs the same function as the primary winding (WHITE-WHITE) did back in Figure 7-8. The main chassis are all identical under various brand names (Gemtronics, Robyn, Teaberry); some use the combo supply, some the

FIGURE 7-10
DC-TO-DC POWER SUPPLY USING TRANSISTOR OSCILLATORS
(Gemtronics GTX-5000, Robyn T-240D)



(Courtesy Howard W. Sams Co.)

straight AC supply. Separate 8-pin octal plugs connect either the AC or DC main primary input.

Q20 and Q21 form a push-pull "Armstrong" type oscillator. The Armstrong oscillator gets its feedback from a small "tickler" coil which is inductively coupled back to an LC circuit of the desired frequency. In this case the tickler coil is the RED-YELLOW winding of T1, and the LC circuit is the BLUE-WHITE winding of T1. The degree of coupling between T1's input and output windings will control the oscillation. The transistors are biased on by R21. C35 and R23 provide emitter stabilization, just like that of a Class B push-pull audio power amp. On initial power-up, current flows through the tickler coils. Their magnetic fields induce current in the LC circuit, which starts to oscillate at the LC frequency.

Since transistors are never perfectly identical electrically, one always turns on slightly faster than the other. Current pulses back and forth in the primary of T1 as each transistor is alternately driven to saturation and then reverse-biased. Because all transistors have current gain, they overcome the circuit losses and can maintain oscillation. The oscillator frequency will be determined by C35, the bias of divider R21/R23, the inductances, and the supply voltage. The actual frequency is on the order of several KHz, greatly reducing the size and cost of the electrolytic filter capacitors when compared to those in a 60 Hz mains input.

D21-D24 form a full-wave bridge rectifier and are AC-coupled from the oscillators by C21. At first glance they seem to be out of place on the primary side of T2, but remember they're actually being supplied by pulsating DC from the oscillator. Compare this to Figure 7-8, where a 17.8 VAC secondary winding (BLUE-BLACK-BLUE) was needed for the solid-state regulation circuits, in addition to the standard RED-RED high voltage secondary. No extra winding is needed here, since there's already about 17 VAC between the BLUE-BLUE of T2. (8.50 VAC on each side of T2's BLACK center tap.) By extending this primary winding length slightly on one end (YELLOW), the 12 VAC tube filament power is also provided. So the cost and complexity of an extra secondary winding has been eliminated.

Unfortunately the SAMS drawing of T2 makes it look like a step-down transformer, and that was done to save space. But the sharp technician should recognize that the total primary winding resistances shown for T2 are much smaller than its secondary winding resistance, as it would be for a step-up transformer. I mention this only to remind you that schematic appearances can be deceiving until you dig into them further! The rest of the branch circuitry is similar to previous examples.

AM/SSB & OTHER MULTIMODE POWER SUPPLIES

All multimode CB radios require much more sophisticated power supplies. Besides the need for highly stable oscillator voltages, each mode (AM, FM, USB, LSB, CW) has voltages used specifically for that mode only. There may also be separate voltages for the Noise Blanker, PA, or other accessory circuits. Obviously some switching is needed, since all supply sources aren't on at the same time.

Modern radios with electronic T/R switching are more complicated because there are more active switching devices to potentially fail. The switching and routing of the various branches becomes more complex, with more chances for problems along the way. But precisely because supply voltages are so specialized, the failure symptoms are also much more specific and logical to troubleshoot. The following four examples will help you analyze the most common AM/SSB power supply circuits.

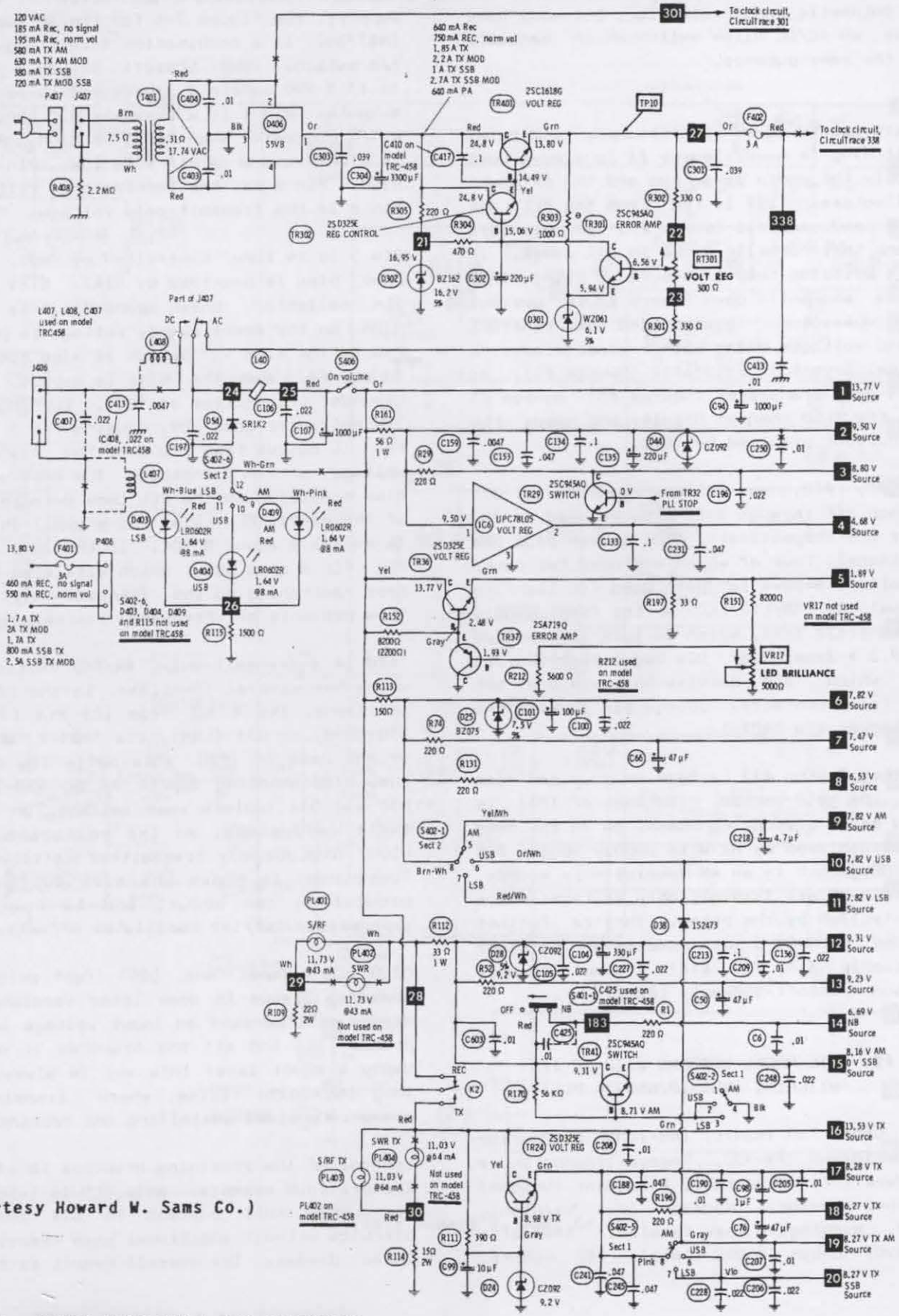
EXAMPLE #1: FIRST-GENERATION UNIDENS WITH RELAY T/R SWITCHING (μPD858 PLL)

Models: Cobra 138/139XLR, Palomar SSB500A (early), President Adams, Grant (old), Madison (old), Washington (old), Realistic TRC449, TRC457, TRC458, Robyn SB510D, SB520D, Stag 357, Teaberry Stalker 101, 102, 202, WKS1001.

Figure 7-11 shows the AC/DC power supply for a very popular early Uniden chassis. I purposely chose this one because it's probably the most complex you'll see; if you understand this circuit, you'll have no trouble with the rest! The mobile versions are identical to the base model shown here, minus the AC power supply at the top of the drawing.

The AC-to-DC converter circuit is exactly like those discussed earlier. Notice J407 includes

FIGURE 7-11
EARLY AM/SSB POWER SUPPLY WITH RELAY T/R SWITCHING
(Cobra 139XLR, Realistic TRC457/458, old President Washington, etc.)



(Courtesy Howard W. Sams Co.)

shorting contacts which route the main 13.8 VDC input from either J406 in mobile use, or from the mains-converted DC at Circuitrace #338. This particular jack is spring-loaded and allows automatic input selection, but many base CBs use an AC/DC slide switch which manually serves the same purpose.

There are twenty DC supply branches, and relay T/R switching is used. Source #1 is always used to supply the audio power amp and the RF power amp collectors. TR29 is fed from the PLL Lock Detector and controls Source #3, which powers an IF amp that normally works in all modes. If the Lock Detector output should go HIGH, TR29 saturates and pulls down Source #3 to prevent unlocked operation. Sources #2-8 are constant regulated voltages using either Zener diodes, a 3-terminal 5-volt IC regulator (Source #4), or a series-pass transistor (Source #5). Source #5 powers the LED channel display and needs the higher current provided by TR36.

Sources #9, #10, and #11 are regulated by D25 and branch off through S402-1 to be used on AM, USB, or LSB respectively. MODE switch S402 has six sections, four of which are used for power distribution. S402-6 is just used for lighting individual AM/USB/LSB LEDs on the front panel. S402-2 controls TR41, which in turn is supplied by the 9.2 V Zener D28. D28 regulates Sources #12-15, which are Receive-only via one set (K2) of relay contacts. Source #14 powers the Noise Blanker via S401-1.

Notice that Source #15 is Receive-only and also AM-only. On USB or LSB, the base of TR41 is grounded so no current can pass. On AM the base is forward-biased by R170 to supply Source #15 with 8 VDC, which is an AM-Receive-only source. Sources #16-20 are Transmit-only voltages which are controlled by the relay. They're further subdivided by S402-5 into sources of constant Transmit-only (#16, #17, #18), Transmit-AM-only (#19), and Transmit-SSB-only (#20).

EXAMPLE #2: LATE-MODEL UNIDENS WITH IC T/R SWITCHING (MB8719/MB8734 PLL)

Models: Cobra 140/142GTL, 148/2000GTL, Courier Galaxy, Midland 79-900, Pearce-Simpson Super Bengal Mark II (Australian), President (Uniden) Grant (new version), Madison (new version), McKinley, Washington (new version), Realistic TRC450/490, Robyn SB505D (late), SBE LCBS-8, LCMS-8, Stalker XX (export), Teaberry Stalker IX, XV, XX, Tram D80, D300.

Figure 7-12 shows the DC section of this power supply; see Figure 7-6 for the AC supply. IC5 (MB3756) is a combination 8-volt regulator and T/R switch. (Sub: ECG1271, SK7789.) The input is 13.8 VDC on Pin 2. There are three regulated outputs. Pin 1 is a constant 8.0 VDC. Pin 5 is a T/R control: when Pin 5 is HIGH, Pin 6 will be HIGH, and when Pin 5 is LOW, Pin 8 will be HIGH. Pin 6 is the Receive-only voltage, and Pin 8 is the Transmit-only voltage.

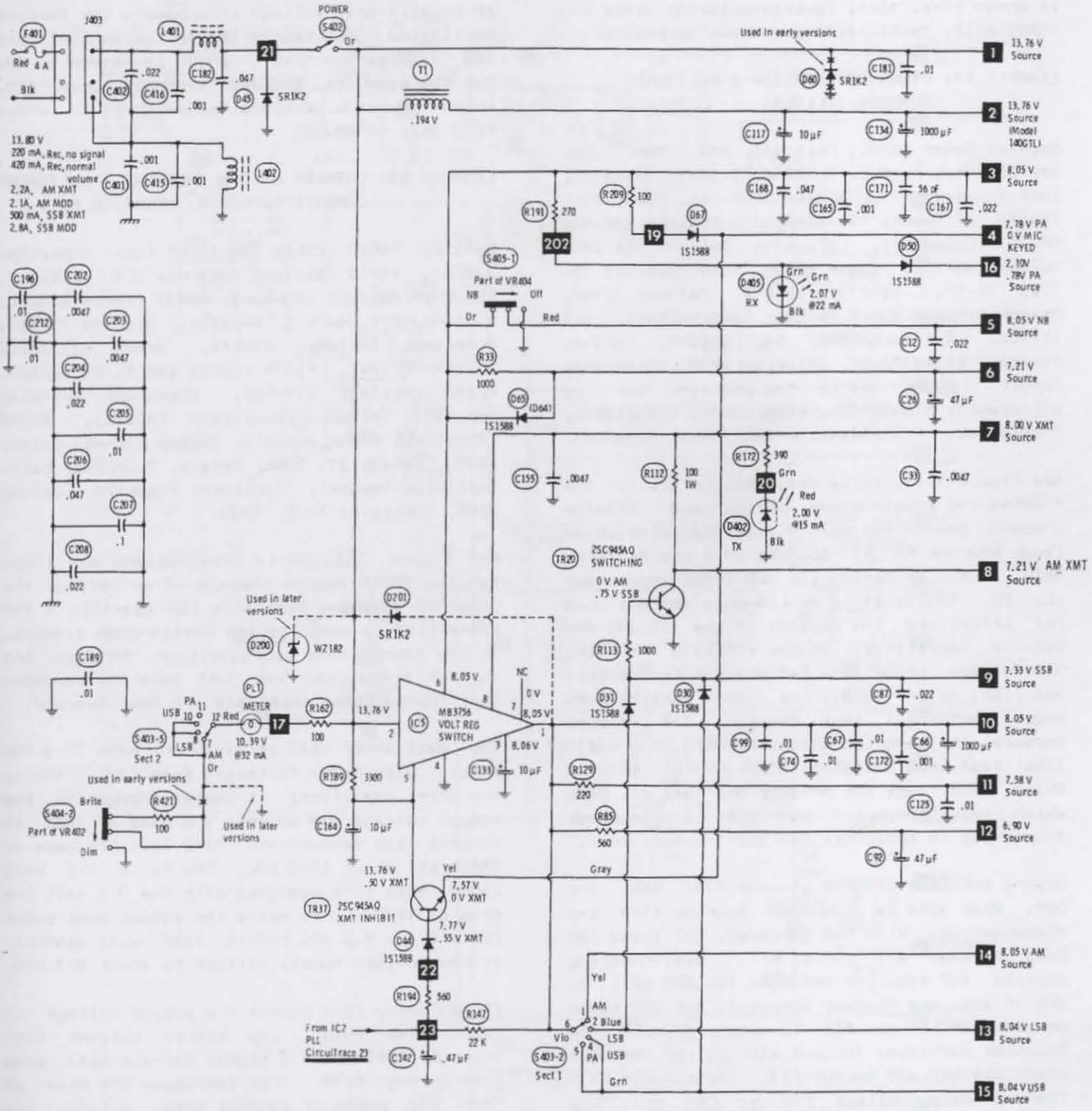
Pin 5 is in turn controlled by TR37. A small base bias is provided by R147. R189 pulls up its collector, which means Pin 5 is normally HIGH so the Receive-only voltage is present on Pin 6. The mike PTT button is also connected to Source #4. When the mike is keyed, Source #4 grounds the emitter of TR37, turning it on. Its collector goes LOW, causing Pin 5 to switch the IC output from Pin 6 to the Transmit-only voltage at Pin 8 instead. The base of TR37 is also connected to the PLL Lock Detector. (Pin 6 of the MB8719 PLL chip, not shown.) This LD pin is normally about 8 VDC. If the loop unlocks, PLL Pin 6 goes LOW, which will also keep TR37 from switching to the Transmit-only voltage. This prevents off-frequency transmission.

TR20 is a Transmit-only, AM/SSB control switch which has several functions. In the LSB or USB positions, the 8 VDC from IC5 Pin 1 turns on D30 (USB) or D31 (LSB) via S403-2, which turn on the base of TR20. This pulls its collector LOW, disconnecting Source #8 on SSB-Transmit. D30 and D31 isolate each voltage. On AM, TR20 isn't conducting, so the collector remains HIGH. This AM-only transmitter voltage has two functions: to close the mike audio path so modulation can occur, and to control the appropriate Carrier Oscillator offsets.

D200 (18 V Zener) and D201 (fast switch) were added as clamps in some later versions; these diodes will conduct on input voltage spikes to protect IC5 and all the branches it supplies. Using a shunt Zener this way is always a good idea in mobile radios, where transients are common. Consider installing one routinely.

Control of the remaining branches is similar to the previous example. Note IC5 is large enough to supply full current to all the branch circuits without additional pass transistors or Zener diodes. The overall result is that the

FIGURE 7-12
UNIDEN AM/SSB POWER SUPPLY WITH IC T/R SWITCHING
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



(Courtesy Howard W. Sams Co.)

MODE switch now has fewer poles and the T/R relay has been eliminated, lowering costs.

NOTE SAMS ERRORS: Source #8 is just present for AM-Transmit-only; it should have said, "7.20 V AM-TX, 0.20 V USB/LSB-TX." The correct reading is shown here. Also, reverse-polarity diode D45 (SAMS #219, "McKinley") was drawn backwards.

EXAMPLE #3: CYBERNET AMERICAN & MULTIMODE CHASSIS (PLL02A)

Models: Boman CB950, Colt 480, 485, 1000, 1200, Dak SSB Mark X, G.E. 3-5825A, 3-5825B, 3-5875A, Gemtronics GTX-77, HyGain 2705 (V), 2785, 3108 (VIII), JC Penney 981-6247, JIL Citizen SSB-M6, MPL-5 (Canadian), Lafayette Telsat SSB-140, Telsat SSB-120, Major M360, M588, Midland 78-574, 78-891, 78-999, 79-892, Palomar 2900, Pearce-Simpson Super Panther (Australian), RCA 14T302, Rystl CB4082, SBE LCBS-4, LCMS-4, Truetone CYJ4837A-87, Universe 5600 (Canadian). Export Chassis (parts designations may be different): PTBM059C0X, PTBM121D4X, PTBM122D0X, PTBM125A4X, PTBM131A4X, PTBM133A4X, PCMA001S.

See Figure 7-13. Parts designations are for the PTBM048/058 single-board American and Canadian chassis. Q44 is the main 9-volt regulator which feeds Sources #5-18. Sources #5-8 are Receive-only, with #6 having its own Zener regulation via D2. Source #9 is an LSB-only voltage used for offsetting the crystal in the 10.692 MHz Carrier Oscillator. Source #10 is a constant SSB voltage, since it's fed via S2a from either D46 (LSB) or D47 (USB); the diodes isolate each mode. Source #11 is a constant SSB voltage because the same two diodes feeding Source #10 also feed the collector and base of Q41. A third path feeds the emitter and base of Q40, which only conducts when D48 is grounded; Source #12 is therefore for SSB-Transmit-only.

Keying the mike grounds grounds D54, D48, and D49. When D54 is grounded, Sources #5-8 are disconnected. With D48 grounded, Q41 loses its base voltage and turns off, disconnecting certain SSB receiver voltages (Source #11) to the IF amps and Product Detector. But Q40 turns on instead (Source #12) to supply power to the Balanced Modulator IC, and also to the Transmit Mixer via D45 and Source #13. Source #13 is a Transmit-only voltage fed by D45 and the collector of Q40, and by the collector of Q42 and D52/D44. Two series diodes are used for greater isolation between Sources #14 and #16, since high-level RF from the power stages is present. Along with D45 they isolate Q40 from Q42. Chokes L4 and L5 further decouple this RF.

D49 also conducts on Transmit, turning Q43 off and Q42 on like the previous NPN/PNP pair. With Q43 off, Source #17 is disconnected; it's an AM-Receive-only voltage and powers the Carrier Oscillator (not needed for AM reception) and the 455 KHz 2nd Mixer, which is needed on AM. Now Q42 conducts instead to supply Source #16, which powers a separate Transmit Mixer stage used only on AM.

EXAMPLE #4: CURRENT UNIDEN AMERICAN & MULTIMODE CHASSIS (μPD2824, MC145106 PLL)

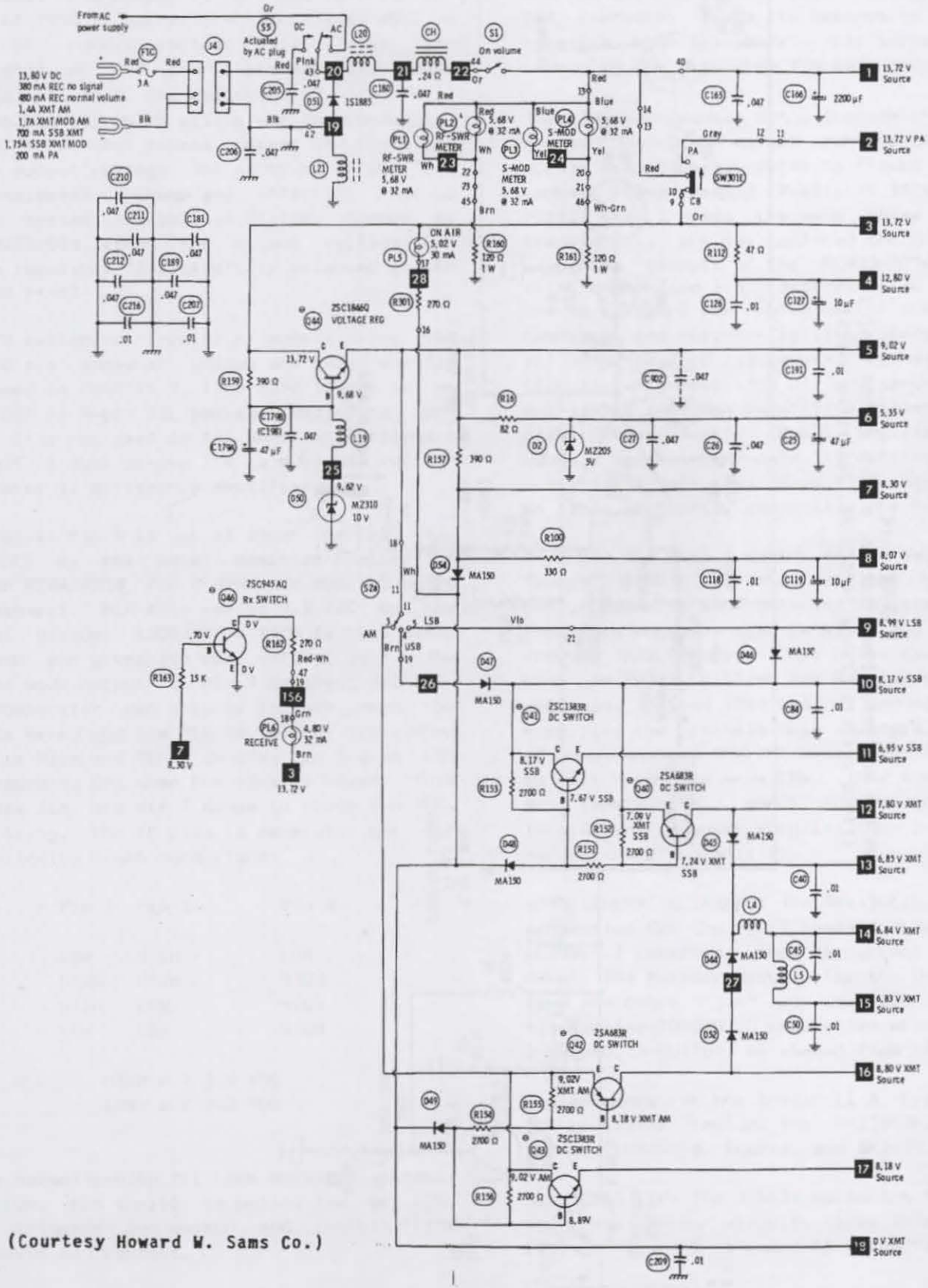
Models: PB010 (Cobra 148GTL-DX late, Superstar 360FM), PB015 (Midland 7001 new U.S. version), PB042 (President Jackson), PC833 (Cobra 146GTL, Midland 6001 new U.S. version, Midland 79-260, President AR-144, AX-144, Sears 663.3810, Uniden PC244), PC879 (Cobra 148GTL-DX early), PC893 (Stalker ST9-FDX, President McKinley export), PC965 (Realistic TRC451), PC999 (President Grant export). Uniden clones: Galaxy 2100, Galaxy II, Super Galaxy, Excalibur base, Excalibur Samurai, President Franklin, Galaxy 2100, Superstar 3600, 3900.

See Figure 7-14. Parts designations are those for the PB010 Uniden chassis. I've redrawn the original Japanese schematic for clarity. A PNP transistor is used for the series-pass element, in the common base configuration. PNPs are the current trend, and you just have to remember that input/output terminals are now reversed.

The emitter of TR41 receives the main 13.8 VDC input, with heavy filtering from C227. TR40 is the error amplifier; it senses changes in the output voltage and adjusts the base of TR41 to control its conduction. R241 sets the base of TR41 at about 13.0 VDC. D88 is a 7.5 volt Zener. When it's combined with the 0.7 volt b-e drop of TR40, this means the output must reach 7.5 + 0.7 = 8.2 VDC before TR40 will conduct. So the no-load supply voltage is about 8.2 VDC.

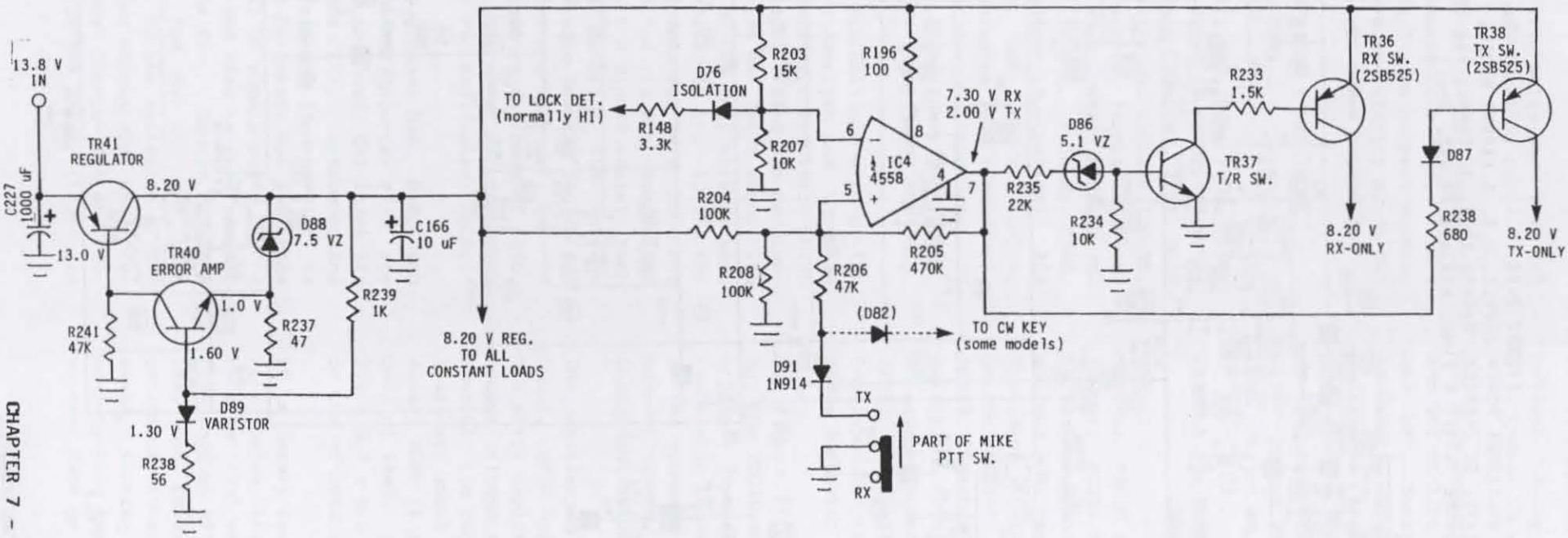
If a heavy load causes the output voltage to fall below this, the higher current flow through TR41 means a higher current will also flow through R239. This increases the bias on TR40 and makes it conduct more, pulling its collector lower. This pulls the base of TR41 lower, turning it on harder and passing more compensating current, which raises the output voltage back up to its correct level.

FIGURE 7-13
CYBERNET MULTIMODE POWER SUPPLY, U.S. & EXPORT MODELS
(PTBM048 chassis: GE 3-5825A, HyGain 2705, JC Penney 981-6247,
Lafayette Telsat SSB140, Midland 79-892, etc.)



(Courtesy Howard W. Sams Co.)

FIGURE 7-14
UNIDEN MULTIMODE POWER SUPPLY, U.S. & EXPORT MODELS
(PB010 chassis: Cobra 148GTL-DX, Superstar 360FM)



The second part of this regulator is a simple overvoltage protector. D89 is a voltage-sensitive varistor, which means its resistance decreases as the voltage applied to it (and therefore the current flowing through it) increases. It's biased by R238 and R239 so the base of TR40 is normally at about 1.60 VDC. A rise in output voltage will lower the resistance of D89 and therefore the base voltage of TR40. The collector of TR40 will pull up higher, which will lower the conduction of TR41 to prevent excess current and therefore excess output voltage. The addition of D89 can be considered a cheap and effective back-up safety system. The voltage divider formed by R239/R238/D89 keeps the output voltage of series regulator TR41 carefully balanced at the desired level.

The T/R switching circuits of models using the 4558 IC are somewhat unique and were briefly mentioned in CHAPTER 5. (The 4558 IC may be an 8-pin DIP or 9-pin SIL package, depending upon model. It's not used in the American versions.) One half of dual op-amp IC4 is a simple voltage comparator or difference amplifier.

On Receive, Pin 5 is set at about one-half V_{cc} (4.0 VDC) by the equal resistor values of divider R204/R208. Pin 5 drops to about 2.0 VDC on Transmit. Pin 6 is set at 3.2 VDC by the unequal divider R203/R207. R205 is the loop feedback and gives IC4 some voltage gain. The Receive mode output at Pin 7 is about 7.3 VDC. The comparator can only be tripped when the mike is keyed and the PLL is locked; i.e., when Pin 6 is HIGH and Pin 5 is LOW. Pin 5 goes LOW by grounding D91 when the mike is keyed. This triggers IC4, and Pin 7 drops to about 2.0 VDC. Summarizing, the IC bias is carefully set for the following truth conditions:

Pin 5	Pin 6	Pin 7
LOW	HIGH	LOW
HIGH	HIGH	HIGH
HIGH	LOW	HIGH
LOW	LOW	HIGH

HIGH = > 3.2 VDC
LOW = < 3.2 VDC

If the normally-HIGH PLL Lock Detector circuit goes LOW, Pin 6 will be pulled low by D76, which triggers the switch and inhibits the changeover to Transmit.

With IC4 Pin 7 normally at about 7.3 VDC, this makes the 5.1 V Zener D86 conduct and turn on TR37. TR37 conducting turns on TR36, so current flows from its collector to the receiver circuits. On Transmit Pin 7 goes LOW, turning off D86 and the Receive-only voltage. Instead D87 conducts, since its cathode is now more negative than its anode. This turns on TR38, supplying the regulated Transmit-only voltage.

The American models don't include the 4558 IC, instead choosing direct control of the T/R supply transistors. Refer to Figure 7-15. The compact PB062 chassis (Realistic TRC453, Uniden PC122, etc.) uses the same three switching transistors, but has replaced the discrete 8 V regulator circuit of the PC833/PC965 chassis with a standard 1 A, 3-terminal IC regulator. The IC contains the equivalent of the amplified feedback and current-limiting circuits. Like all 3-terminal IC regulators, it has an input (Pin 1), an output (Pin 3), and ground (Pin 2), and always includes capacitive filtering (C118, C119). The plastic TO-220 regulator IC is usually heat-sinked. You'll occasionally find a 5-volt, 8-volt, or 12-volt IC regulator used in other CB models, especially the newer ones.

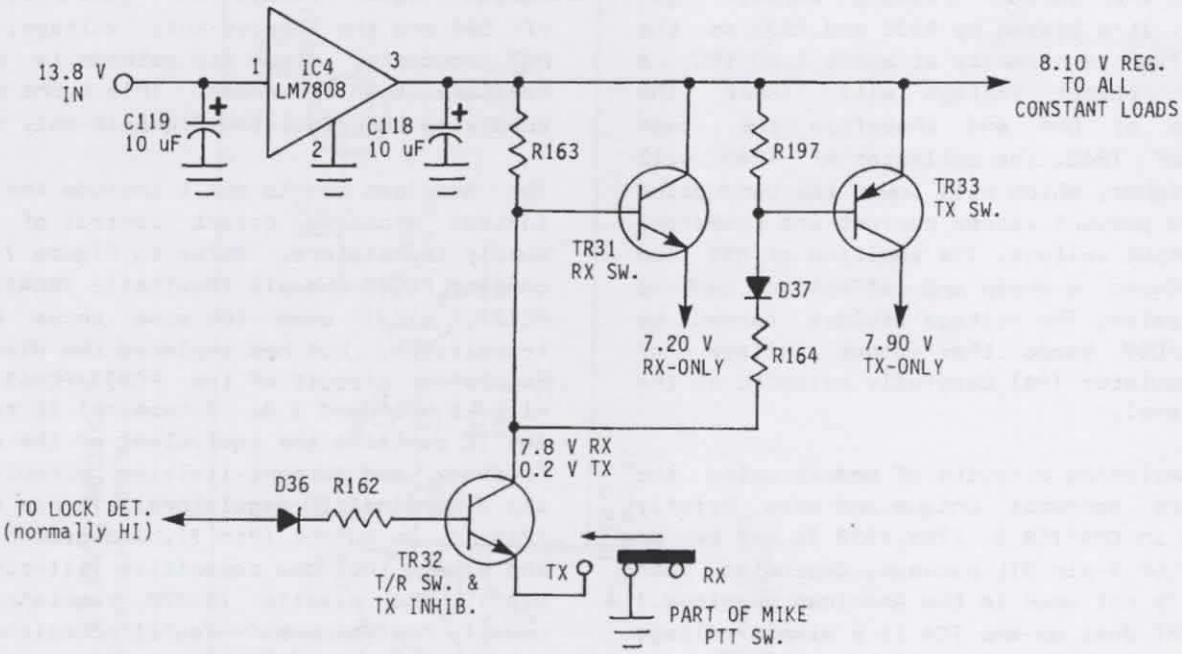
TR32 has the dual function of T/R switching and Transmit Inhibit for out-of-lock conditions. The µPD2824 PLL Lock Detector is normally HIGH; therefore when the mike is keyed and the PLL is locked, TR32 conducts. This pulls down the base bias on TR31, killing the Receive-only supply voltages. Instead TR33 and D37 can now conduct, supplying the Transmit-only voltages. The use of complementary NPN/PNP switching transistors is very common in many CBs. They increase gain and sensitivity, don't invert input/output levels, and in power supplies they increase the current-handling ability.

NOTE SCHEMATIC ERRORS: The Realistic and Uniden schematics for the PB062 chassis show IC4 Pin 1 and Pin 3 reversed; they're correct as shown here! The factory manuals for the Uniden "PRO" line and Cobra "Plus" line are also mismarked. All similar TO-220 IC regulators are: 1-INPUT, 2-GROUND, 3-OUTPUT, as viewed from the front.

Replacements for the 8-volt (1 A) type positive IC regulator include the HA17808W, µPC78M8, LM7808, LM340T-8, ECG964, and SK3630.

SERVICING TIP: The 2SB525 switching transistors in these Uniden circuits (like TR36/TR38 and TR33 in Figure 7-14 and 7-15 respectively) are

FIGURE 7-15
SIMPLIFIED UNIDEN AM/SSB POWER SUPPLY USING IC REGULATOR
(PB062 chassis: Realistic TRC453, Uniden PC122, etc.)



very common failures. They're underrated and can't handle the heavy current demand. This is one of the first things you should check with a symptom of "No Receive" or "No Transmit" when the other mode is working normally. Replace a bad one with a heavier PNP audio-type device such as an ECG294, or even a TO-220 transistor like the ECG292/SK3441 or TIP30.

TROUBLESHOOTING THE POWER SUPPLY

Power supply failures usually give little or no warning, especially in solid-state circuits. A device can open and kill the associated supply voltage. A short circuit can cause excessive current to flow; by the time you see the smoke the damage is done. Or something less than a complete short could pull a supply voltage down so low that the circuit(s) being powered by it doesn't work. But power supply circuits are among the easiest to troubleshoot, because they can be logically analyzed by what they power.

Symptoms of power supply problems include:

1. Blows fuses. (DC input, AC input, or both where applicable.)
2. Stuck on Transmit (or Receive) all the time; won't switch properly.
3. No Receive, Transmit normal.
4. No Transmit, Receive normal.
5. No Transmit or Receive, meter lights only.
6. Base radio operates from its 12 VDC input but not the AC mains input.
7. No Receive, No Transmit, or both, one mode only. (AM/FM/USB/LSB or both SSB.)
8. USB or LSB off frequency.
9. No AM modulation present with normal RF carrier output, but SSB-Transmit normal.
10. Excess hum or "motorboating."

Blown Fuses

A voltmeter and ohmmeter are the only tools usually needed for power supply problems. A 'scope can be used to measure the effectiveness of filter capacitors on ripple reduction, although usually it's easier just to bridge a good capacitor across a suspicious one and note any change. Fuses sometimes blow just from old age; always see if a new fuse blows too. If not, don't worry about it. If the new one blows, then start looking for a short across the load. The most common causes of blown fuses are a shorted reverse-polarity diode, shorted audio power transistor or IC, or shorted RF Driver or Final transistor. These are all directly across the main 13.8 VDC bus and are therefore independent of operating modes.

The first test with the "Blows Fuses" problem is an ohmmeter check directly across the DC power input wires or socket. With the VOLUME control or power switch turned "ON," you should measure a definite resistance which changes when you reverse the test leads. A reading near zero ohms both ways indicates a short. Any power supply feeding semiconductor devices will always measure higher resistance one way than the other, and this applies to branch circuits as well as the main 13.8 VDC input. If a short is indicated, isolate the appropriate load from its source to determine which one is the cause.

Completely Dead Radio

In the case of radios that don't even light up, start by looking outside the radio. The in-line fuseholders sometimes fail to make contact internally, so there's no measurable voltage on the radio side and the fuse itself checks good. You can stretch the fuseholder springs a bit to cure this. Slide mounts are another major source of missing supply voltages, if contact between the mating halves is poor or open. The copper contacts can usually be bent up higher by slipping a screwdriver underneath them and twisting. With the flat type of slide mount contact, apply some extra solder to make them thicker so the sections will mate more tightly.

Never overlook a poor vehicle ground as a problem source either. I've had cases where a mobile unit worked fine on Receive, but the higher current drain on Transmit dropped so much DC voltage it couldn't function. If you consider that a solid-state transmitter will typically draw about 1.5 A or more, a dirty contact having only a few ohms of resistance could drop several volts! The grounding question can be logically answered by seeing if the radio works normally on a bench DC supply.

Replacement DC power cables are available from Radio Shack (#21-550), Dick Smith Electronics (#D-9001), and GC Electronics (#18-508) in the standard 3-pin versions. GC carries the 2-pin, coaxial, and direct cables to fit many of the older mobile models too. Gold Line also sells the standard 2-pin (#1147) and 3-pin (#1148) CB power cords.

Mikes and T/R Switching Problems

Bad mikes are a major source of problems that first appear to be internal to the radio. A Transmit keyline that doesn't change states because of a bad switch, cable, or plug will obviously cause problems in one mode only. With electronic T/R switching several things must happen at once and if the Transmit keyline doesn't ground, the radio stays in the Receive mode. Likewise if any of the associated T/R switching diodes were to short, the radio could remain stuck on Transmit all the time. (Or stuck on Receive, depending on the specific diode function.) Faulty T/R diodes can also cause some strange squeals or oscillations, because circuits which should only be powered in one mode are turned on all the time. In some circuits one main transistor switch controls several other T/R devices further downstream; if the main transistor isn't switching the other devices sure won't either.

In relay T/R circuits, one side of the relay coil normally grounds on Transmit. If you don't hear a click or see the contacts move, first assume it's a mike problem. You should measure about 13 VDC on both sides of the relay coil on Receive; if one side shows no voltage, measure the coil for DC continuity, which is typically 150-300Ω. Relay coils do go bad occasionally. You can also check the relay by jumpering a 13.8 VDC source to the hot side of its coil while pushing the mike button; if the coil and mike wiring are both good, the relay will energize. Mikes can be easily checked for continuity and T/R switching with an ohmmeter.

AC/DC Base Problems

In base radios the AC supply is often the problem, with the radio working normally on DC power. This is the first thing to check with the "Dead Radio" symptom. Assuming it works normally on DC, the problem will usually be found in the rectifier, filter capacitors, or regulator transistor/IC. The active devices are the most likely failures. If shorted, they blow the fuse. If open, the fuse will be OK but there's no output voltage. In full-wave bridge circuits using discrete diodes, all four diodes should be replaced when a shorted one is found; the excess current usually weakens the others, which may fail too at just the wrong time!

An electrolytic filter capacitor that's shorted or leaky can burn out the bridge and blow fuses too. When voltage arcs across the dielectric, it carbonizes and creates a low resistance path which allows heavy current to flow. In such cases the shorted bridge is easily found but

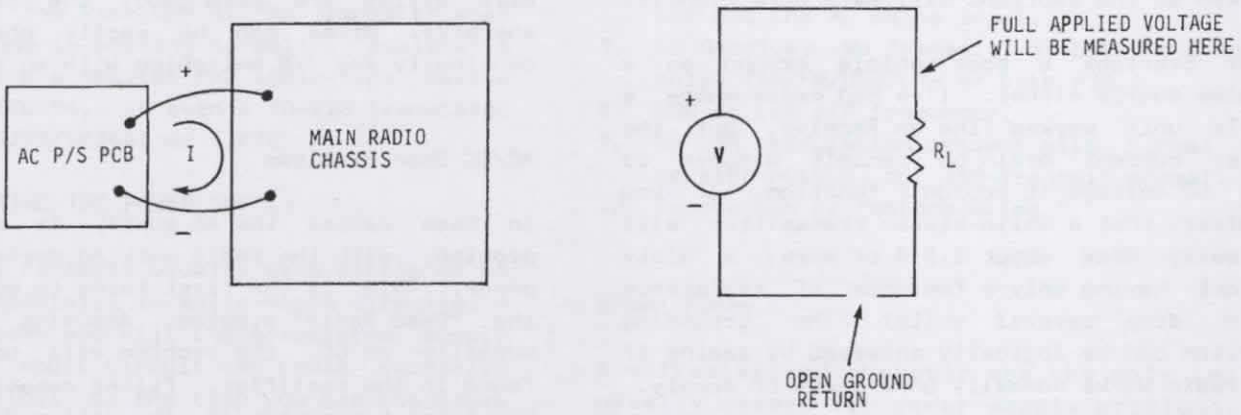
the shunt capacitor(s) that caused it isn't so obvious, so always check them too.

Large capacitors of 0.1 µF or more can be checked for leakage with an ohmmeter, and will produce a needle kick when first touched with the test leads. One capacitor lead must be removed from the circuit first, which in the case of PC types means wicking off the solder from one pad and wiggling the lead to break its connection to the foil. Use a high scale like xlK. A good electrolytic will initially read a low resistance, gradually rising to 100KΩ or more as it charges. If the ohmmeter leads are reversed, it normally reads a different value. The old tube radios often used paper dielectric capacitors in high-voltage locations; these should read 10MΩ or more after a few seconds.

Power transformers occasionally fail. Turns may short together if the insulation breaks down, causing a heavy primary current flow regardless of which side had the breakdown. The fuse will likely blow and there may also be smoke and/or the smell of burning tar. Isolate the secondary from its load and if the transformer continues to smoke, replace it. In older tube models having a center-tapped secondary, shorted secondary turns or an open center-tap return cause reduced voltage, because the circuit functions more like a half-wave than a full-wave supply. An open diode in a voltage doubler would also cut the output voltage in half.

An open ground return wire between the AC power supply board and the main PC board will cause the radio to remain dead, but all branch circuits will read 13.8 VDC. Figure 7-16 shows how this can happen. The AC-to-DC board is always tied to the main radio PC board by both [+] and [-] wires to complete the DC loop. If one side of the radio load (R_L) is open a voltmeter will read the full applied voltage, since there's no load to pull it down. Check these wires and the applicable foil traces for potential open circuits.

FIGURE 7-16
EFFECT OF OPEN GROUND BETWEEN AC POWER SUPPLY & MAIN CHASSIS



Hum Problems

Hum or "motorboating" is caused by bad filter capacitors. In the simpler radios with shared audio power circuits, hum may show up on both the received signals and the transmitted audio. This problem is much more common to AC-powered base units and all tube radios in general. Electrolytic filter capacitors dry out with age, and given the age of most tube radios and the heat they radiate, it's almost guaranteed. Electrolytics can also fail when a radio has been sitting around unused for a couple of years. Bridging a new electrolytic across a suspicious one will quickly answer this question. Tube CBs are still extremely popular and common among American radio oldtimers.

The Branch Power Circuits

A radio which lights up but is otherwise dead will be found to have one or more (or all) of its branch voltage supplies missing, assuming the synthesizer itself is running. For example,

suppose the meter lights work but the LED channel display is dead. The display is usually driven from a regulated branch source, but the metering lights are powered directly from the 13.8 VDC input before any branch circuits, so they wouldn't be affected. Think logically!

In simple regulation circuits without current limiting, an emitter-to-collector short in the series-pass transistor would supply the full unregulated input voltage to the load. This can be disastrous, since it may zap transistors and ICs all over the place! Likewise, an open Zener reference on the series-pass transistor will heavily forward-bias the transistor, possibly burning it out and causing load damage too.

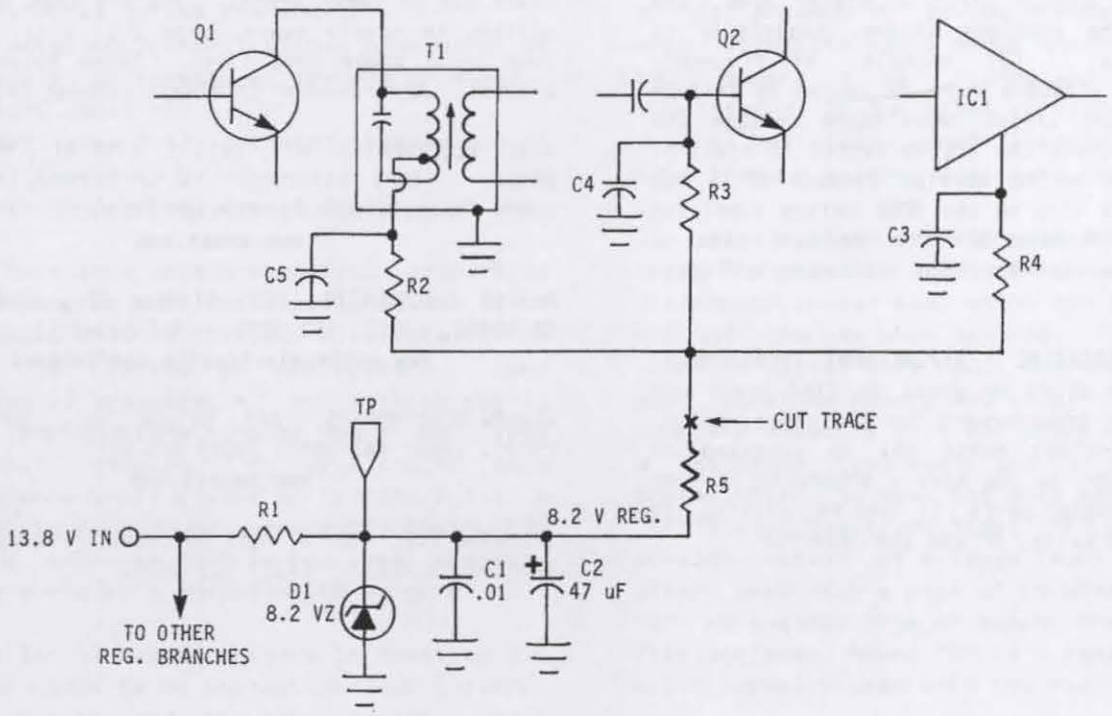
IC voltage regulators have very high gain and can oscillate when not properly filtered. Normally the input and output pins are heavily decoupled, and these electrolytic and/or disc capacitors should always be checked whenever an IC regulator fails. A common failure with the MB3756 Uniden regulator is caused by improper Clarifier modifications: when attempting to increase varactor control voltage, the series resistance is often jumped out at the Clarifier pot's cold end; this leaves nothing to limit the current when the Clarifier is turned to its minimum resistance knob position.

Isolating Source vs. Load Problems

Sometimes a short in the load circuit causes the same symptoms as a short in the power supply itself. To determine which is faulty, they must be isolated from each other. This may be as easy as unsoldering one lead somewhere, but often it's more complicated because the source voltage is powering several circuits. Figure 7-17 shows one troubleshooting approach you can easily use in such cases.

Q1, Q2, and IC1 are all being powered from a Zener-regulated 8.2 VDC source. Suppose the voltage on this bus (TP) is way low, only a few volts. Excessive current draw somewhere must be pulling it down. The components shunted across this supply bus are C1-C5, Q1, Q2, and IC1, any one of which could cause the problem if shorted or leaky. If an active device were shorted but had enough series resistance connected to it, there probably wouldn't be anything as obvious as a blown fuse. Once the current divides down

FIGURE 7-17
PROBLEM ISOLATION IN BRANCH CIRCUITS



into the various branch circuits, the failure is often more subtle, and results from an abnormally low voltage instead of an outright short.

By disconnecting the Zener circuit from the three active devices, you'd know immediately in which half the problem lies. In this particular example, you could isolate each half by lifting one end of R2, R3, and R4. (Assume R5 isn't present.) If the voltage at TP doesn't rise to normal, the problem can only be D1, C1, or C2. I'd start with the electrolytic and the Zener, since ceramic disc capacitors don't seem to fail nearly as often. Apply the same logic if the Zener had been replaced by a series-pass transistor of similar ratings.

Assume the voltage rises to normal after disconnecting the three loads. This means one or more of the three branch circuits is the problem. But which one? Replace each component lead one at a time, until the problem reoccurs; you'll then know which specific load circuit is the cause and must be investigated further. There's very often some series resistance (R5) between the Zener and the load, in which case you'd then only have to lift R5 instead of three individual load resistors.

In this example isolation was relatively easy. But sometimes a regulated branch feeds so many different circuits all over the radio that it's easier to cut the main PC trace that separates the source from the load (Point "X"), instead of unsoldering numerous parts. Just don't forget to bridge your cut with a bare jumper wire again once the problem is fixed!

The further the branch circuits divide down, the more specific the problems become, especially in multimode radios. For example, off-frequency operation on one sideband might be caused by failure to switch in some offset capacitance because the voltage that controls the active switch is missing. Or maybe there's no FM Receive because of a bad contact or broken wire on the MODE switch supplying voltage to the FM detector IC. In each case, a logical and systematic approach will quickly locate the problem area.

SERVICING TIP: LOCATING A REPLACEMENT TRANSFORMER. Many people have asked me where to find power and audio replacement transformers for the older radios. Although the original parts may be unmarked or unreadable, as long as you have a schematic you can still find suitable parts if you're willing to write, make phone calls, or use the Internet.

You really don't need an exact replacement if the voltage winding tap(s) and current ratings (for power types) and input/output impedances (for audio types) are somewhere close in value. And you may need to physically remount the new transformer on the chassis, usually by just drilling one new hole in the chassis to match the replacement to the new mounting bracket hole spacing.

So, where to find a replacement transformer these days? You can start by checking the two antique radio parts sources on Page 25. If you strike out, then contact the manufacturers or distributors on this page. The best-known American manufacturers of old CB power and audio transformers from the tube era are all still actively in business:

STANCOR PRODUCTS, Arizona: (602) 275-3800.
www.stancor.com

THORDARSON-MEISSNER INC.
11969 Hwy. 1, Mt. Carmel IL 62863. (618) 262-5121. (800) 712-3000. The link below has a huge list of distributors to find the one closest to you:
www.thordarsonmagnetics.com/contacts.php

TRIAD MAGNETICS, 22520-B Temescal Canyon Rd., Corona CA 92883. (951) 277-0757.
www.triadmagnetics.com

They probably won't sell to you directly, but they will give you the name(s) of their distributors. It might even be faster to go directly to a major electronics parts distributor like those listed in Chapter 1. Most of those guys will always carry at least one of these brands. The big ones have sales offices in nearly every large U.S. city, so check your local phone book first. Shown below are the biggest. And remember to always request catalogs!

AVNET ELECTRONICS INC., 2211 S. 47th St., Phoenix AZ 85034. (480) 643-2000. U.S. offices in nearly every state, plus many foreign offices.
www.avnet.com

MASTER ELECTRONICS, 1301 Olympic Bl., Santa Monica CA 90404. (310) 452-1229. (All brands.)
www.masterelectronics.com/contact

NEWARK ELECTRONICS, 217 Wilcox Av., Gaffney SC 29341. (864) 487-1900, (800) 463-9275.
www.newark.com

STERLING ELECTRONICS, 4201 Southwest Freeway, Houston TX 77027. (713) 623-6600.

8 ANTENNAS & TRANSMISSION LINES

Until now we've talked only about the internal generation and reception of CB signals. Those circuits would be useless without some way to transfer the 27 MHz intelligence reliably from one radio to another. So a third and equally important link in the communications chain is the antenna system. Since it's shared by Transmit and Receive, its efficiency and quality affects both modes.

CB operators are generally more concerned with range than with anything else, and since all (legal) CBs have the same transmitter power, it's the antenna system that really determines range. This means the antenna itself, the coax transmission line, and their connectors. In my experience, each of the three system components contributes about equally to antenna problems.

Symptoms of antenna problems include:

1. Poor transmitter and receiver range.
2. No Receive or Transmit.
3. Intermittent Receive or Transmit.
4. Burned out Final and/or Driver RF power amp transistor(s) in the transmitter.
5. S/RF meter on Transmit either pegs hard at full scale, or remains at low end of scale.
6. AWI light comes on.
7. High SWR (over 3:1) indicated, regardless of channel frequency being used.
8. Transmit RF feedback squeal due to high SWR.

Antennas have some unique electrical properties and this chapter must necessarily review some very general antenna theory, with details on specific CB systems as appropriate. Some duplication is unavoidable, but I think you'll find my explanations simpler and a lot less mathematical. However I do urge you to read the reference books listed in CHAPTER 1 for a more complete background. You must thoroughly understand antennas before you can properly analyze a customer's installation or problem.

There's a lot of bad CB antenna information out there that needs to be corrected! Your customer expects honest and accurate advice about specific hardware, as well as the ability to fix his problems. Since antennas will involve maybe half of all CB repairs (and arguments), no professional could limit himself just to inside bench work. Your competition won't!

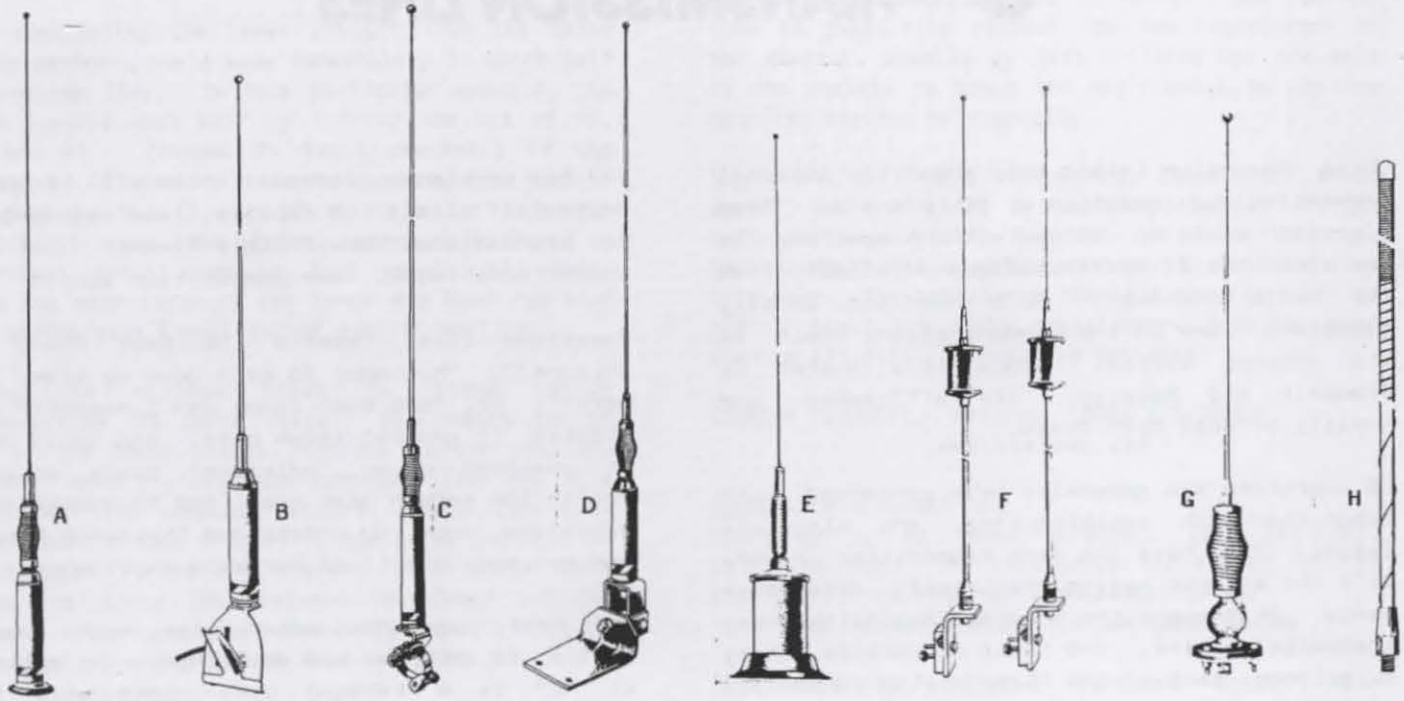
Questions like, "What's the best brand of antenna?", "How many dB gain does my brand XYZ have?", or, "How much range can I expect?" are treated in general terms here, and could only be answered on an individual basis anyway. You're the person best qualified to answer such questions, once you understand the basic theory and get some practical hardware experience.

The next page shows some of the most common mobile CB antennas and mountings. The antenna at "A" is a standard base-loaded whip for mounting in a 3/8" hole on a rooftop. At "B" is a clip-on spring type for temporary mounting on a vehicle's rain gutter. "C" shows a hatchback mount. "D" mounts on the flat top of a camper shell. Antenna "E" is a trunk lid mount and also uses the larger "Big Momma" type loading coil. Oversize center loading coils are also used in the dual mirror-mount "trucker" whips of "F." Antenna "G" is the standard 102" steel whip with its heavy shock spring and swivel ball mount; a 96" fiberglass whip can be substituted for the steel version. At "H" is a typical helically-loaded fiberglass whip; these come in many colors, and sizes from 3' to 7'.

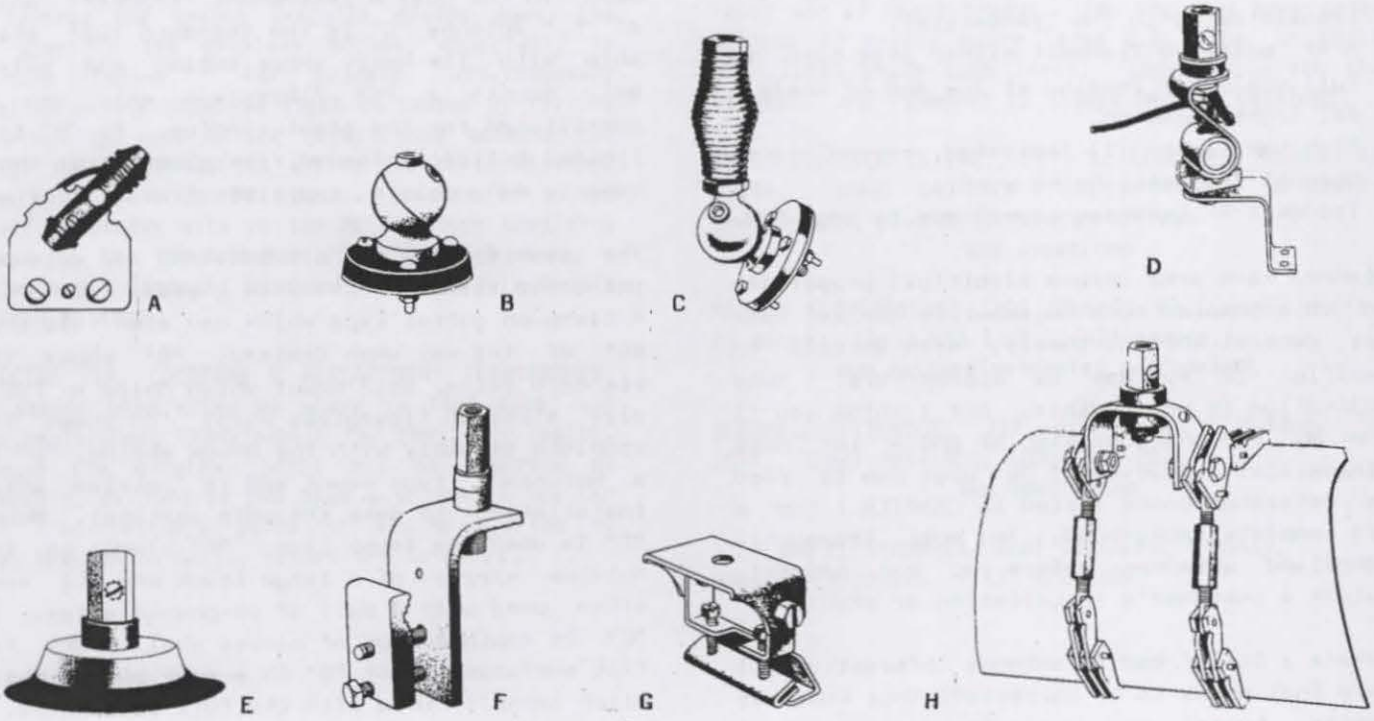
The mounts shown are all intended for antennas using the standard 3/8" x 24 threads. At "A" is a clamp-on gutter type which can also fold over out of the way when desired. "B" shows the standard swivel ball mount which holds a full-size steel or fiberglass whip; "C" shows the complete assembly with the shock spring. "D" is a hatchback type mount and is rotated after installation to make the whip vertical. Mount "E" is used for trunk lids. "F" clamps on the outside mirror of a large truck and is most often used with a pair of co-phased whips. At "G" is another type of camper shell mount for flat surfaces. Mount "H" is a rear bumper chain hitch normally used with the full-size whips.

Almost any desired choice of mount and whip can

MOBILE CB ANTENNAS
(Courtesy Antenna Specialists Co.)



ANTENNA MOUNTS FOR 3/8" X 24 THREADS
(Courtesy Antenna Specialists Co.)



be combined for mobile CB use. For example, whips of "A" and "E" are often combined with a magnetic base for temporary use on a rooftop or a trunk lid. Many brands use standard mounting hardware such that one manufacturer's whip can be fitted to another's mount if so desired. But a few manufacturers like Hustler and K-40 use their own unique mounting hardware, which isn't compatible with other brands.

CHARACTERISTICS OF RADIO WAVES AT 27 MHz

Why Antennas Radiate

An antenna is a tuned circuit of inductance and capacitance, just like any other LC circuit. When connected to an RF voltage source, it oscillates. The differences between antennas and internal tuned radio circuits result from their physical sizes. Ordinary LC circuits are so small relative to their wavelength that most of the energy is used up within the circuit, but a good antenna radiates most of its energy into space. This radiation is the radio "wave."

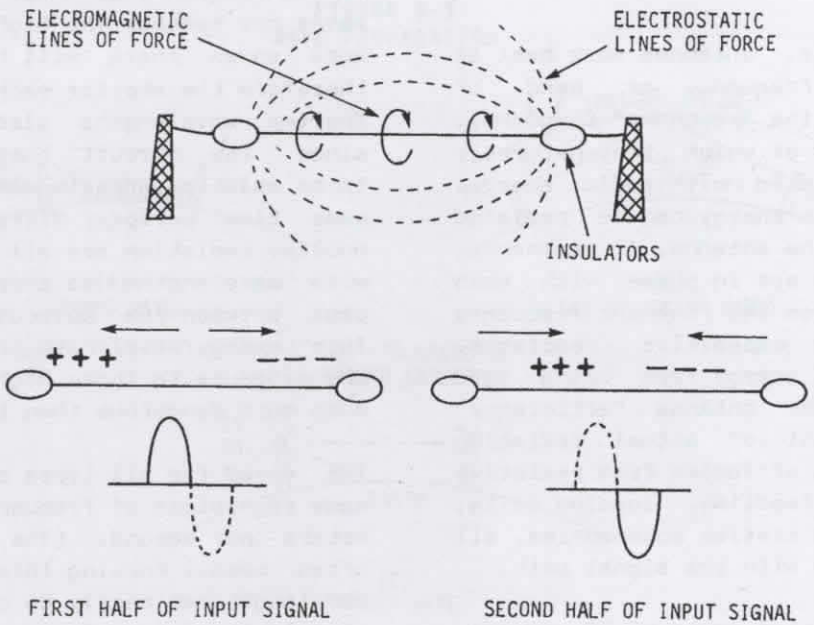
Figure 8-1 illustrates why this happens. When a signal is applied, free electrons are forced to one end and build up a strong negative charge. This leaves the opposite wire end missing its electrons, which results in a strong positive charge. Electrostatic and electromagnetic lines of force are thus generated, which are oriented perpendicular to each other.

With nothing to maintain the charges on the ends they start moving back towards each other, and the magnetic field begins to collapse back into the wire. This collapse drives the excess electrons towards the end that was formerly positive. But then another RF wave comes along. If the antenna is long enough, some electrons won't be able to reach the end and reverse themselves before the driving signal changes again. These electrons are permanently lost as radiation of electrostatic fields into space, and thus a transmitting antenna is created. If such waves should strike another electrical conductor a current of the exact same frequency is induced in it, creating a receiving antenna.

Effect Of Antenna Size On Reception

Although the qualities which make antennas radiate and receive electrostatic fields are basically reciprocal, there's a large practical difference between them. Assuming no losses, virtually all of a transmitter antenna's RF energy is radiated, regardless of its physical size. When receiving though, the antenna can only pick up energy from the incoming wavefront

FIGURE 8-1
ELECTRICAL FIELDS GENERATED IN THE ANTENNA



in a radius within about a 1/4-wavelength from each side of the conductor, meaning 1/4 + 1/4 = about 1/2-wavelength total. All electromagnetic radiation obeys the "Inverse Square Law," which means its strength fades as the square of the distance from the source. For example, if you were to triple the receiving distance from the transmitter antenna, the field strength will be reduced not by 1/3, but by $[1/3]^2$, or 1/9.

Now a 1/2-wavelength 27 MHz CB antenna is about 17' long. But up at say, 470 MHz (which is U.S. UHF-TV Channel 14), a 1/2-wave antenna is only about 1' long. They're equally efficient when transmitting. Using the Inverse Square Law and equal transmitter power, the CB antenna (being 17 times longer) will capture about $[17]^2 = 289$ times more RF energy than the 470 MHz antenna! Therefore the higher the frequency, the less energy received. This disadvantage can often be compensated by the fact that at those higher frequencies, it becomes physically practical to build very high-gain beam antennas.

But antenna gain still isn't anywhere close to the total gain resulting from all the receiver amplifier stages. A top-of-the-line CB beam antenna might have a maximum of 10-15 dB power gain. A typical CB receiver has about 130 dB total gain from antenna to speaker. When combined with the effect of the Inverse Square Law, this explains why you can often hear local stations that are much further away than your ability to transmit to them.

Effect Of Resonance

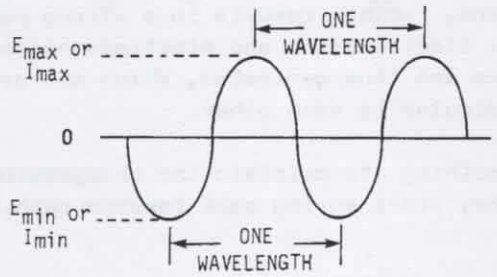
Like all tuned circuits, antennas work best at only one specific frequency or band of frequencies, known as the "resonant" frequency. This is the frequency at which they naturally oscillate when stimulated with radio energy, and where the maximum energy can be radiated from or induced into the antenna. At resonance, all antenna currents are in phase with each other. Moving away from the resonant frequency creates inductive or capacitive reactance, which prevents the RF energy from being used most efficiently. The antenna "efficiency" refers to the amount of actual radiation compared to the amount of losses from resistive heating in the coax feedline, loading coils, connectors, or various station accessories, all of which are in series with the signal path.

With the low transmitter power of CB radios, reactive antennas are extremely undesirable. To maximize efficiency, the antenna must be tuned or made resonant at the desired frequency. In practice this means adjusting its physical length relative to the electrical or RF wavelength. The process of making CB antennas resonant is commonly called "matching" or "SWR matching," or simply "tuning."

Frequency & Wavelength Basics

Since radio waves are sine waves, they have peaks ("maxima") and valleys ("minima"). The frequency of a radio wave ("wavelength") is the number of voltage (or current) maxima and minima per second. A wavelength is the distance from any point on one wave to the same point on the next wave. This is shown in Figure 8-2 by the familiar sine wave.

FIGURE 8-2
DEFINING THE WAVELENGTH



At CB frequencies, there are 27 million such waves per second. The higher the frequency, the more waves there will be in one second and therefore the shorter each wavelength must be. Shorter wavelengths also have more energy, since the circuit that produced them had to be able to generate many more of them in the same time period. Microwaves, X-Rays, and nuclear radiation are all forms of radio energy with wavelengths so short they can literally pass between the molecules of human tissues. This energy/wavelength principle also explains why exposure to those higher frequencies can be much more dangerous than the lower frequencies.

The speed for all types of radio waves is the same regardless of frequency, about 300,000,000 meters per second. (The metric system is most often used.) Knowing this speed, the actual wavelength can easily be calculated. Since CB signals occur in a frequency range of millions of cycles per second or MHz, the wavelength

formula is conveniently simplified to:

$$\text{wavelength in meters} = \frac{300}{\text{freq.(MHz)}}$$

At 27 MHz, one wavelength is about 300 ÷ 27 = 11.11 meters, or 36.44 feet. (A meter is equal to 3.28'.) This is the wavelength in air, but will actually be about 5% shorter when passing through a more dense medium like the steel, copper, or aluminum used in CB antennas. So the practical wavelength is about 95% of 36.44', or 34.62'. A simplified formula which accounts for this difference in speed and simultaneously converts the measurement to feet is:

$$\text{practical wavelength in feet} = \frac{936}{\text{freq.(MHz)}}$$

Using this formula, one CB wavelength is about 34.67 feet, which is close enough to the above figure for a practical antenna design.

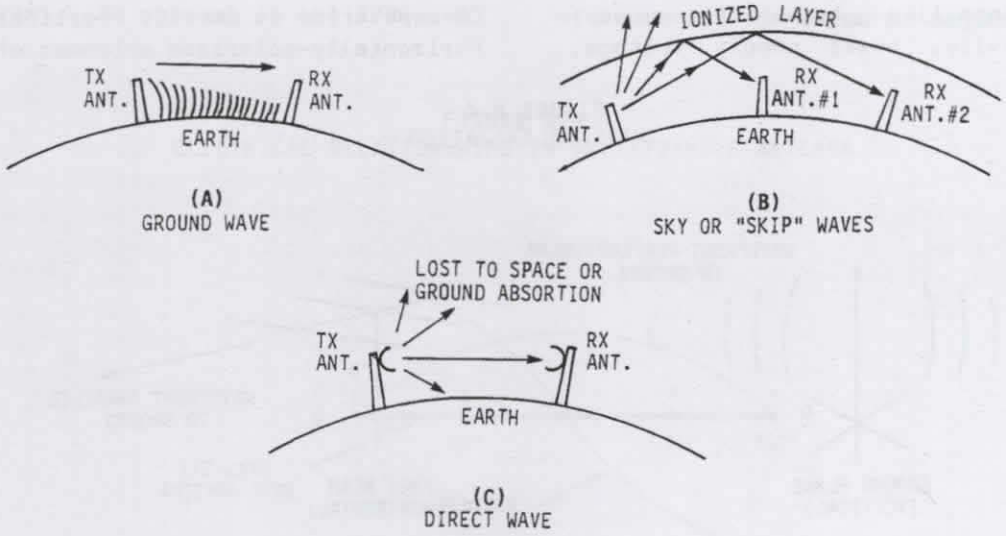
Wave Propagation

Radio waves can be categorized according to how they "propagate" or travel outward from the antenna. See Figure 8-3. "Ground" waves move only along the earth's surface, following the contour of the ground. They'll actually travel about 10% beyond the distance to the horizon due to atmospheric bending. "Sky" waves travel upward into the earth's atmosphere and may be reflected back to the earth under the right conditions, sometimes thousands of miles away. (This is the familiar "skip" or "DX," meaning distance.) "Line-of-sight" or "direct" waves are somewhere in between, unable to move along the ground or to be reflected back from the earth's atmosphere. Which wave form dominates will depend mainly on the operating frequency.

The sky wave reflection is caused by ionized particles in the earth's atmosphere, which form layers at various heights above ground. When sky waves are reflected, they're received only where they return to earth. The area in between is a dead zone completely skipped over by the signal. Figure 8-3B shows two outgoing waves at different angles from the transmitting antenna. The reflection angles and therefore the skip distances are different. Any location besides RX ANT #1 or RX ANT #2 (and beyond ground wave range) can't receive the transmission. This explains why very often only one station in a shortwave conversation can be heard; a third-party listener may be just the right distance to receive one station, but inside the skip zone of the other station. Sky waves can also often be reflected more than once, making communications possible over great distances. For example, Amateur operators in the western U.S. can easily work Japanese Hams using multihop skip; salt water makes an excellent reflector of radio waves.

As the frequency increases, ground waves are absorbed more and more until they disappear completely. This explains why you might hear a commercial AM broadcast station at say, 630 KHz

FIGURE 8-3
WAVE PROPAGATION



perhaps 150 miles away, but a station with equal power on 1570 KHz may fade out beyond just 30 miles. The fact that distant broadcast stations skip in at night is coincidental and due only to sky wave propagation. At the other extreme are some very low frequency (10 KHz!), high-power military transmitters that are able to communicate with submarines anywhere in the world using only ground waves.

Line-of-sight wave propagation is chosen for commercial VHF, UHF, satellite and microwave use, where the small physical wavelength makes highly directional antennas practical. Skip is basically nonexistent. The "shortwave" or HF bands (3-30 MHz) were intended for skip type propagation, since these broadcasters primarily want distant coverage. The end use determines the frequency, and therefore the choice of ground wave vs. direct wave vs. sky wave. Antenna designs can favor any particular type.

The 27 MHz CB band is a shortwave band. Ground waves don't propagate well and when combined with the low (legal) CB transmitter power, communications are limited to just a few miles. Sky waves do propagate very well, which explains why CB is more of a hobby than a serious local business service as originally intended. Many CB operators prefer "shooting skip" (DX) to local communications, which seems only natural. (The FCC may disagree though!)

Predicting how radio waves will behave is a science in itself, and is affected by many factors like antenna height, time of day, time of year, the 11-year sunspot cycle, terrain, temperature, operating frequency, and ground conductivity. Range depends upon all these factors plus things like transmitter power, receiver sensitivity, power supply voltage, losses in cables and connectors, and ambient background noise or interference. That's why there are no definite rules about CB range!

The effective range of all radio waves is directly related to the efficiency of the antenna system. Maintaining high efficiency is a large part of the CB technician's job.

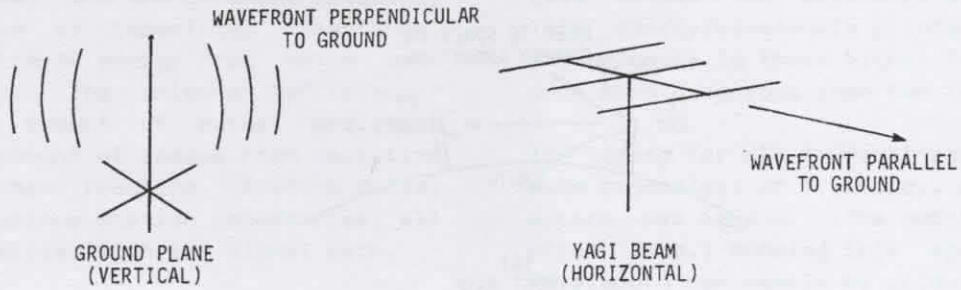
Wave Polarization

The angle of the electrostatic wave relative to the earth is called "polarization." Antennas parallel to the ground radiate horizontally-polarized waves, and those perpendicular to the ground radiate vertically-polarized waves. See Figure 8-4. (Polarization shouldn't be confused with directivity, discussed later.) For best efficiency, the transmitting and receiving antennas usually have the same polarization. Attenuation from cross-polarization can exceed 20 dB at 27 MHz, and some CB base antennas are purposely designed with switchable or "dual-polarization" to take advantage of this. Home satellite TV uses line-of-sight propagation and depends upon cross-polarization, where adjacent transponder channels use opposite polarizations to reduce the adjacent-channel interference.

Another possibility is circular polarization, where rotating radio waves leave the antenna at every polarization angle. It's commonly used in FM and TV broadcasting because of the need to reach homes with horizontal Yagi antennas, cars with vertical whips, and "rabbit ears" with everything in between. This can be further broken down into left-hand rotation and right-hand rotation to control the cross-attenuation.

CB operation is usually vertically-polarized; horizontally-polarized antennas of the required

FIGURE 8-4
WAVE POLARIZATION



length are physically harder to support and not very practical, especially for mobile use. (In CB jargon horizontal polarization is called the "flat side.") A major disadvantage of vertical polarization is its tendency to pick up more ignition noise in mobile operation. Otherwise there's no reason why two stations wanting to communicate on a regular basis can't both use horizontal polarization. For skip propagation polarization doesn't matter, because the waves will bend in many directions when bouncing off the earth's atmosphere to the point where the original polarization changes anyway. That's why you can "shoot skip" regardless of what type of polarization is being used at each end.

ELECTRICAL RELATIONSHIPS IN THE 1/2-WAVE ANTENNA

The "1/2-wavelength" antenna is the simplest LC circuit that will resonate at a given frequency. It's the basis for all CB antenna designs. That's because it's the shortest length of wire or tubing that will allow an electrostatic charge to travel from one end to the other and back again in the time of one RF cycle. Since the charge goes down the wire, turns around and comes back in one cycle or wave, it has actually travelled the wire twice. Therefore the wire needs to be only half this length for one full wave to travel down and back. While this assumes the energy is fed into one end, in practice it's usually fed at the center with the same results. From the earlier formula, this means a 1/2-wavelength at 27 MHz is slightly over 17' long.

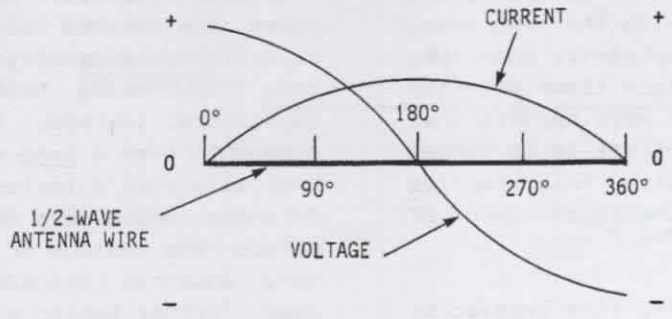
Figure 8-5 illustrates the voltage and current distribution in such an antenna when the RF energy is applied at the exact center. Since electrons accumulate at the ends, they always have the highest RF voltage. And as these electrons try to move towards the oppositely-charged end, the greatest number of them pass through the center, which therefore has the highest RF current. So current in the 1/2-wave antenna is always maximum at the center, and voltage is always maximum at the ends.

The maximum voltage/current points are called the "loops" and the minimum points are called the "nodes." Since by Ohm's Law R = E ÷ I, the lowest impedance point must be the current loop, and the highest impedance is the voltage loop. Most CB antennas are "current fed," or fed at the (low-impedance) center in the case of a 1/2-wave antenna. This is needed to match the low impedance of the transmitter output.

The voltage and current curves resemble the familiar sine wave, which is exactly what they are. If you could put an RF ammeter into the wire at many points, the measured current distribution would confirm this. As the length increases past a 1/2-wavelength, the curves simply repeat at regular 1/2-wave intervals.

The figure shows that at any point where the voltage is increasing, current is decreasing, and vice-versa. So the "phase" or timing of either component has a specific relationship to the other. It's common to describe the phasing of antennas in terms of degrees, where 360°

FIGURE 8-5
ELECTRICAL RELATIONSHIPS IN THE 1/2-WAVE ANTENNA



represents one wavelength. This means 180° is a 1/2-wavelength, 90° a 1/4-wavelength, etc. In this example the voltage and current both go from maximum to minimum every 1/2-wavelength or 180°, but not at the same time; the peaks are shifted out of phase with each other by 90°.

Figure 8-5 also represents "standing waves" of voltage and current, because they appear to be standing still when the antenna is exactly resonant at the frequency of the applied energy. A good analogy is a rope tied to a tree at one end; as you swing the other end up and down at precisely the right speed, it forms a sine wave that appears to stand still. If you change the swinging speed slightly, the wave begins to move away from its previous position. This principle is extremely important: standing waves are required on antennas for efficient radiation, but are very undesirable when they occur on the coax cable transmission line.

Reactance & Antenna Tuning

Unlike the simpler DC circuits, an alternating voltage is only in phase with its current when flowing into a pure resistance. This happens only when the circuit is resonant and has no reactance. But at radio frequencies it's very difficult to have purely resistive loads, because reactance increases with frequency.

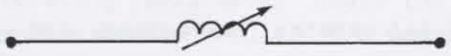
"Reactance" in its simplest terms means the reaction or opposition to any change in current (inductive reactance) or voltage (capacitive reactance) in an AC circuit. This makes sense when you consider that capacitors will tend to maintain a constant voltage, while inductors will tend to maintain a constant current.

Reactance will cause the voltage/current timing relationship to shift away from its normal 90° phase difference, producing standing waves on the transmission line. This is like changing the speed of the swinging rope in the earlier example; occasionally a wave will arrive at the starting point out of sync with the next wave, dampening the second wave's intensity when they meet. Thus there will be certain times when the voltage/current phase in one wave opposes that of the next wave; the net effect is to cancel part of the energy completely. This implies that reactive loads can't absorb as much RF energy as resistive loads.

Since reactance is undesirable, it's removed by making the antenna electrically resonant at the operating frequency; this length is exactly a 1/2-wavelength. That's why you match a mobile CB antenna by making the whip rod shorter or longer; you're tuning out the reactance. At resonance, inductive and capacitive reactances are equal in amplitude but opposite in phase, exactly cancelling each other out.

Now refer to Figure 8-6. If the antenna is too short, is has too little inductive reactance and too much capacitive reactance. More inductive reactance is needed. This can be increased by putting a "loading coil" in series with the wire. The coil adds inductance to make the antenna electrically longer, even though it's physically too short. Loading is the most common tuning method for mobile CB antennas, which are usually much shorter physically than electrically. The loading coil may be placed anywhere along the antenna, like the base or center with steel whips. When a wire antenna is wound around a fiberglass support rod, the loading is continuous through its entire length and usually concentrated at the top.

FIGURE 8-6
CONTROLLING RESONANCE OF ANTENNAS



ADDING INDUCTANCE LENGTHENS ANT.

ADDING CAPACITANCE SHORTENS ANT.

TUNABLE OVER BAND OF FREQS.

If the antenna is too long, it has too much inductive reactance and needs more capacitive reactance instead. Adding series capacitance makes the antenna electrically shorter. The capacitance is usually added at the base or the top. By using both adjustable coils and capacitors instead, the antenna can be made resonant over a band of frequencies. (This is basically what's inside a good antenna tuner.) Antennas which are 50Ω and non-reactive will absorb the maximum RF power. But in practice many antennas have additional reactances and need further tuning with loading coils or rod length adjustments.

A 17' CB antenna is obviously only practical for a base installation, and loading is rarely used there. But for mobile operation a loading coil is almost always used. There's not much chance of a mobile CB antenna being too long, so you won't see tuning with capacitance except what's present in the rod length itself.

Effect Of Impedance

"Impedance" refers to an AC load having both resistance and reactance, which means the load depends upon the frequency. In the special case where capacitive and inductive reactances are equal (i.e., at resonance), they cancel each other and the impedance is equal to the pure resistance. For maximum energy transfer from radio to antenna, both impedances must match. To the degree they don't, energy will be reflected back to the transmitter instead of coupling to the antenna and radiating.

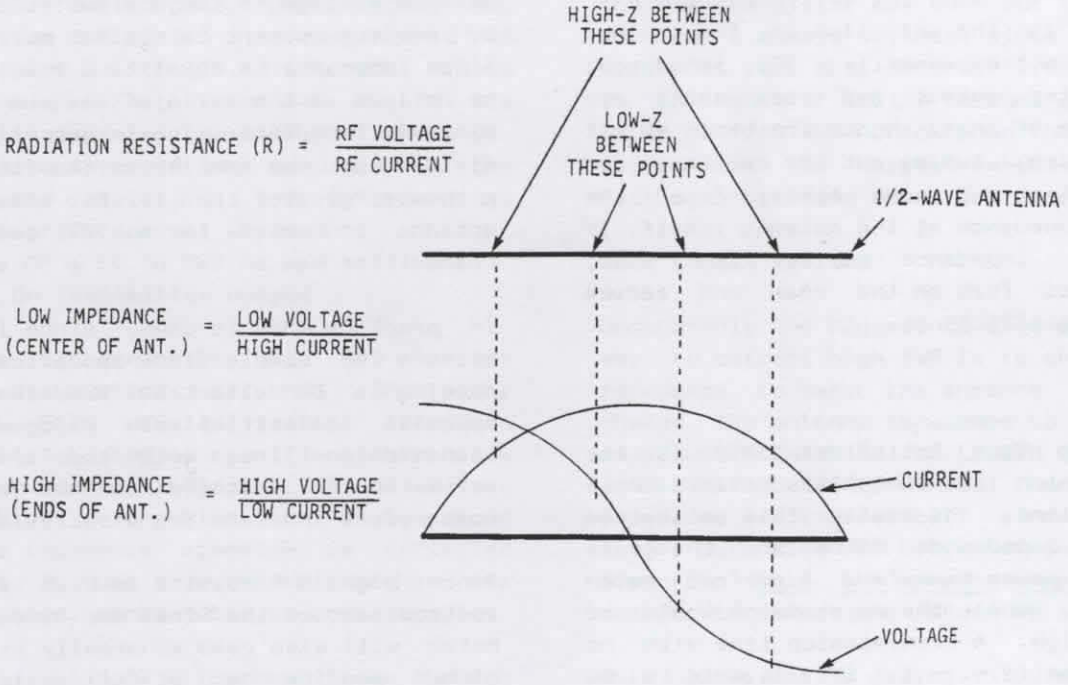
Since impedance is a complex value composed partly of reactance, which in turn depends upon frequency, changing that reactance changes the impedance. CB operation is 27 MHz by design, so you can't change the operating frequency to match a particular antenna impedance. The coax also has a fixed impedance value. Therefore you can only change the antenna impedance to match the other impedances.

All CB radios are designed with a 50Ω output impedance at the antenna socket. For maximum power transfer the impedance connected there must also be 50 ohms. The antenna is usually connected to the radio by 50Ω "coaxial" cable, which is two parallel conductors sharing a common axis; i.e., they're concentric. (A few special cases use 75Ω coax.) Coax impedance is determined by the size of the conductors, their spacing, and the dielectric insulating material between them. Since the cable has the same impedance as the radio, this means maximum transmitter power can be coupled to the radio end of the cable. Whether maximum power can be coupled from the far end of the cable into the antenna is another question entirely!

Radiation Resistance

The "50Ω" antenna impedance figure is a bit misleading. Obviously if the antenna is resonant, there's no reactance and the impedance is equal to the DC resistance alone. But the actual DC resistance in a few feet of

FIGURE 8-7
RADIATION RESISTANCE (IMPEDANCE) ALONG 1/2-WAVE ANTENNA



copper wire or aluminum tubing is typically less than 1Ω. So where do they get 50 ohms?

The 50Ω value is a special one called the "radiation resistance." This is the resistance which, when substituted for the antenna, absorbs the same amount of power as that which actually disappears by radiation. Thus antenna impedance and radiation resistance mean the same thing, if there's no reactance.

The actual ohmic value of radiation resistance is only important when small enough to approach the DC resistance value, since this would mean heat losses are becoming a larger part of the total power consumption compared to the power consumed in useful radiation. If the radiation resistance is at least ten times higher than the DC resistance, there's not much to worry about. Factors which might lower this ratio include close proximity to the ground, or loading coils made of long, thin wire. These conditions sometimes occur in mobile CB antennas. With a value around 50 ohms, the antenna remains very efficient.

Since the voltage/current loops and nodes on a 1/2-wave antenna occur at different points, the radiation resistance (R) is also different between any two points. This is confirmed by Ohm's Law, $R = E \div I$. The radiation resistance could also be defined as the ratio of RF voltage at any point on the antenna to the RF current at that point. Knowing this, Figure 8-7 shows how the radiation resistance or impedance is lowest at the center and highest at the ends, with intermediate values in between. At some point between the exact center and one end the impedance approaches 50 ohms, which just happens to be what's needed for CB antennas.

STANDING WAVE RATIO (SWR)

To absorb (and therefore radiate) the maximum RF energy, the antenna must present a load into which maximum RF current flows for a given transmitter power. The higher the antenna current, the further the radiation. Maximum current flows when the driving source impedance (the transmitter) equals the load impedance (the antenna). Under these conditions there are no standing waves on the transmission line.

The antenna is the only link in the signal chain that's not necessarily a 50Ω impedance; the transmitter output and coax cable are designed to be 50 ohms. Hence the basic object of SWR matching: tuning out the reactance so the transmitter and coax cable "see" the correct 50Ω impedance at the antenna itself. If the antenna impedance varies from this, standing waves form on the coax and reduce power coupling efficiency.

SWR Defined

The "Standing Wave Ratio" or "SWR" is the degree to which standing waves exist on a transmission line. The smaller this ratio, the closer the impedances match and the more efficient the power transfer. A perfect match would be 1:1, while the worst match would be infinitely high. A transmission line with no standing waves (i.e., 1:1 SWR) is said to be "flat." SWR is measured by an SWR Meter or Reflectometer, or by a directional RF wattmeter like the Bird 43. Unfortunately it's the interpretation of SWR that causes so much argument among CB operators and inexperienced technicians! A lot of time, energy, and money is wasted chasing the "perfect match," which isn't even necessary. Such a match is generally only important beyond VHF, because transmission line losses increase with frequency.

SWR is defined more precisely as the maximum antenna voltage to the minimum voltage (VSWR), or maximum current to minimum current (ISWR). Since impedance is equal to $E \div I$, SWR can also be defined as the ratio of maximum impedance to minimum impedance. The larger value is always divided by the smaller so the ratio will be a number greater than 1. For example, a 75Ω antenna connected to a 50Ω coax line and transmitter has an SWR of $75 \div 50 = 1.5{:}1$.

In practice VSWR is used, since it's easy to measure by simple diode rectification of RF driving a DC voltmeter. When two diodes of opposite polarities are bridged across a transmission line, both the forward and the reflected RF voltages can be measured and compared to indicate SWR directly on the meter.

Since high SWR results in high reflected RF voltages around the Final amp circuit, the S/RF Meter will also read abnormally high or low, either pegging hard at full scale or barely moving from the low end. The specific needle direction depends on the relative phases of the forward and reflected voltages when they

combine at the S/RF metering circuit. If in phase, the reflected voltage adds to the normal RF voltage to make the meter read higher than normal. If out of phase, the voltages will subtract and the meter reads lower. Most S/RF meters read higher with high SWR, and this is often the first symptom of an antenna problem.

Power Loss Percentage

The heart of the SWR argument concerns the power loss in a mismatch. Most operators wrongly believe that anything worse than 1:1 is something to worry about, when nothing could be further from the truth. Let's prove it!

The ratio of voltage (or current) reaching the antenna to that reflected back down the coax is called the "coefficient of reflection" or "k." This is calculated by,

$$k = \frac{SWR - 1}{SWR + 1}$$

Using the earlier example of a 75Ω antenna with a 50Ω transmitter, the k factor is $(1.5 - 1) \div (1.5 + 1) = 0.2$. Since power is proportional to I^2 or V^2, this means the reflected power is k^2, in this case $0.2 \times 0.2 = 0.04$. So only 4% of the power is reflected, which means 96% is delivered to the antenna! An SWR of 1.5:1 is therefore not even significant. Most SWR meters display the reflected power percentages, and that's why an SWR of 1.5:1 corresponds to 4% reflected power, 2:1 to 11%, 3:1 to 25%, 4:1 to 36%, and so on. Furthermore SWR meters are notoriously inaccurate, especially at the ends. (All DC voltmeters are most accurate in the center of the scale.) So low SWR readings aren't necessarily correct anyway.

SWR Effects On Transmitter Output

The biggest concern with high SWR is the potential destruction of the RF power transistors. This usually results from an antenna that's shorted or open. In either case SWR is theoretically infinite. The RF Driver sometimes blows along with the Final, since part of the impedance mismatch is reflected back to it. In tube rigs SWR mismatches are better tolerated, since tubes are more rugged.

With a short, the full RF current flows through the Final transistor, since there's no load to absorb the power. With opens, the reflected RF voltage may be high enough when combined with the DC supply to exceed the maximum safe V_{ceo} breakdown rating, typically about 18-25 VDC for most common Japanese and Motorola RF power transistors. Remember, high antenna impedance develops high RF voltage, while low impedance develops a high RF current. The high reflected voltage can also cause an RF feedback squeal, especially when combined with a linear amp.

To emphasize the effects of high RF voltage, I remember when I worked at KPOL in Los Angeles, which was 50,000 watts, AM directional. The towers had base impedances of about 600 ohms. Touching a tower ball insulator with the wood handle of a shovel would shoot a flaming arc about 2 feet! The RF voltage was tremendous. In that particular case, it didn't mean the SWR was high. The towers happened to be fed at voltage loops with suitable matching networks, since that was the station's FCC-approved antenna system. And AM broadcast transmitters run on tubes, which are high-impedance devices. With CBs using transistors, the antenna must present a low-impedance load to minimize RF voltages. This implies current feed instead.

Most Finals blow due to the SWR extremes caused by an outright open or short, and rarely from conditions in between. For example, the MRF477 Final in the Uniden Jackson is rated at a 30:1 maximum SWR tolerance! When you replace a bad Final, always suspect the antenna; check it or the new transistor may burn out too. Obviously you can't always do this, since the radio may arrive at your shop in a different vehicle. Get in the habit of asking antenna questions. And offer a free SWR check when the customer can return with the correct vehicle. Methods for testing shorts and opens are described later.

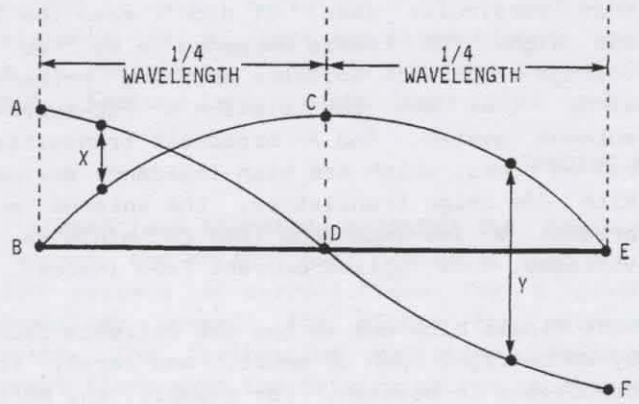
Coax Length vs. SWR

Undoubtedly the biggest CB argument! The only way to correct high SWR is to change the coax impedance to match the antenna impedance, or change the antenna impedance to match the coax impedance. **CHANGING THE LENGTH OF THE COAX HAS ABSOLUTELY NO EFFECT ON SWR!** Changing the coax impedance isn't practical, since that would no longer match the 50Ω output of the transmitter. Therefore only the antenna impedance can be changed to affect the SWR in CB installations.

This can be easily proven. You must understand it to eliminate customer resistance to the truth! Figure 8-8 repeats the previous 1/2-wave voltage/current graph. Only now assume it

represents a 1/2-wavelength of mismatched coax instead of the antenna. Standing waves of voltage and current now appear on the cable. At the two ends current is minimum and voltage maximum, so both ends (A-B and E-F) have the same impedance. (Recall that impedance or radiation resistance is simply E ÷ I or I ÷ E.) Since the pattern repeats itself regularly every 1/2-wavelength, this coax length is an "impedance repeater;" the SWR measured at one end will be the same at the other end.

FIGURE 8-8
SWR ALONG A 1/2-WAVE TRANSMISSION LINE



At the center (C-D), current is maximum and voltage minimum, making the impedance different than at the ends. Compare the center to the ends, which are a 1/4-wavelength away. The voltage/current relationships are inverted; if voltage is decreasing towards the center it's increasing towards either end, and vice-versa for the current. A 1/4-wavelength is therefore an "impedance inverter;" at this spacing center and end impedances oppose each other instead of being the same.

An SWR Meter at the center and either end would measure totally different values because of these different impedances. In fact measuring at many places along the coax (like points "X" and "Y") would give many unique readings. If standing waves weren't there in the first place (which they wouldn't be if the antenna had an impedance of 50Ω), all measurements would be the same. That's where they got the term "flat" line. Coax length changes the <u>apparent</u> SWR when standing waves are present, but not the fact that the antenna is what's causing them!

The cure for suspicious SWR readings is to measure at the antenna itself where practical. Base antennas use standard coax sockets but mobiles don't, so this isn't always possible. Use a 1/2-wavelength of coax or its multiple (2/2, 3/2, 4/2, 5/2, etc.) instead. Such a length repeats whatever impedance actually exists at the antenna, while a 1/4-wavelength feedline inverts it.

Coax Characteristics

The coax length important for SWR measurements is the electrical length, not the physical length. The electrical length will always be shorter than the free space length, since electricity slows down in any material having resistance. This "Velocity Factor" shortens the physical coax length and must be considered. The Velocity Factor is the degree to which the signal slows down when compared to air, and is determined by the type and thickness of the conductors and the dielectric material. These same characteristics also affect signal loss and the coax impedance itself. The chart below lists the most important characteristics of CB

COAX TYPE & DIELECTRIC*	IMPEDANCE	VEL.%	ATTENUATION PER 100 FT. AT 27 MHz	POWER RATING AT 27 MHz (SWR = 1.0)
RG58/U PE	53.5 ohms	66	2.5 dB	550 watts
RG58/U CPE	50 ohms	79	2.2 dB	550 watts
RG59/U PE	73 ohms	66	2.1 dB	720 watts
RG59/U CPE	75 ohms	79	1.6 dB	720 watts
RG8A/U PE	52 ohms	66	1.2 dB	1720 watts
RG8/U CPE	50 ohms	80	0.9 dB	1720 watts
RG213/U PE	50 ohms	66	1.2 dB	1720 watts
RG8/X CPE	52 ohms	78	1.2 dB	- - - - -

*PE = Polyethylene, CPE = Cellular Polyethylene ("FOAM")

coax. (Incidentally, the "RG" cable prefix is an old military term meaning "Radio Grade.")

The chart shows the Velocity Factor as a percentage of the free space wavelength. Note it's slower in standard polyethylene dielectric (PE) cables than foam dielectric cables. This seems reasonable, because foam cable also has less initial signal loss due to its lower resistance; RF can travel further through foam cable in the same time period. Also note the heavier the cable, the more power it can handle due to larger physical conductors. Power ratings and attenuation depend on frequency, always getting worse with increasing frequency.

Assuming a Velocity Factor of 0.66 for standard cables, this means the electrical length of the cable must be 66% of the computed free space wavelength. So the 1/2-wavelength formula for standard coax is,

$$\text{1/2-wavelength (in feet)} = \frac{468}{\text{freq.(MHz)}} \times 0.66$$

Therefore a 1/2-wavelength of coax at 27 MHz is about 11.44'. A 1/4-wavelength is about 5.72'. In practice 12' and 6' are close enough. For accurate SWR readings in a base antenna, use a multiple of 12'. (Assuming standard coax; for foam types, calculate using the higher Velocity Factor.) Prepackaged mobile antennas usually come with 17' of RG58/U coax to reach from the trunk to the dashboard. This amount is almost 3/4-wavelength, which means it's a potential impedance inverter and may give false readings if the SWR is already high. (An odd multiple of a 1/4-wavelength is the same electrically as one 1/4-wavelength.)

To prove this fact to yourself or to a stubborn customer, make the test cable set-up shown in Figure 8-9. By paralleling two 50Ω dummy loads with a "T" connector, you've made a 25Ω non-reactive impedance. The SWR Meter when placed as shown should read 50 ÷ 25 = 2:1 SWR. You'll find that it does read this with 12' (1/2-wavelength) of coax, but reads something quite different with the 6' (1/4-wavelength) cable! This should end the argument...

Effect of Antenna Tuners & Other Accessories

Antenna Tuners are in-line devices which help reduce SWR by cancelling antenna reactance. Examples are the GC Electronics #18-716 and Gold Line #1046 or #1086. It's important to understand how these work, how to use them, and what to realistically expect from them. In Figure 8-10A, such a tuner is shown installed at the radio end of a 3:1 SWR (i.e., 25% loss) mismatched antenna. When adjusted to 50 ohms, the tuner allows the full 4 watts of RF power to be coupled to the coax. The problem is that the antenna is not resonant and therefore the 3:1 SWR still exists at the antenna end of the coax! All you've done is fooled the transmitter into thinking it sees the correct load. The losses are still there. And as shown, only 1.5 watts is actually available to be radiated. Maximum power can't be coupled from the far end of the cable into a mismatched antenna.

Nothing you can do at the transmitter end of the coax has the slightest effect on antenna SWR. The correct tuner location would be as shown in Figure 8-10B, at the antenna itself. The tuner then becomes part of the antenna and reflects the correct impedance all the way back

FIGURE 8-9
TESTING COAX LENGTH VS. SWR MEASUREMENT IN A REACTIVE LOAD

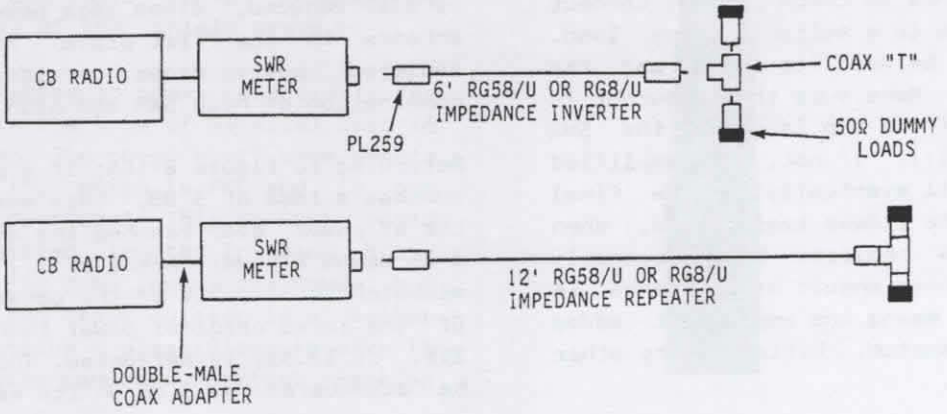
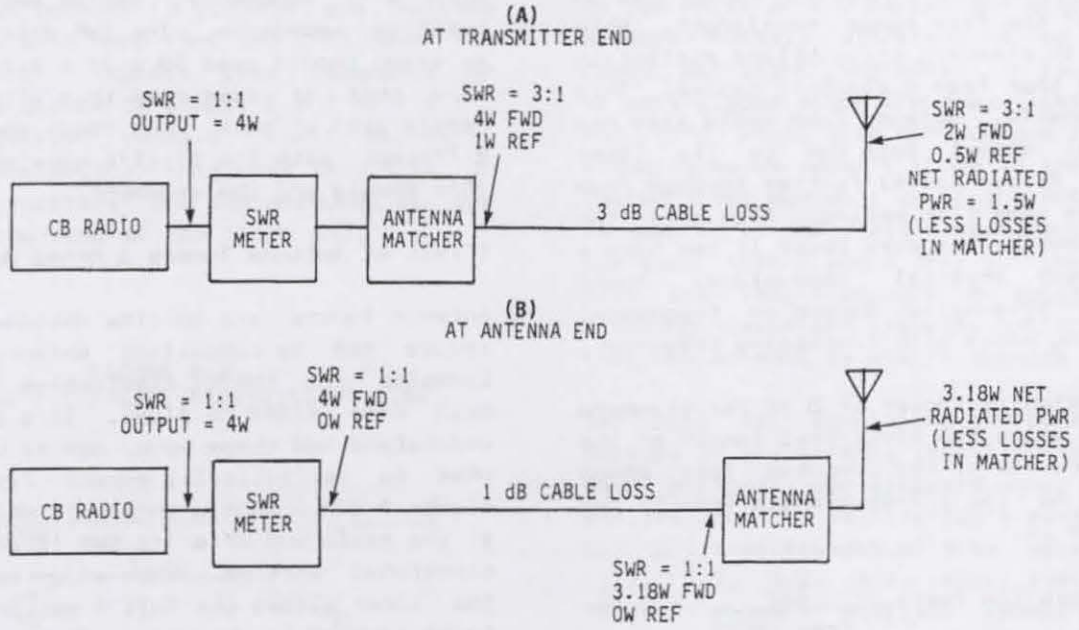


FIGURE 8-10
EFFECT OF ANTENNA "MATCHER" & COAX LOSS ON RADIATED POWER



to the transmitter. Except for the coax loss and a tiny insertion loss from the matcher, most of the original 4 watts is radiated.

This brings up another important point: the correct placement of an SWR Meter is always before other any in-line accessories like a tuner, low-pass filter, coax switch, frequency counter, or linear amp. It then shows the combined effect on impedance from such accessories being added in series. (Assuming the antenna itself was correctly matched.)

Many RF Finals blow by using linear amps with high input SWR. The input SWR can be affected by a mismatched antenna or the wrong amount of RF drive power from the radio. (See CHAPTER 5.) Figure 8-11 shows how to check this. Connect the linear's output to a suitable dummy load, and the SWR meter between its input and the transmitter output. Make sure the CB output is exactly 4 watts. If the amp is good, the SWR should be close to 1:1. If not, the amplified reflected power will eventually fry the Final transistor and/or the linear transistors. When the dummy load is replaced by a properly matched antenna there should be no change in the reading, which means the amp hasn't added any significant mismatch. Ditto for any other in-line accessories.

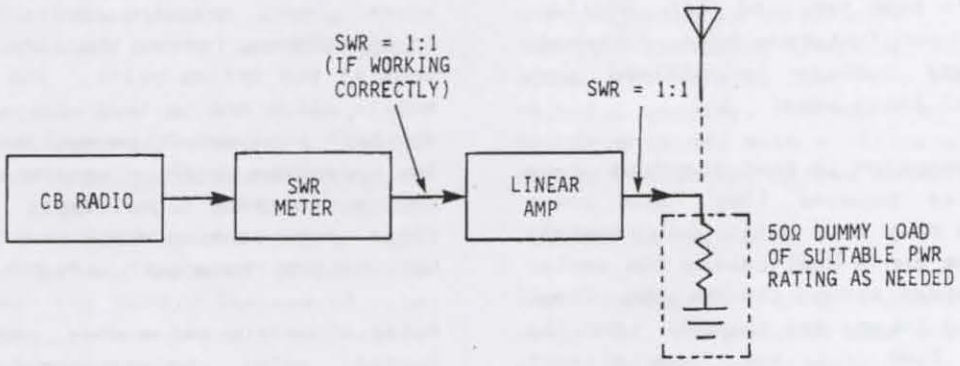
Coax Losses vs. SWR Losses

High SWR increases cable losses, which are normally about 2 dB per 100' for RG58 types and 1 dB per 100' for RG8 types at 30 MHz. In small mismatches, the additional SWR losses aren't enough to worry about. For example, at 2:1 SWR the additional loss is only about 0.5 dB even on very long runs. This is an undetectable change at the receiving end. From a practical standpoint, this means a 2:1 SWR is just as good as the mythical "perfect" match.

On the other hand, coax that's already lossy can cause misleading SWR readings at the transmitter end, which is where most people measure it. This is because the reflected power is also reduced, since less power reaches the antenna in the first place. And the actual radiated power drops considerably with a combination of high SWR and high cable loss.

Returning to Figure 8-10A, if a particular coax run has a loss of 3 dB, this means only 50% of the RF power ever reaches the antenna. (Since 3 dB means a power factor of 2.) If the antenna mismatch is 3:1, 25% of the power is reflected. Of the total original power then, 50% of that 25%, or 12.5%, is reflected. This in turn will be attenuated by 3 dB on its way back to the

FIGURE 8-11
TESTING INPUT/OUTPUT IMPEDANCES OF LINEAR AMPLIFIER



transmitter end of the cable, so only 50% of the 12.5%, or 6.25% of the original transmitted power ever returns completely. At such a small level, the SWR at the transmitter end would measure about 1.7:1, even though it's really 3:1 at the antenna end! Not only are the readings misleading, but as shown there's a large difference in the actual radiated power between the top and bottom sketches.

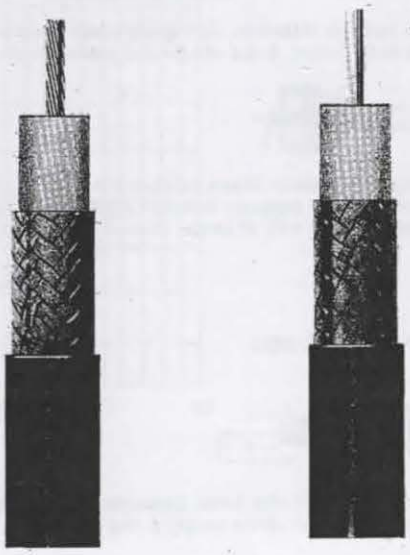
Some Practical Coax Tips

Coax losses are minimized by using quality coax and connectors, and by waterproofing all connections. The coax should specify at least 95% shield braid coverage. Examples: Alpha 9058, Belden 8259 or 8219 for RG58/U, Belden 8241 or 9259 for RG59/U, Belden 8261 or 9212 for RG11A/U, Alpha 9008/9008A, Belden 9251, 8214, Columbia C1198 for RG8/U, and Alpha 9213 or Belden 8267 for RG213/U. (Also the Amphenol equivalents.) RG58 comes with solid or stranded center conductors, electrically the same; use your own preference. You can always tell the good stuff by the density of the braid; the dielectric can't be seen through the braid. Figure 8-12 shows some examples of good coax having stranded and solid center conductors; note the tightness of the shield weave.

A major quality factor in coax, especially for base antennas, is the type of material used in the outer covering. The cheap stuff uses what's known as "Type I", which is PVC and is <u>not</u> suitable for outdoor use! This is what you'd find in preassembled lengths in many hobby stores. It's OK for runs inside the house, but will get brittle and crack outside in a matter of months. It contains a plasticizer to make it flexible, which also causes a chemical reaction or "migration" between the outer covering and the inner dielectric. This eventually ruins the impedance as the cable breaks down. The lifespan of Type I coax cable is only two years from the time of manufacture!

To avoid these problems, insist on "Type IIA" cables, which are made to military specs. These have a "non-contaminating" plastic covering, sometimes listed in catalogs as "NCV." They're more rigid but far superior. Examples are RG213/U, RG8<u>A</u>/U, RG11<u>A</u>/U, RG58<u>C</u>/U, and RG59<u>B</u>/U. So the difference between RG8/U and RG8A/U is that one uses ordinary PVC and the other uses

FIGURE 8-12
EXAMPLES OF GOOD COAX WITH 95% SHIELD COVER



non-contaminating vinyl. The NCV types have a useful outdoor life of up to twenty years. Incidentally, RG8/U is no longer made to Mil Spec because it's been replaced with RG213/U; but many low-end manufacturers have purposely kept the military numbers to mislead you. Insist on the real thing here!

A common misconception is that the foam type cables are better because they have lower losses. This is only true until you install them outside! The sun's heat causes the center conductor to wander around inside the foam, eventually causing impedances changes. And the microscopic air bubbles in the foam attract moisture, also causing undesirable electrical changes. You're much better off with the stiffer, solid dielectric NCV cables from the start. RG213/U is my overall choice for base antennas; it's popular with cable TV companies and many professionals for 50Ω applications. The retail price is only about $0.30 per foot.

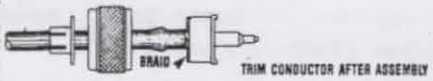
Splicing of coax should only be done with appropriate 50Ω "T" or double-female "barrel" connectors, never by direct pigtails on the wires. Hand splicing causes "impedance bumps" or mismatches, where the line is no longer 50 ohms at the splice point. The same is true for mobile slide mounts that use quick-disconnects for both coax and DC power. These not only ruin the impedance match, but the extra male/female splice increases signal loss. Better to ignore their coax section and connect directly to the back of the radio with a PL259 plug.

Water absortion ruins coax. When not properly sealed, water can soak right up the braid by capillary attraction, changing the dielectric properties and therefore the impedance. That's why some base antennas show drastic SWR changes in rainy weather. I've seen cases where water ran 20 or 30 feet into the cable from a poorly sealed connector! Don't spare the plastic electrician's tape. Or use a good silicone

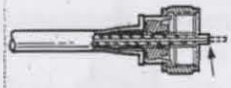
FIGURE 8-13
PROPER ASSEMBLY OF COAX PLUGS ON CABLE
(Courtesy Amphenol Div. Bunker-Ramo Inc.)

83-58FCP

1. Strip cable — *don't nick braid, dielectric or conductor.* Slide ferrule, then coupling ring on cable. Flare braid slightly by rotating conductor and dielectric in circular motion.



2. Slide body on dielectric, barb going under braid until flange is against outer jacket. Braid will fan out against body flange.



3. Slide nut over body. Grasp cable with hand and push ferrule over barb until braid is captured between ferrule and body flange. Squeeze crimp tip only of center contact with pliers; alternate-solder tip.

83-1SP PLUG (PL-259)

1. Strip cable, *don't nick braid, dielectric or conductor.* Tin exposed braid and conductor. Slide coupling ring on cable.

2. Screw body on cable. Solder braid through solder holes. Solder conductor to center contact.

3. Screw coupling ring on body.

83-1SP PLUG WITH ADAPTERS

1. Strip jacket. *Don't nick braid.* Slide coupling ring and adapter on cable. Note — use 83-168 adapter for RG-58/U and 83-185 for RG-59/U.

2. Fan braid slightly, fold back over adapter and trim to 3/8". Strip dielectric and tin exposed conductor. *Don't nick conductor.*

3. Screw body on adapter. Follow 2 and 3 under 83-1SP plug.

rubber sealant such as Radio Shack #64-2314, G.E. 361, or GC Electronics #10-150. Cheap coax gets lossy with age, so expect periodic cable replacement every few years unless the installation already uses the better NCV types.

Coax connector installation can be tricky, and often makes the difference between a system that works right and one that's intermittent or lossy. Refer to Figure 8-13 for the correct installation of the RG58/U and RG8/U type connectors. The solderless Amphenol 83-58FCP is highly recommended for RG58/U instead of the standard PL259 plug, since there's no tricky shield soldering to worry about.

Summary

I hope that I've emphasized the importance of correct SWR measurement and interpretation, and the need for quality coax cable. For mobile installations, cable losses aren't significant and the connection of SWR meters at the antenna end isn't practical. RG58 cable is perfectly acceptable and can be measured from the radio end. But if you have doubts about mobile SWR readings, add a temporary 7' coax test section in series with the 17' line from the packaged antenna. This 24' total makes a full-wavelength line, which is the same as two 1/2-wavelengths for impedance-repeating purposes.

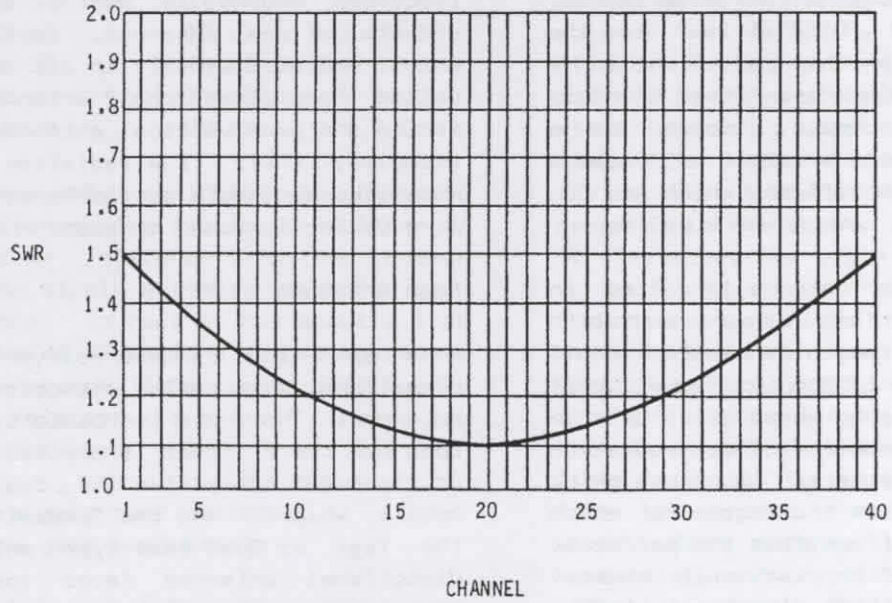
For base installations it's worth the extra effort to meter the antenna end, even though it takes two people yelling back and forth while the adjustments are made. Always use the shortest possible length of RG8A/U or RG213/U coax. For really long runs where money is no object, consider the superior RG214/U; this is double-shielded with a silver-plated shield and center conductor, priced about $1.50 per foot.

ANTENNA BANDWIDTH

The "bandwidth" of an antenna refers to the range of frequencies over which it can work with minimum reactance. Figure 8-14 shows a typical CB antenna bandwidth response as a function of SWR. The factor having the greatest effect on bandwidth is the physical size of the conductor; specifically, the ratio of length to diameter, or L ÷ D. The smaller this ratio, the more broadbanded it will be, and the higher the ratio, the more critical or narrowbanded its tuning over the desired frequency range.

This antenna characteristic corresponds exactly to the Q of ordinary LC tuned circuits, where low-Q circuits have relatively small reactance changes with frequency changes, and high-Q circuits have large reactance changes. Thus a thick antenna (like aluminum tubing) is more broadbanded than a thin steel whip or a wire

FIGURE 8-14
TYPICAL 40-CH. ANTENNA BANDWIDTH VS. SWR
(Courtesy McGraw-Hill Book Co.)



wound on a fiberglass rod. This is one reason base CB antennas are generally more broadbanded and easier to match than mobile antennas. The L/D ratio has little effect on actual radiation resistance, but a great effect on reactance.

This basic principle makes more sense when you consider it in terms of the effective Q. Using the standard formula,

$$Q = \frac{X}{R}$$

where X = reactance
R = radiation resistance,

you can see that Q increases as reactance increases, assuming a constant radiation resistance. As the antenna gets shorter and shorter relative to a 1/2-wavelength the capacitive reactance increases, which increases the Q. It must be loaded with more and more inductance to compensate and make it resonant. Thus the shorter the antenna, the more narrowbanded it becomes. For example, cutting 1" from a 102" steel whip would have little effect on SWR, but that same 1" off a typical 40" loaded whip causes a drastic SWR change.

This explains why short loaded mobile antennas are so much harder to match than full-size versions. It also explains why base-loaded whips with oversize coils (A/S "Formula 1" and A/S MR510 "Big Momma," K-40, Hustler "Super Resonator", etc.) are more broadbanded than those with standard coils on the same whip length. The standard and oversize coils may have exactly the same inductance values, but the larger coil has a lower Q; it has heavier wire and fewer turns on a larger diameter, lowering the L/D ratio. The heavier wire also has less DC resistance, so the radiation resistance remains high relative to DC resistance and heating losses are minimized.

Poor bandwidth is more of a problem now than it used to be, due to the inevitable channel expansion of most American models, and the popularity of export radios having up to 240 channels. This is especially true for mobile operation, where loaded whips are naturally more critical than full-size base antennas. For example, my President Jackson when used with a 1/2-wave Shakespeare "Big Stick" base antenna will cover about 160 of its 225 channels with a maximum 2:1 SWR, increasing rapidly beyond that. There's little you can do about this without using an antenna tuner to extend the range of reactance adjustments. Tuners may be practical for base operation, but obviously inconvenient for mobile use.

GAIN & DIRECTIVITY

Two other important properties of CB antennas are their gain and directional characteristics, both closely related. "Directivity" is the ability to concentrate the radiation in a specific direction. "Gain" or "Power Gain" is the apparent power increase compared to a standard antenna. There's a subtle difference here from the gain in amplifiers, which are DC-powered; antennas don't have power supplies.

The standard comparison antenna is called an "isotropic radiator." This is a radiation source where signal strength is exactly equal at all points equidistant from it. Visualize it as a pinpoint of RF energy whose electrostatic field forms a perfect sphere. Since radiation is exactly equal everywhere, it has no gain. Antenna gain is therefore the degree to which the actual radiation differs from the perfectly spherical radiation of an isotropic source. There can be no gain without directivity too.

Perfect antennas aren't possible, because many factors distort the radiation pattern. But the isotropic source is useful to compare the effects of real antennas. Isotropic antennas which radiate equally in all directions are called "omnidirectional" antennas. The common mobile and base vertical antennas are practical examples; their true radiation patterns look more like doughnuts or flattened balloons than like perfectly round spheres.

Beam Antennas

Antennas which radiate well only in certain directions are called directional or "beam" antennas. There are two basic types, depending upon how the RF power is applied: the "driven" or "phased" array like the dual mirror-mount mobile whips, and the "parasitic" array like the Yagi or Quad base type antenna. Because directional antennas favor specific compass directions and/or elevations (vertical angle above ground), radio waves concentrate in those directions and decrease in all others.

This apparent power increase compared to omnidirectional antennas has exactly the same effect as if it resulted from increasing the transmitter power. It has this effect on received signals too, amplifying those from the favored direction and rejecting all others. A beam's increase in signal strength over a non-directional antenna is called its "forward gain." Beams are commonly used to compensate for the low CB transmitter power limits.

Measurement of Gain

Signal strength follows the Inverse Square Law, decreasing logarithmically with distance. It's convenient to describe antenna gain in terms of decibels, which are a logarithmic function. The standard dB power factors described earlier also apply to antennas. For example, an antenna having 3 dB power gain means that its effective strength is double (x2) that of an antenna with 0 dB gain. Put another way, this means a 4-watt transmitter using a 3 dB gain antenna has the same effective signal strength as an 8-watt transmitter using a 0 dB gain antenna. The following summarizes the power multiplication factors for practical CB antennas:

dB GAIN	POWER FACTOR	dB GAIN	POWER FACTOR
1 dB =	x 1.26	11 dB =	x 12.6
2 dB =	x 1.60	12 dB =	x 15.8
3 dB =	x 2.00	13 dB =	x 20.0
4 dB =	x 2.50	14 dB =	x 25.1
5 dB =	x 3.00	15 dB =	x 31.6
6 dB =	x 4.00	16 dB =	x 40.0
7 dB =	x 5.00	17 dB =	x 50.1
8 dB =	x 6.30	18 dB =	x 63.1
9 dB =	x 8.00	19 dB =	x 80.0
10 dB =	x 10.0	20 dB =	x 100.4

Gain figures are only meaningful when compared to a known reference. The isotropic radiator is only one possible reference. Another common reference is the dipole antenna, which has gain in two directions. In fact it has about 2.1 dB gain in the favored directions when compared to an isotropic reference. It's common practice to specify gain relative to one of these two references, as follows:

dBi = gain over isotropic
dBd = gain over dipole

Thus to state that a certain antenna has a gain of "7.5 dB" is totally meaningless. Most CB operators don't know this and fall for misleading claims by manufacturers. For example, a two-element Yagi beam has a theoretical gain of about 7.5 dBi, which is the equivalent of 7.5 dB - 2.1 dB = 5.4 dBd. Not so impressive when expressed this way, is it? Manufacturers are famous for using dBi (often without telling you), since it's always a bigger number and therefore more impressive. Be aware! Demand to know their reference point.

Front-To-Back Ratio

Since directional antennas have power gain for receiving too, the relative signal strengths from the desired and undesired directions can also be compared and expressed in dB. For a beam antenna this is called its "Front-to-Back" ratio, or F/B. The "front" is the desired direction and the "back" is 180° opposite; i.e., if the front is facing East, the back is West, etc. So a "25 dB F/B" means that signals received from the East direction will be 25 dB stronger than comparable signals from the West.

Some antennas are "bidirectional," meaning stronger in two directions (say, East/West) and weaker in the two perpendicular directions. (North/South.) Practical examples are the dual co-phased trucker whips. For such antennas it's really more accurate to discuss "Front-to-Side" rather than Front-to-Back power ratios.

ANTENNA RADIATION PATTERNS & FIELD STRENGTH

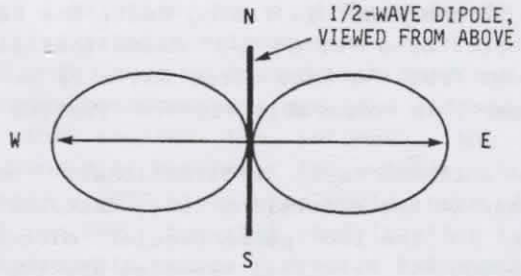
A graph showing the relative strength of radio waves as a function of direction from the antenna is called a "radiation pattern" or "field intensity pattern." All real antennas radiate in three dimensions, making it hard to visualize in a book drawing, so use some imagination here. The most important radiation fields are those in the horizontal plane or parallel to the earth, and the vertical plane or elevation, the angle above the earth.

The concept of field intensity is not the same as polarization. Most CB communications is vertically polarized, but the actual field strength varies greatly. Polarization is the orientation of the waves relative to the earth; field intensity is the total strength resulting from the entire three-dimensional field of waves. Each antenna type will have different horizontal and vertical radiation patterns affecting range. This section describes their most important directional qualities. Later we'll discuss SWR matching methods for each.

The 1/2-Wave Dipole

The basis for studying horizontal radiation is the 1/2-wave dipole. It's rarely used for CB though because it's horizontally polarized, being wire or tubing mounted parallel to the earth's surface. The pattern is bidirectional, with the strongest field at right angles to the direction of the wire. The typical "Figure 8" pattern of a 1/2-wave horizontal dipole antenna is shown in Figure 8-15. The strong directions are called the "lobes" and the weak ones the "nulls." In this example the lobes go East and West, the nulls North and South.

FIGURE 8-15
HORIZONTAL PATTERN OF 1/2-WAVE DIPOLE

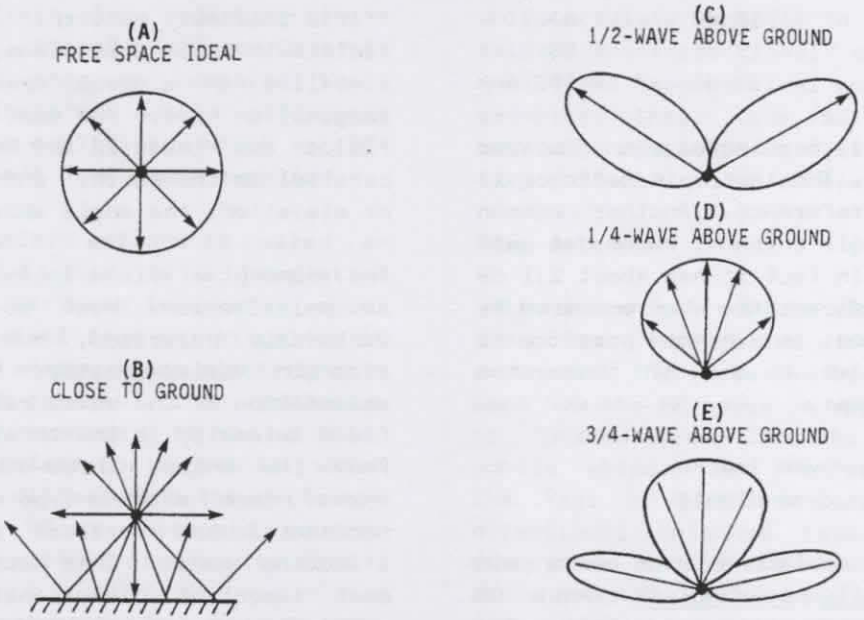


What about its vertical pattern? The dipole is radiating not only East and West, but also towards the sky and the earth, since antennas have three-dimensional fields. Therefore it also has a vertical radiation pattern to consider. This is especially true for base antennas because the height above ground has a direct effect on the vertical radiation angle of the strongest lobe(s). You can't do much about the effects of height in a mobile installation, but you can for a base antenna.

The effect of height above ground is shown in Figure 8-16. Figure 8-16A represents a 1/2-wave dipole in free space. Imagine it's a horizontal wire sticking straight up out of the page at you, which is why you see just a dot; you're looking at it from one end. Under perfect isotropic conditions the field around the wire would be exactly the same in all directions, so the pattern shown is a perfect circle.

A real antenna isn't perfect. If placed closer to the ground (Figure 8-16B), some of the downward waves will bounce off the ground and be reflected back towards the antenna. Whenever a radio wave bounces off an object, its phase reverses. In Figure 8-16C the antenna is a 1/2-wavelength above ground, which means it takes the time of one full wavelength to travel to

FIGURE 8-16
HOW VERTICAL RADIATION CHANGES
AS A FUNCTION OF HEIGHT ABOVE GROUND
(Viewed end-on)



the ground and bounce back; 1/2 + 1/2 = 1. The reflected wave reaches the antenna just as the next wave appears, but exactly out of phase with it. This cancels the upward radiation, resulting in two main lobes with the maximum strength about 30° above the horizon.

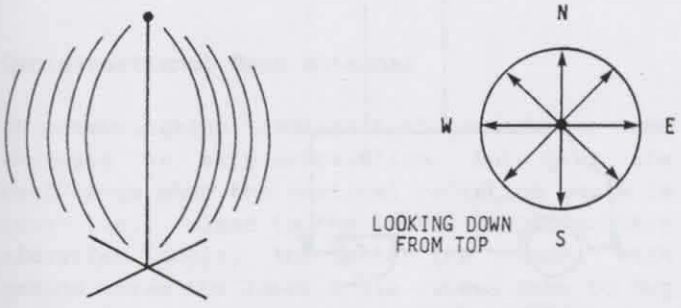
In Figure 8-16D the antenna has been lowered to a 1/4-wavelength above ground, so some of the reflected waves arrive in phase and add to the vertical radiation. The elevation angle of the strongest field is now higher above the horizon. This partly explains why mobile CBs have less ground-wave range than the higher base antennas; the higher angle of a mobile whip sees a closer horizon than that possible in a base, so the wave can't travel as far. At 3/4-wavelength above ground (Figure 8-16E), the effect is a combination of the 1/2-wave and 1/4-wave height, increasing both the horizontal and vertical lobes. As the height is raised still further more lobes develop, one for each additional 1/4-wavelength above ground.

By the way, these sketches show the lobes and nulls as being very sharply defined. In reality the imperfectly-conducting earth and shifting phases cause them to blend together somewhat. Don't take these mounting heights too literally when planning a base antenna installation.

Omnidirectional Mobile Antennas

Most mobile and base CB antennas consist of a single vertical radiating element. The horizontal radiation is equal in all compass directions, assuming there aren't any nearby objects or irregular ground conditions to distort the pattern. (In practice there always are.) Figure 8-17 shows the ideal horizontal pattern of such antennas. Note it's also a perfect circle like the ideal dipole, but this time it's rotated 90° so you're looking down on its top instead of horizontally end-on.

FIGURE 8-17
OMNIDIRECTIONAL RADIATION PATTERN
OF VERTICAL ANTENNA



In a real installation this pattern will be distorted. The worst distortion occurs in mobile operations when the whip is mounted somewhere other than the exact center of the roof; i.e., the "ground plane" is irregular. The strongest field will generally be in the direction of the greatest mass of vehicle body. With the antenna in the center of the roof the mass is roughly equal in all compass directions and this is usually the best location, although not always practical with long whips or low garages. With the whip on the trunk lid or a corner of the rear bumper, the pattern is distorted. Figure 8-18 shows this effect.

Never mount the whip on the bumper of a van or camper; the close proximity to the body not only distorts the pattern, but the coupling capacitance between the whip and vehicle body causes a serious SWR mismatch. Mount the whip up as high as possible. See Figure 8-19.

Effect Of Loading Coils On Field Strength

Loading coils are added to most mobile CB antennas to compensate for capacitive reactance; i.e., the antenna is physically shorter than the required electrical length. In addition to the whip mounting location, the location of the loading coil on the whip can have a marked effect on performance.

The larger the antenna current, the greater the field strength. Since reactance limits current flow, the only part of a loaded antenna that carries a significant current is that section before the loading coil. Thus with base loading there's very little current in the rod. With center loading there's current from the center down, and with top loading (or the full-size steel or fiberglass whip), current flows along the entire length. ("Top-loaded" fiberglass CB whips aren't truly top-loaded; the wire's concentrated at the top, but is continuously or helically wound along the entire length. This effects its current distribution.) The straight length before the coil also affects radiation resistance, being higher with center or top loading than with base loading. This makes it easier to transfer power, since from Ohm's Law $P = I^2R$, and "R" is higher with top loading.

FIGURE 8-18
RADIATION PATTERNS OF MOBILE ANTENNAS
BY MOUNTING LOCATION

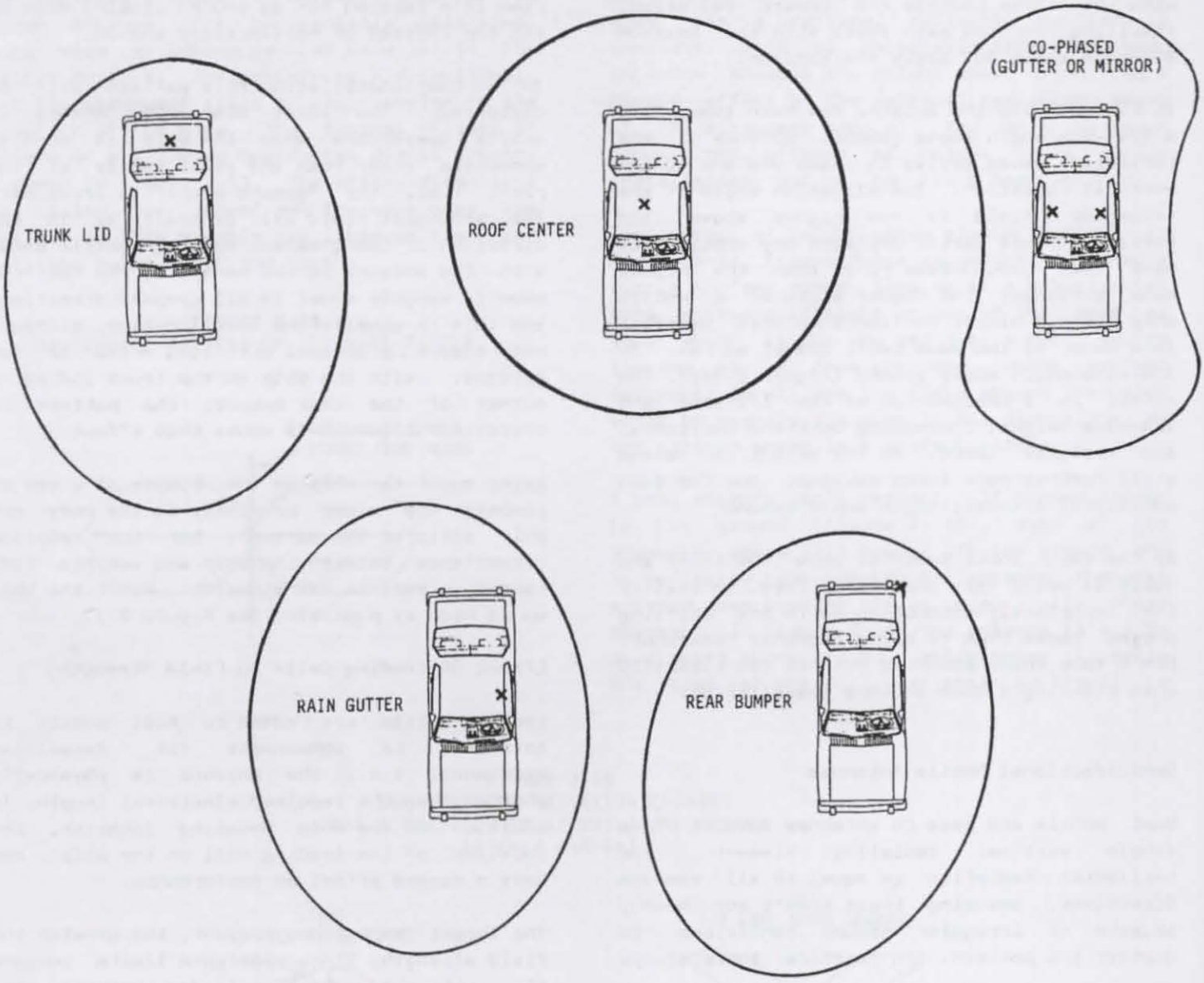
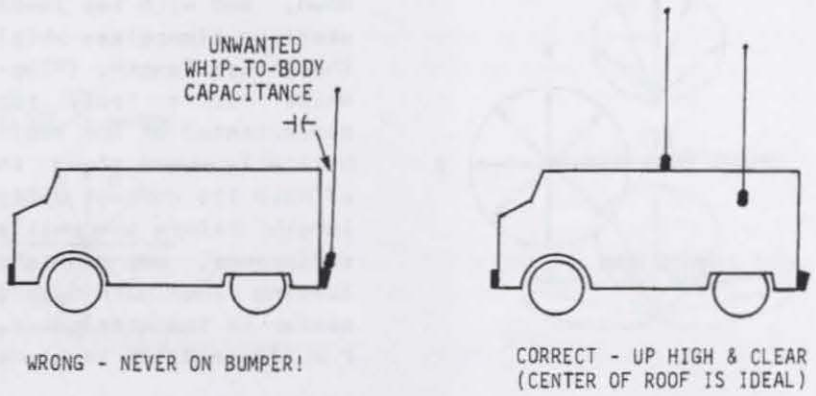


FIGURE 8-19
WHIP MOUNTING ON A VAN



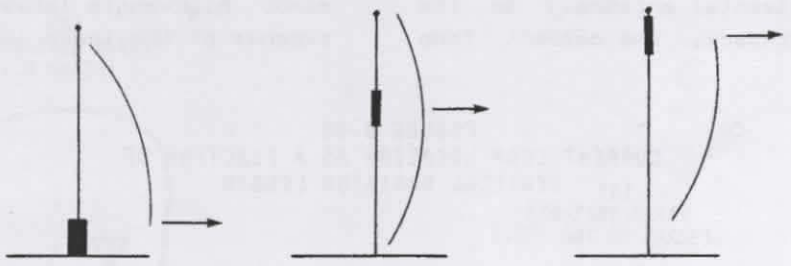
All other things being equal, top loading would have the best range of loaded whips, since the main lobe is highest above ground and therefore sees the furthest horizon. This is like seeing further from the roof of a building than from the ground floor. Figure 8-20 illustrates this effect. Of course the full-size 102" whip has the advantages of full radiation and no coil losses. But these advantages are offset by wind loading at high speeds, bending the whip away from pure vertical polarization.

Before dismissing base-loaded antennas as poor performers, consider this: in loaded whips, the capacitance of just that section above the loading coil appears across its coil. With base loading, the capacitive reactance is a function of the entire whip length. As the loading coil is raised though, the amount of whip remaining above the coil is shorter, increasing the capacitive reactance. This means more inductive reactance will be needed to resonate it, and that means a bigger coil. A bigger coil means more turns and thinner wire, increasing the DC resistance and therefore losing some of its advantage. You could always make the coil physically bigger to offset these losses, but then there's the problem of increased wind drag! Antenna Specialists makes at least one center-loaded whip model using oversize "beer can" loading coils to minimize such losses.

Selecting a good mobile antenna is therefore a compromise between available mounting location and hardware, physical size, type of loading, wind drag, looks, and of course price. For every guy who says his K-40 works best, there's another guy claiming the same for his PAL Firestik. As a general rule, I recommend mobile antennas at least 40" or longer. Any of the better brands like A/S, Francis, Hustler, K-40, PAL Firestik, and Shakespeare will meet this criterion and give excellent and comparable results. Avoid antenna "bargains" when you buy!

The cover of this book shows me adjusting a Hustler HQ-27 center-loaded whip on my car. Except for the mounting hardware, this is the very same whip that's used in the Hustler "Twin Huskies" popular with truckers. I use a bayonet type 3/8" x 24 quick-disconnect with a special two-piece hideaway mount. Unlike standard trunk lid mounts, everything shown in the picture can be removed and thrown in the trunk when not needed, leaving no exposed mounting base visible to would-be thieves. The HQ-27 is sold with many types of mounts. It's 55" long and works quite well. (For example, I've worked Alaska from Phoenix on 4 W when the skip's in!)

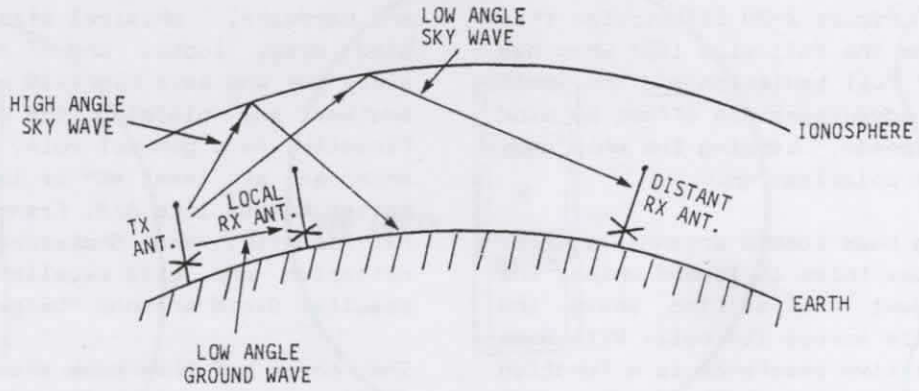
FIGURE 8-20
RF CURRENT DISTRIBUTION AS A FUNCTION
OF LOADING COIL LOCATION



Omnidirectional Base Antennas

CB communication involves both ground-wave and sky-wave or skip propagation. Both give the best range when the vertical radiation angle is low; i.e., close to the earth. The lower this elevation angle, the better the range. With ground waves the lower angle causes them to hug the ground so they cover more distance before fading out. The same is true for skip waves; but instead of hugging the ground, the wave travels further towards the horizon before striking the earth's atmosphere and bouncing back to earth. The effect of both types is shown in Figure 8-21. Note that the sky waves are reflected at the same angle they originally struck the atmosphere, which means the lower angles result in the greatest skip range.

FIGURE 8-21
EFFECT OF VERTICAL RADIATION ANGLE ON COMMUNICATIONS DISTANCE



We've seen how the location of whip loading coils affects their vertical radiation angles. Similar effects occur on vertical base antennas. The location of the current loop still depends on the radiator length, which can be controlled to change the vertical radiation angle. But losses are much smaller on base antennas, since it's physically practical to use full-size radiators with no loading needed.

Omnidirectional base antennas come in three popular heights: the 1/4-wave, the 1/2-wave, and the 5/8-wave, corresponding to about 9', 18', and 22' respectively. Figure 8-22 shows the current distribution pattern for each. ("Height" in a vertical antenna means the same as "length" in a horizontal antenna.) As the radiator height increases, the current loop moves up the antenna, always reaching a peak a 1/4-wavelength below the top.

Raising the current loop lowers the vertical radiation angle, so the 5/8-wave antenna has the lowest angle and the 1/4-wave the highest. The lower the angle, the less radiation lost towards the sky. See Figure 8-23. Visualize this in three dimensions by starting with a perfectly round balloon; squeezing it from the top spreads it out further horizontally while maintaining the same volume or "field."

Up to about 5/8-wavelength, the main lobe angle is low and theoretically has about 2 dBd gain over a 1/4-wave radiator. Beyond this height, minor high-angle lobes begin to appear at the expense of the lower lobes. Thus the 1/2-wave

FIGURE 8-22
CURRENT LOOP LOCATION AS A FUNCTION OF
VERTICAL RADIATOR LENGTH

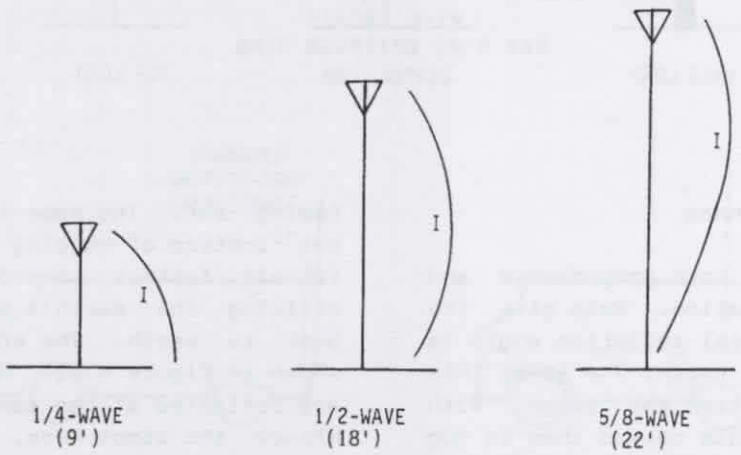
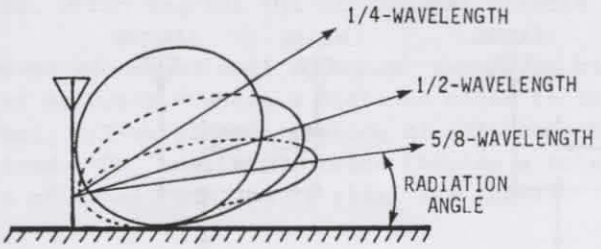


FIGURE 8-23
VERTICAL RADIATION ANGLE AS A FUNCTION OF VERTICAL ANTENNA LENGTH



and 5/8-wave antennas are the most effective omnidirectional types; 5/8-wave is the best you can do with just a single vertical element.

Since verticals are base-fed but the base isn't always the low impedance point, the 1/2-wave and 5/8-wave antennas generally need matching circuits to compensate for their higher base impedances. The 1/4-wave vertical can be fed directly by 50Ω coax with no special matching.

Directional Mobile Antennas

The most popular directional mobile antennas are the dual "trucker" mirror-mount whips. These come under the general category of driven arrays, where both whips are directly driven by the transmitter. The pattern is bidirectional like a dipole. This system was developed to solve the problem of field distortion caused by the large metal trailer, and the fact that truckers are most interested in communications up and down the road they're traveling. The field is usually strongest towards the front and back, although it's just as easy to make it perpendicular to the vehicle. Figure 8-24 shows both possible patterns.

These antennas work on the phasing principle. See Figure 8-25. If two vertical antennas are spaced a 1/2-wavelength apart and fed equal currents in phase, the radiation will be perpendicular to the line of the antennas. This is called a "broadside array" and is the usual case with truck installations. When the same whips are fed 180° out of phase, the radiation will be in line with the antennas and is known as an "end fire" array. Theoretically dual antennas have 3 dB gain over a single vertical radiator. The phasing is accomplished by controlling the whip spacing, and by feeding them with a special coax "phasing harness."

For the end-fire pattern, a 1/2-wave "phase delay" section using an extra 12' of coax could

FIGURE 8-24
HORIZONTAL RADIATION PATTERN OF CO-PHASED MOBILE WHIPS

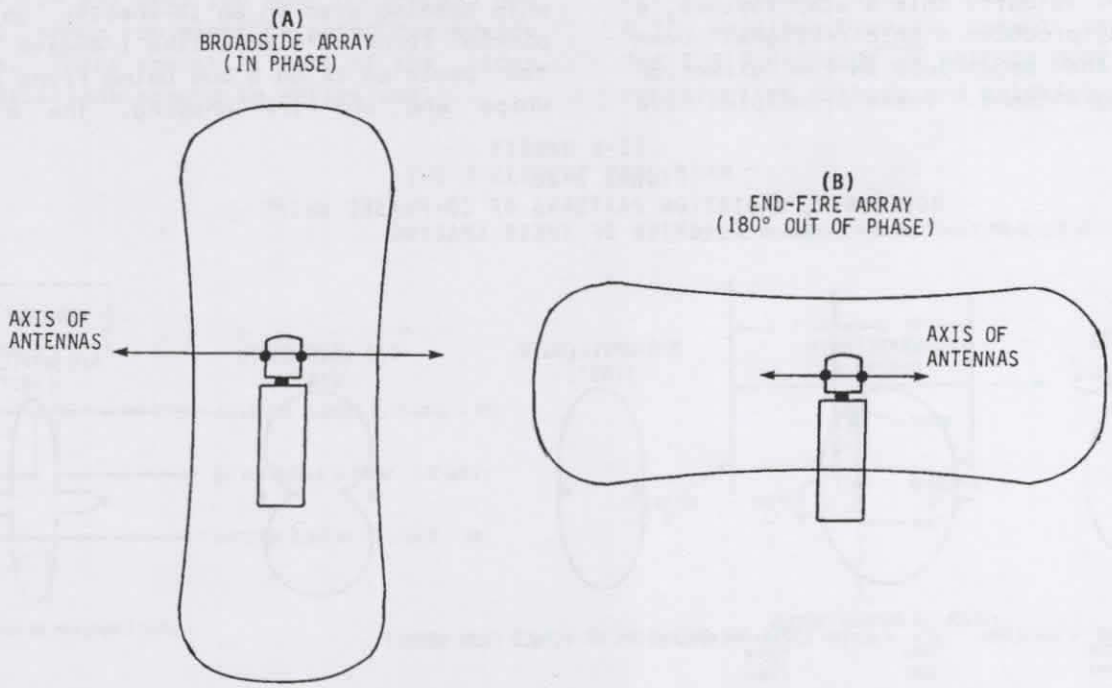
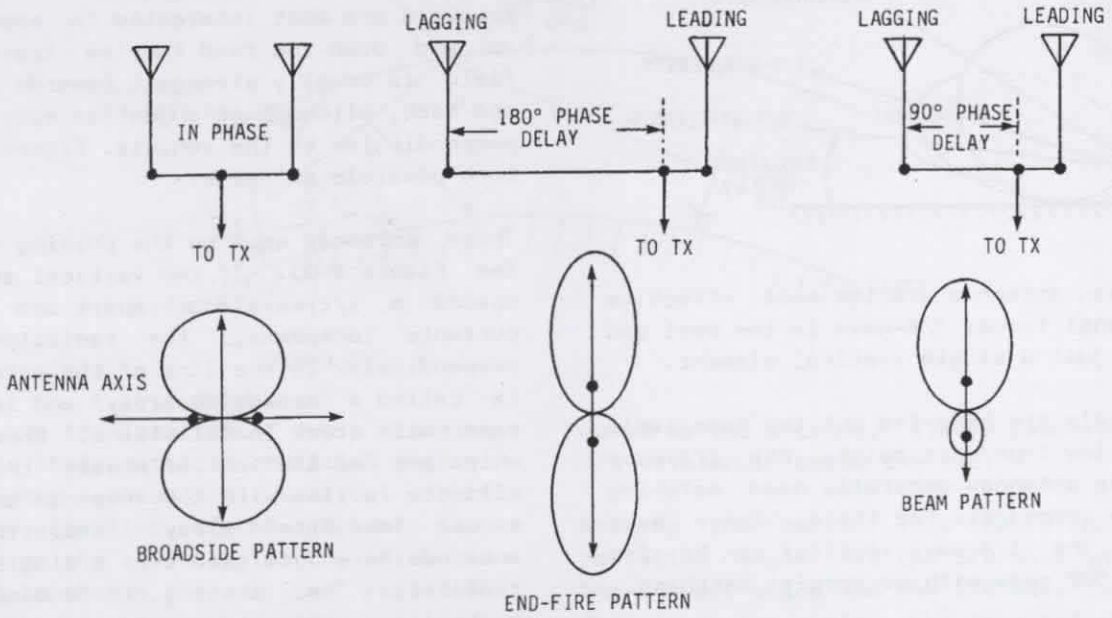


FIGURE 8-25
USE OF PHASING TO CONTROL RADIATION PATTERN

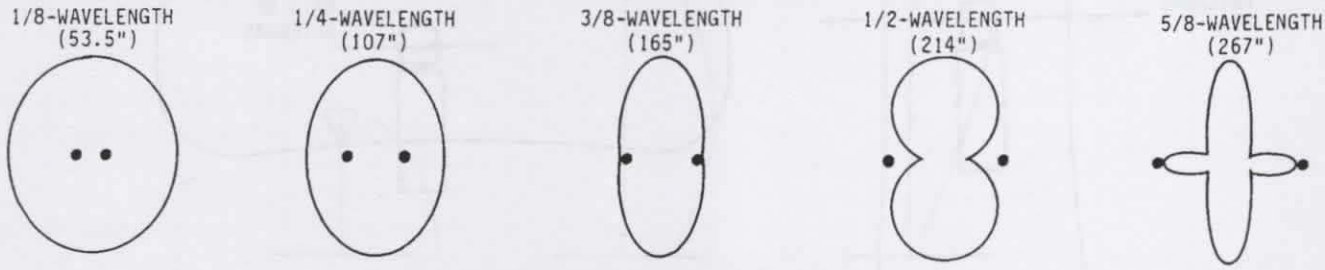


(THE DOTS ARE THE TWO VERTICALS AS VIEWED FROM ABOVE, SPACED 1/2-WAVELENGTH APART)

be added to one side of the balanced feedpoint, as shown. (12' is a 1/2-wavelength including the coax Velocity Factor.) This means the whip with the extra coax lags the leading whip by 180°, since its signal is delayed by that amount of time. To carry this a step further, a 90° phase delay produces a unidirectional beam antenna with the major lobe in the direction of the leading antenna. These principles have been applied for years in most directional AM broadcasting towers, and were simply copied for use in CB antennas.

In practice it's nearly impossible to get a 17' whip spacing even on an 18-wheeler. On a car or pickup trunk it's more like 1/4-wave spacing! You could do it on a bus using front and rear whips and end-fire phasing. The effect of

FIGURE 8-26
HORIZONTAL RADIATION PATTERNS OF CO-PHASED WHIPS AS A FUNCTION OF THEIR SPACING



(DOTS ARE THE WHIPS AS VIEWED FROM ABOVE)

the different whip spacings is to distort the horizontal signal patterns. See Figure 8-26. Notice the 1/4-wavelength spacing adds only a tiny improvement over that of a single whip, and by 5/8-wavelength minor side lobes begin to appear, which degrade the directional effects.

I never recommend dual antennas except on big trucks or buses, where a distance close to the correct 1/2-wavelength spacing of 17' can be realized. On smaller vehicles they're a total waste of money. But you'll still see them!

DIRECTIONAL BASE ANTENNAS

Base beam antennas come under the general category of "parasitic" arrays, where only the "driven" element gets RF directly from the transmitter. The parasitic elements operate by induction of the radiated field from the driven element. CB parasitic beams commonly used are the Yagi (named after its Japanese inventor) and the Quad or Cubical Quad.

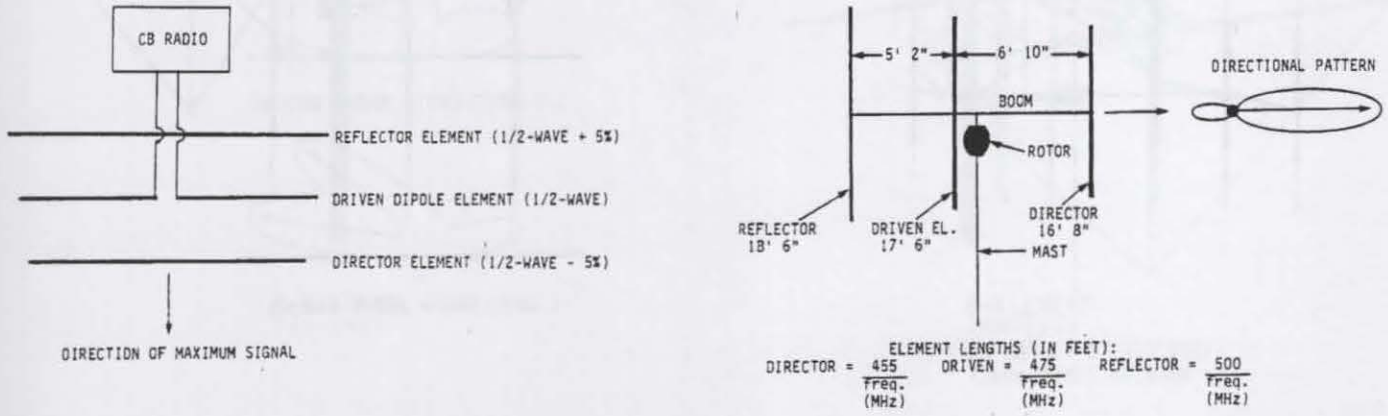
There are few American CB antenna companies still selling beams. Some brainless morons got fried by installing them next to high-voltage power lines, so the government naturally passed a law requiring manufacturers to add special insulation. Most companies decided the extra expense and hassle wasn't worth it, so they simply quit making them. You may find it challenging and educational to build your own; the design and mechanical construction tips are readily available from the antenna books in CHAPTER 1. In any case you must understand how they work, since you might be asked for advice or service. There are still lots of the older beam installations around in active use.

The Yagi Beam

The most common Yagi antenna is the 3-element beam, Figure 8-27. The elements consist of a driven element or 1/2-wave dipole fed by the transmitter, a parastic 1/2-wave element about 5% longer called the "reflector," and a parasitic element about 5% shorter called the "director." Maximum radiation is in the direction shown. When the parasitic elements are located within a 1/4-wavelength of the driven element (the usual case), the current phasing either subtracts from or adds to the field from the driven element. With reflectors the waves are reflected back towards the driven element, and with directors they're absorbed and re-radiated in the forward direction.

The beam has about 7.5 dBd forward gain, a six-fold power increase. (A 4-watt CB sounds like 24 watts using a dipole!) The F/B ratio is typically 20-25 dB, which will greatly improve reception from the power gain in the desired direction and the rejection from the unwanted directions. This drawing shows the beam vertically polarized for CB use, but in Ham or TV applications it's horizontally polarized. In any case, the signal is so concentrated that a remotely-controlled electric motor (rotator) is needed to aim it in the desired direction. Some practical dimensions are shown for builders, as well as the most practical formulas for calculating the element lengths. Generally the best overall performance occurs with the Reflector spaced about 0.15 wavelength from the Driven Element and the Director spaced about 0.20 wavelength away. Consult the ARRL RADIO AMATEUR'S HANDBOOK or ANTENNA BOOK for detailed construction methods and matching networks.

FIGURE 8-27
THE 3-ELEMENT YAGI BEAM



The gain and F/B can be further improved by adding more directors, but eventually you reach a point of diminishing returns and mechanical support problems. Commercial CB Yagis are generally limited to 5 elements, which gives almost 10 dBd gain. The Hustler Co. still sells a 4-element Yagi (Model #11-MB4) which has a power gain of 9.4 dBd and a 28 dB F/B ratio.

A pair of Yagis can be stacked on a common boom and fed with a phasing line for even more gain and directivity. See Figure 8-28. (And also Figure 8-43.) By doubling the number of Yagis a theoretical extra gain of 3 dB is possible, assuming the same number of elements in both. The spacing between Yagis is important, and must be at least a 1/2-wavelength for good gain. Under a 1/2-wavelength the gain falls off but the Front-to-Side ratio improves. At 27 MHz the physical support, wind drag, and required rotator torque make them too impractical and expensive for most CB operators.

The most important design considerations for the Yagi include forward gain, F/B ratio, bandwidth, and input impedance. Unfortunately the best of each characteristic rarely occurs at the same physical spacing and dimensions! The spacing for maximum gain is different than the spacing for maximum F/B, and so forth. Suffice to say that with commercial CB beams, the engineers already made the best overall compromise when they designed it. Figure 8-27 indicated the most practical dimensions.

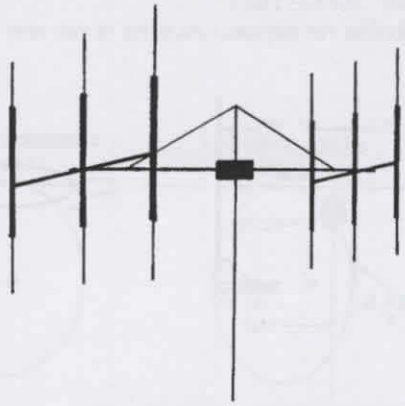
The same height-above-ground patterns for dipoles also apply to Yagi and Quad beams. Figure 8-29 shows the vertical patterns for a 3-element Yagi at a 1/2-wavelength and one wavelength above an ideal ground, viewed from one side. At a 1/2-wavelength there's one major lobe concentrated about 30° above the horizon. Increasing the height to one wavelength yields two lobes at about 15° and 45° elevation. The lower lobe can improve the DX and ground-wave propagation, while the higher lobe is sometimes useful during short skip conditions.

The Cubical Quad Beam

The other major parasitic beam is the Quad. Figure 8-30 summarizes its main characteristics and design dimensions. It consists of two or more closed one-wavelength wire loops in a diamond or square shape. The first parasitic element is generally chosen to be a reflector; additional elements will be directors. Each full-wave loop has four 1/4-wavelength sides, hence the name. Like the Yagi, only one loop is driven; the reflector is about 3% longer than one wavelength and the director(s) about 3% shorter. Polarization is determined by the feedpoint location. Constructional details and matching methods are found in the antenna books described in CHAPTER 1.

Radiation patterns are like the Yagi. However the Quad has several advantages which make it extremely popular with DXers, and that's why

FIGURE 8-28
"STACKING" TWO 3-ELEMENT YAGIS FOR INCREASED GAIN & DIRECTIVITY



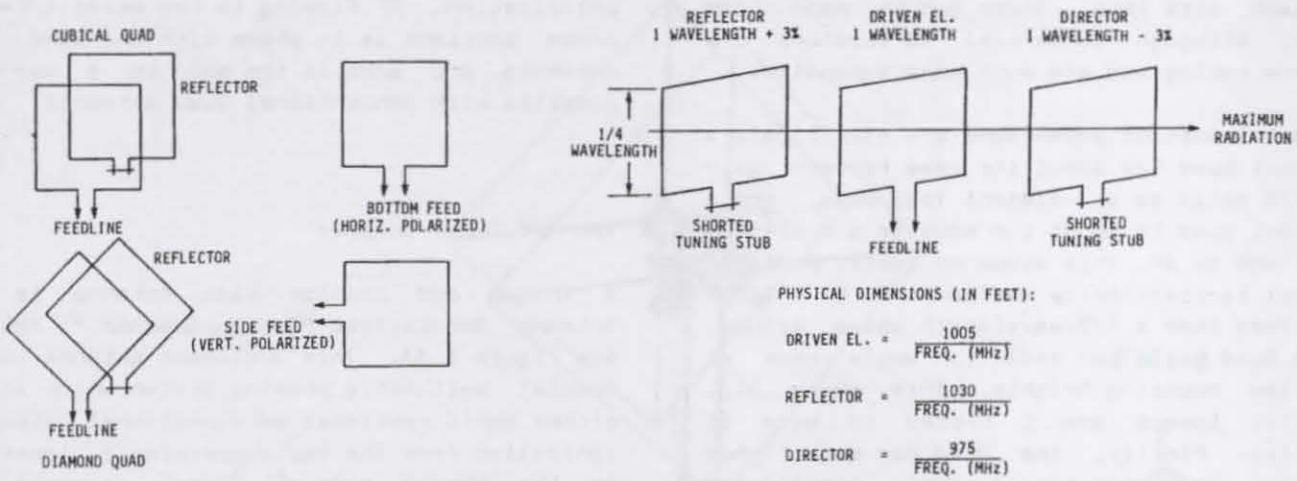
(SEE FIG. 8-43 FOR COAX HARNESS DIMENSIONS)

FIGURE 8-29
VERTICAL BEAM RADIATION PATTERNS (SIDE VIEW)

1/2-WAVELENGTH ABOVE GROUND

1 WAVELENGTH ABOVE GROUND

FIGURE 8-30
THE QUAD BEAM ANTENNA



PHYSICAL DIMENSIONS (IN FEET):

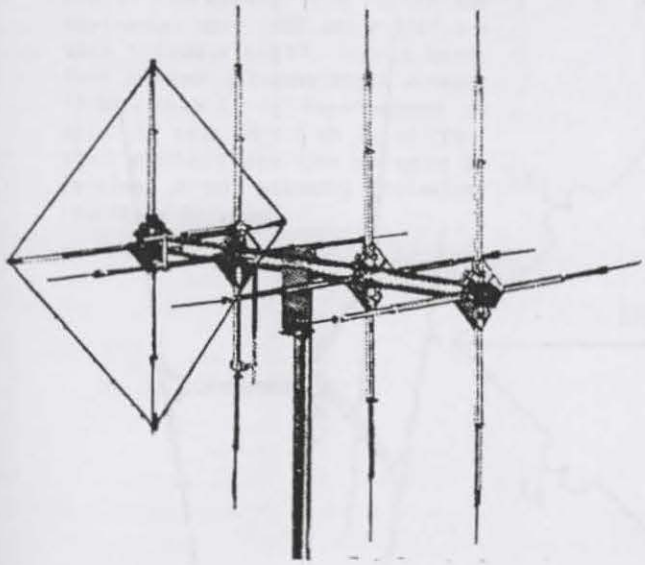
$$\text{DRIVEN EL.} = \frac{1005}{\text{FREQ. (MHz)}}$$

$$\text{REFLECTOR} = \frac{1030}{\text{FREQ. (MHz)}}$$

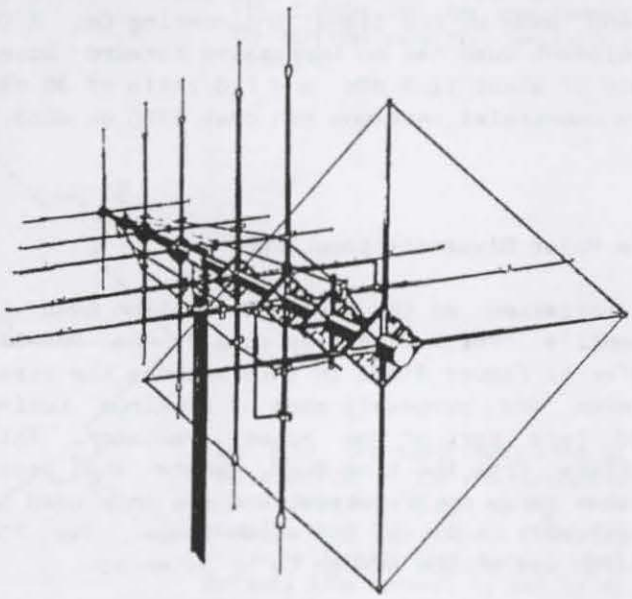
$$\text{DIRECTOR} = \frac{975}{\text{FREQ. (MHz)}}$$

ELEMENT SPACING: 0.15 TO 0.20 WAVELENGTH

FIGURE 8-31
MOONRAKER 4- & 6-ELEMENT HYBRID BEAMS
(Courtesy Antenna Specialists Co.)



4-ELEMENT
(AV-140)



6-ELEMENT
(AV-146)

they're still being made for CB use. From a constructional standpoint it's much simpler, needing only one short boom and an "X" frame for each wire loop. These can be made from bamboo, although commercial CB versions use aluminum tubing and are much more expensive.

The most important advantages are electrical: a 2-element Quad has about the same forward gain and F/B ratio as a 3-element Yagi beam, and a 3-element Quad is about the same as a 4-element Yagi, and so on. This saves on costs. A dipole or Yagi is practically useless as a DX antenna when less than a 1/2-wavelength above ground, but a Quad has a low radiation angle even at very low mounting heights. This means big, expensive towers aren't needed to make it effective. Finally, the Quad has much higher radiation resistance than a Yagi, simplifying RF power transfer from a 50Ω transceiver.

The best-known CB Quads are the Avanti PDL-II and Moonraker 4-element and 6-element, shown in Figure 8-31. (Avanti is now part of the Antenna Specialists Co. and is still sold through A/S distributors.) The Moonraker-4 and Moonraker-6 are actually Quad/Yagi hybrids. Only the driven element is a loop; the parasitic elements are crossed Yagis which allow both vertical and horizontal polarization by suitable feed switching of the driven loop. The reflector is designed around the "PDL" principle. (See the following description.) True Quads are still being made by the Signal Engineering Co. A CB 6-element Quad has an impressive forward power gain of about 11.5 dBd and F/B ratio of 30 dB. The commercial versions can cost $300 or more.

The Polar Diversity Loop (PDL)

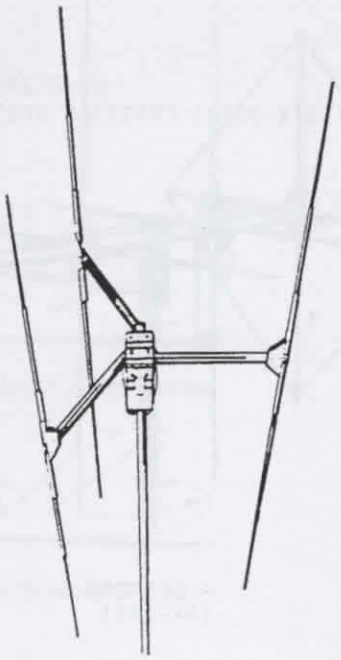
A variation on the dual-polarization Quad is Avanti's "Polar Diversity Loop," the PDL-II. Refer to Figure 8-32. In this antenna the cross braces are purposely made of aluminum tubing and form part of the actual radiator. This differs from the true Quad, where the cross braces carry no RF current and are only used to physically support the wire loops. The PDL design was unique enough to be patented.

Electrically the PDL resembles a Wheatstone bridge circuit; the tubing across each "V" adds another 1/2-wavelength such that horizontal and vertical signals are isolated from each other by the balancing effect of the bridge. This balance is remotely controlled at the radio location so the operator can choose the desired polarization. RF flowing in the extra 1/2-wave cross sections is in phase with the Quad loop currents and adds to the gain in a way not possible with conventional Quad antennas.

The A/S Super Scanner

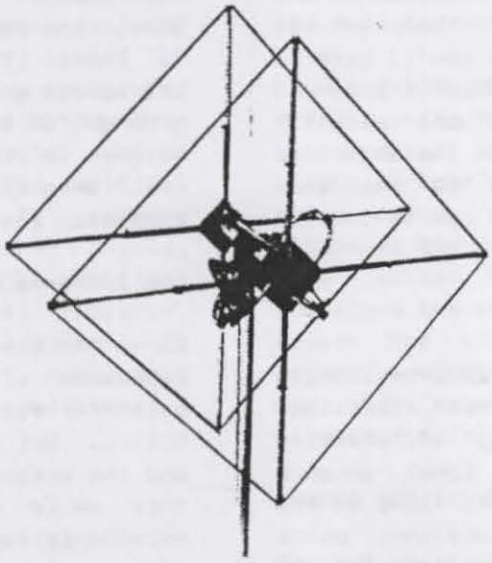
A unique and popular base antenna is the Antenna Specialists "Super Scanner," #MS119. See Figure 8-33. This 3-element antenna uses a special switchable phasing system which allows either omnidirectional or directional patterns, controlled from the radio operator's location. In the "Omni" mode all three elements are active, with some gain in all directions. In the "Beam" mode one compass direction is chosen which activates the appropriate two elements in the same vertical plane, like a Yagi beam. The main disadvantage is its limit of only three main lobe directions for a given mounting orientation. But it eliminates the need for an expensive rotator, and represents a very clever compromise for the standard Yagi antenna.

FIGURE 8-33
THE A/S "SUPER SCANNER"
(Courtesy Antenna Specialists Co.)



MS-119

FIGURE 8-32
THE POLAR DIVERSITY LOOP (PDL) BEAM ANTENNA
(Courtesy Antenna Specialists Co.)



PDL-II
(AV-122)

FIG. 1

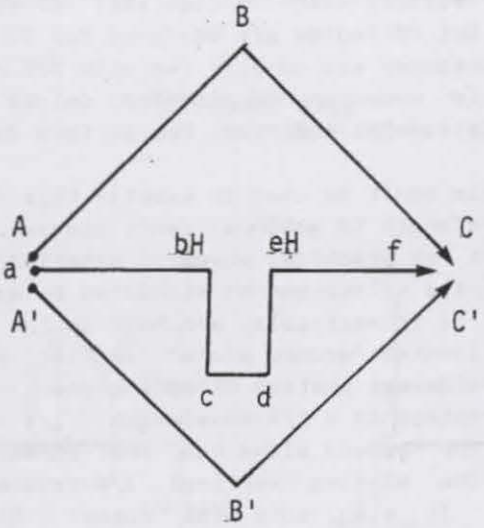


FIG. 1 represents the PDL in the horizontal mode. ABC and A'B'C' are each 1/2-wavelength, like a Quad. Then another 1/2-wavelength element (a-bH-c-d-eH-f) is superimposed on this. If stub bH-c-d-eH is omitted, then connections can be made at terminal bH-eH, assuming equivalent reactance is added.

FIG. 2

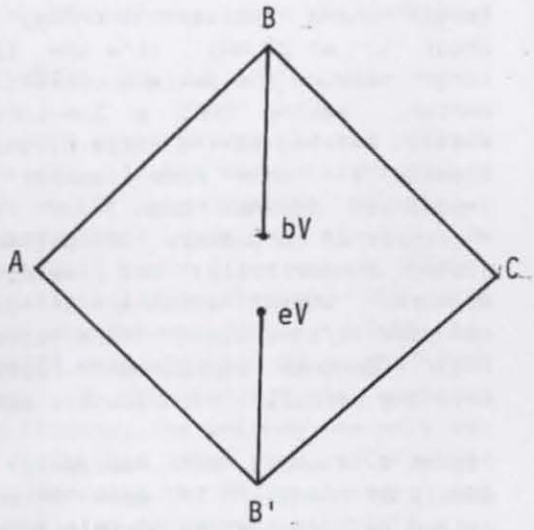


FIG. 2 shows the same loop connected for vertical polarity. Terminals are bV and eV.

FIG. 3

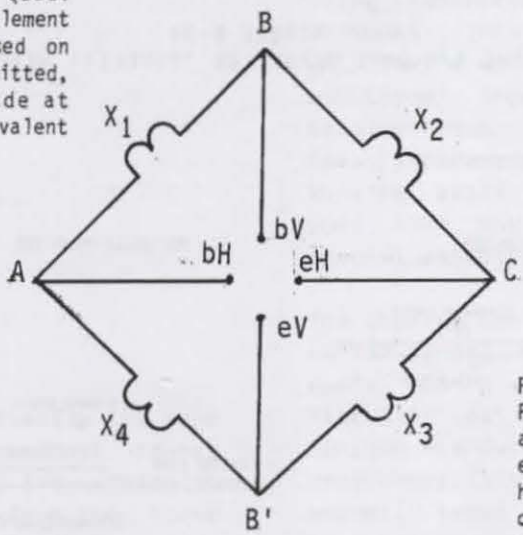


FIG. 3 is the superimposition of FIG. 1 on FIG. 2. The arm reactances are represented by X_1-X_4. For example, when the PDL is receiving horizontally-polarized waves, equal currents flow through X_1 and X_2 as well as X_3 and X_4; the bridge is balanced so that no voltage exists at B to B', thereby isolating the horizontal and vertical signals.

In this section we'll examine various methods for matching the most common CB antennas to the transmitter and coax cable. It's important to understand these principles so you'll have a better idea of where to look when things go wrong. Each basic antenna type uses slightly different matching circuits, but the objective is always the same: to create a 50Ω impedance at the antenna so maximum power can be coupled with minimum VSWR.

The 1/2-Wave Dipole Reference

Most CB antennas operate on the 1/2-wavelength principle. This is the shortest electrical length which radiates RF energy efficiently, about 17' at 27 MHz. It's the ideal antenna length because the maximum current flows at the center, making that a low-impedance point easily matched to the radio by inexpensive and readily available coax cables. The actual impedance depends upon many factors like thickness of conductors, height above ground, ground conductivity, and proximity to nearby objects. While antennas of other than a standard 1/2-wavelength are sometimes used, their unusual impedances require special matching circuits. Examples are covered later.

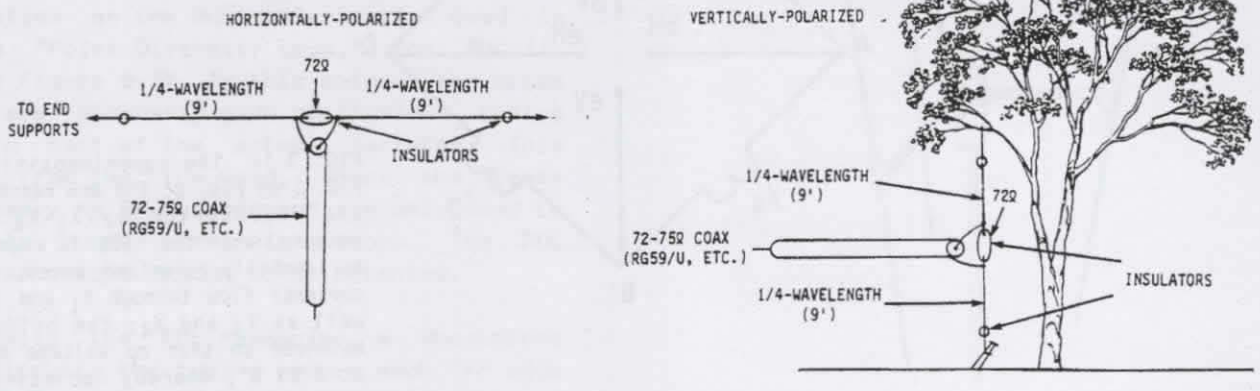
Figure 8-34 shows both horizontal and vertical models of the basic 1/2-wave antenna, usually called a "dipole" or "doublet" because it's split in half. Each half is a 1/4-wavelength long, or about 8.5'. When a dipole is opened at its center and connected to a transmission line, the nominal feedpoint impedance is about 72 ohms, if the antenna's mounted at least a 1/2-wavelength above a perfectly conducting ground. For base installations this 17' minimum height is easily achieved, but not in mobile use. When the height is closer to ground, the radiation resistance decreases considerably.

The 1/4-Wave Ground-Plane Antenna

Since the basic 1/2-wave dipole antenna has an impedance of 72 ohms, it makes an excellent match for feeding with 73Ω coax like RG59/U or RG11/U. But CB radios are designed for 50 ohms and the antennas are usually fed with 50Ω coax. This would cause an SWR mismatch unless the antenna is somehow modified. How is this done?

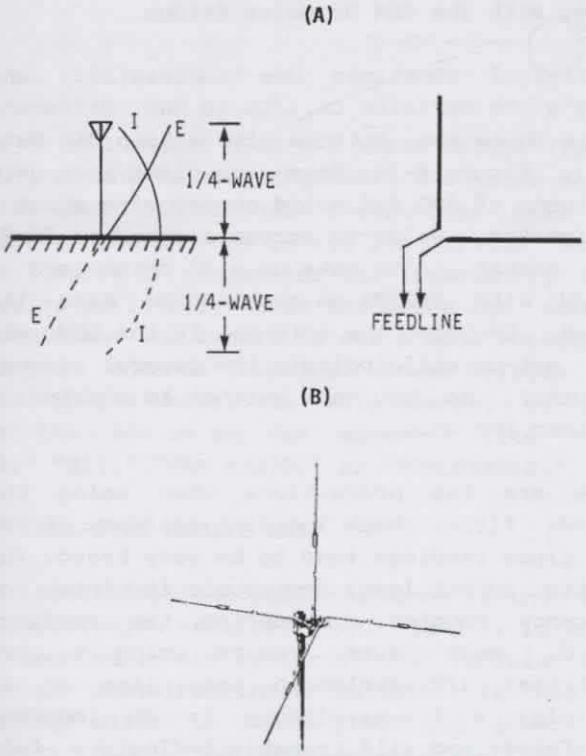
The dipole won't be used in exactly this form. A 1/2-wavelength CB antenna isn't always very convenient or practical anyway, especially on cars. But its effect can be simulated by making only half of it vertical, and half in the form of a horizontal "ground plane" section which goes off sideways instead of up and down. Each section represents a 1/4-wavelength; 1/4 + 1/4 = 1/2. The ground plane has the effect of adding the missing vertical 1/4-wavelength section. It also cuts the normal dipole impedance of 72Ω in half, or 72Ω ÷ 2 = 36 ohms. This makes a much closer match for 50Ω coax.

FIGURE 8-34
THE 1/2-WAVE DIPOLE OR "DOUBLET" ANTENNA



A ground plane can be formed using any large conducting surface at least a 1/4-wavelength long, although in practice it can be smaller. See Figure 8-35A. The 1/4-wavelength vertical radiator produces a mirror image of itself in the ground plane. Visualize it as a center-fed dipole which instead of being straight has been bent into an "L" shape; the horizontal part of the "L" is the ground plane and the vertical part is the radiator. A simple "L" antenna would be bidirectional like any other dipole, but by adding several horizontal "L" sections spaced equally around the vertical radiator, the pattern becomes omnidirectional instead. CB base antennas use three or four horizontal spokes or "radials" to form the ground plane.

FIGURE 8-35
THE 1/4-WAVE GROUND PLANE ANTENNA



Another example that works on exactly the same principle is the 1/4-wave AM broadcast tower; the ground plane is formed using 1/4-wavelength copper wires fanning out evenly from the tower base. Usually at least 120 radials are used; that's a lot of copper! And even though they're laying on the ground, it's these wires and not the soil which form the ground plane. Another name for a ground plane is a "counterpoise," since it electrically balances the antenna. The counterpoise is often used for marine antennas when the boat's fiberglass; a copper sheet in the hull forms the needed ground plane.

Figure 8-35B shows a typical 1/4-wave CB base antenna using three 1/4-wavelength radials. In some compact models the radials are shortened with loading coils, which like all loading coils reduce efficiency. The ground plane exists at the mounting height, not the ground. This raises the radiation resistance and therefore the efficiency. The ground plane also raises the electrical height above actual ground, resulting in lower radiation angles. And when mounted well above ground, it can eliminate stray RF currents below the radials.

LOADED MOBILE WHIPS

The 1/4-wavelength vertical whip is the primary mobile CB antenna. It has many variations but always works on the ground-plane principle. Instead of horizontal rods or wires, the vehicle body itself becomes the ground plane. While electrically a 1/4-wavelength, the whip is often much shorter physically, since few people want a 9' whip sticking up on the roof of their car. By shortening the vertical radiator with loading, the antenna has more eye appeal and rigidity but loses some performance; loading coils increase the DC resistance and heat losses, and also narrow the bandwidth.

There are still a few mobile fiberglass whips being advertised as "1/2-wave" or "5/8-wave" antennas. This is simply not true! Any single whip that's more than a 1/4-wavelength requires additional impedance matching circuits, since true antennas of those dimensions will have base impedances much higher than 50 ohms. But they're still connected directly to 50Ω coax just like any other mobile whip, with no special matching circuits. I wonder why...

The shorter the antenna, the more critical and narrow-banded the tuning. As a general rule, don't use a whip less than about 40" long. Virtually all base-loaded types will meet this minimum standard. However there are still some very short (like 18") center-loaded clip-on or magnetic types available, and they're extremely poor antennas. At least a few manufacturers now sell an on-glass CB whip made to look like a cellular mobile telephone antenna! Besides being far too short, you won't even get the benefit of a metal-to-metal ground contact.

Avoid these antennas like the plague, unless you're on some ego trip and need to feel like a VIP when talking to the car next door; that's probably all the range you'll get anyway. Besides potential SWR problems, transmitter damage, and very narrow bandwidth, the reduced capture area of such short antennas also kills the receiver sensitivity. Not recommended!

Tuning The Mobile Whip

Mobile whips are tuned by changing the physical length so the VSWR is lowest over the desired frequency range. The full-size whips don't need any adjustment, since they're already correct electrically. The whips that do need adjustment are those with base, center, or top loading.

The general tuning procedure begins by checking the SWR at Ch.1 and Ch.40. When higher on Ch.40 than Ch.1, the rod is too long and must be shortened. If higher on Ch.1 than Ch.40, the rod must be lengthened. All the better quality base- and center-loaded whips have a metal sleeve/set-screw arrangement which adjusts the length. If the whip needs shortening more than it will drop down into the holder, you must cut it. Use a hacksaw and never cut more than ½" at a time, rechecking the SWR after each cut.

With any 3/8" x 24 loaded whip using a bayonet type quick-disconnect, the extra few inches of this adapter can affect the SWR and must be considered when adjusting the antenna length. This is also true when adding a shock spring.

If the rod needs lengthening more than it can be raised out of the holder, you have a problem! Recheck the grounding and cable connections and whip location first. I've never seen this problem with name brand hardware, but I have with the "economy" brands; you get what you pay for. If you have some extra rods laying around, you can try a slightly longer one and sometimes succeed, but the best solution is to use a good quality antenna in the first place. Replacement rods are available from sources like GC Electronics (#19-112, 36", and #19-114, 40"). They also have the loading coil (#19-110) and the spring hardware (#19-100) to match. A/S also sells these standard replacement parts.

Never play "mix and match" with different brands of coils and whips even though they often look the same; each was designed for a very specific inductance-to-whip length ratio. For instance, a Radio Shack coil may require a completely different whip length than an A/S base coil. A couple inches either way and it'll never tune. If you suspect this may have been done in a problem situation, get a history from the customer or try the methods described next.

Shortened fiberglass whips are top-loaded. The better ones have an adjustable tip whose length can be changed like those on the base-loaded types. If not, peel off some of the shrink wrap and remove some wire, ½" at a time while rechecking the Ch.1/Ch.40 SWR after each cut. Once it tunes correctly, replace the cap. If it needs lengthening, there's little you can do without experimenting: since fiberglass rods use standard 3/8" x 24 threaded mounts with lugs for the coax, try removing the center coax wire lug and adding a small series RF choke, less than 1.0 µH (Mouser 43LQ type), to start. Eventually you'll hit the right inductance for resonance, and the SWR will drop to normal.

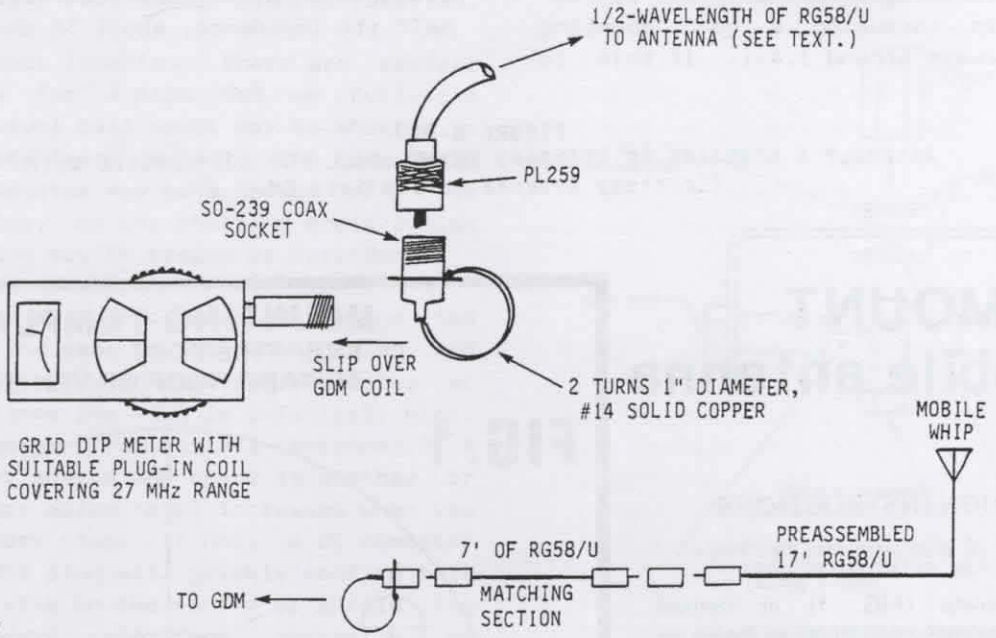
Tuning With The GDM Or Noise Bridge

A trick I sometimes use successfully when there's no definite Ch.1/Ch.40 SWR difference is to check the antenna with a Grip Dip Meter (GDM), Figure 8-36. Make a coupling loop using two turns of AWG #14 solid copper wire about 1" in diameter, soldered across a standard SO-239 coax socket. Also make up a 7' patch cord of RG58/U with PL259s on each end in case it's needed. Coupling the antenna to the GDM with this set-up will indicate the general resonant frequency, so you know whether to shorten or lengthen the whip.

There are two precautions when using this method: first, check the dial accuracy of your GDM, since readings tend to be very broad. Turn up its output level and couple it into your frequency counter, comparing the readings. Second, make sure you're using a true electrical 1/2-wavelength coax line or its multiple; a 1/4-wavelength is an impedance transformer and will probably indicate a false resonant frequency. A convenient true length would be 12' or 24' of coax, assuming the standard 66% Velocity Factor. For mobile whips having the usual 17' of preassembled coax, add an extra 7' patch cord in series using a PL258 double-female barrel connector. This makes a full-wave impedance repeater line.

Another method when working with unknown antennas is to use a special impedance bridge, like the MFJ Model 204B Antenna Bridge (about

FIGURE 8-36
USING GRID DIP METER TO DETERMINE RESONANT FREQUENCY
OF AN UNKNOWN MOBILE WHIP



$80), MFJ Model 202B R-X Noise Bridge (about $60), or the Palomar Engineers R-X Noise Bridge (also about $60). These instruments tell you whether the antenna is too long or too short, the degree of resistance vs. reactance, etc. They're definitely worth the price for serious technicians who expect to see a wide variety of drive-in antenna repairs! These bridges are sold in the better Ham radio stores, or look for the ads in any Ham magazine like "CQ," "73," "QST," "HAM RADIO," or "WORLDRADIO."

THE FULL-SIZE MOBILE WHIP

The most efficient mobile antenna is the true 1/4-wavelength vertical whip. Ideally it would be mounted in the center of the vehicle roof for an omnidirectional pattern. It has no loading coils to waste power and lower the current loop. The disadvantages are obvious: it's ugly, clumsy, and requires a much stronger physical support than the shorter loaded whips.

Some recent evidence by Antenna Specialists Co. suggests that a 1/4-wavelength antenna shows an incredible 2.5 dB gain improvement by simply moving it from the usual trunk lid location to the center of the roof. And a 5/8-wavelength has a 1 dB gain location improvement. There are no 5/8-wave mobile CB whips; these figures are based upon unloaded VHF antennas, which are physically practical to install here. Loaded CB whips would offer reduced improvement. But this gives you some idea of the potential range increase if you're willing to mount a full-size CB whip at roof center. Just convince the wife you really need that big hole in the roof!

The length of a full-size whip depends upon its material. Steel whips are about 102" and fiberglass 96". Ever wonder why? Fiberglass is shorter because its radiating element is a copper wire buried in the fiberglass; copper is a better conductor than steel, so RF propagates through it faster. Same idea as the coax Velocity Factor. Shakespeare does sell a 102" fiberglass whip that's 3/8-wavelength in copper with a very slight gain (1 dBd) over a standard whip, resulting from its lower radiation angle.

Troubleshooting The Full-Size Whip

There's no tuning with a full-size whip when correctly installed. "Correctly" means never on the bumper of a van or camper! Otherwise you've got several feet of the vehicle body being capacitively coupled to the whip, totally detuning it. Nothing will correct the problem except relocation. Acceptable locations are high up along one side of the body, or on the roof. Bumpers are OK for cars though, since the body is lower and relatively far away. In any

case the radiation pattern is distorted and will be much stronger in the forward direction, towards the greatest mass of vehicle metal.

The normal SWR reading of a 102" steel or 96" fiberglass whip (assuming a good mounting location) is always around 1.4:1. If this is the ideal mobile antenna, why shouldn't it match perfectly when loaded whips often do? The reason is radiation resistance. The 1/2-wave dipole has an impedance of about 72 ohms but a 1/4-wave whip, which is half its size, has only half its impedance, about 36 ohms. Since SWR is

FIGURE 8-37
ASSEMBLY & MOUNTING OF STANDARD SWIVEL BALL FOR 102" MOBILE WHIP
(Courtesy Antenna Specialists Co.)

BALL MOUNT for mobile antenna

INSTALLATION INSTRUCTIONS

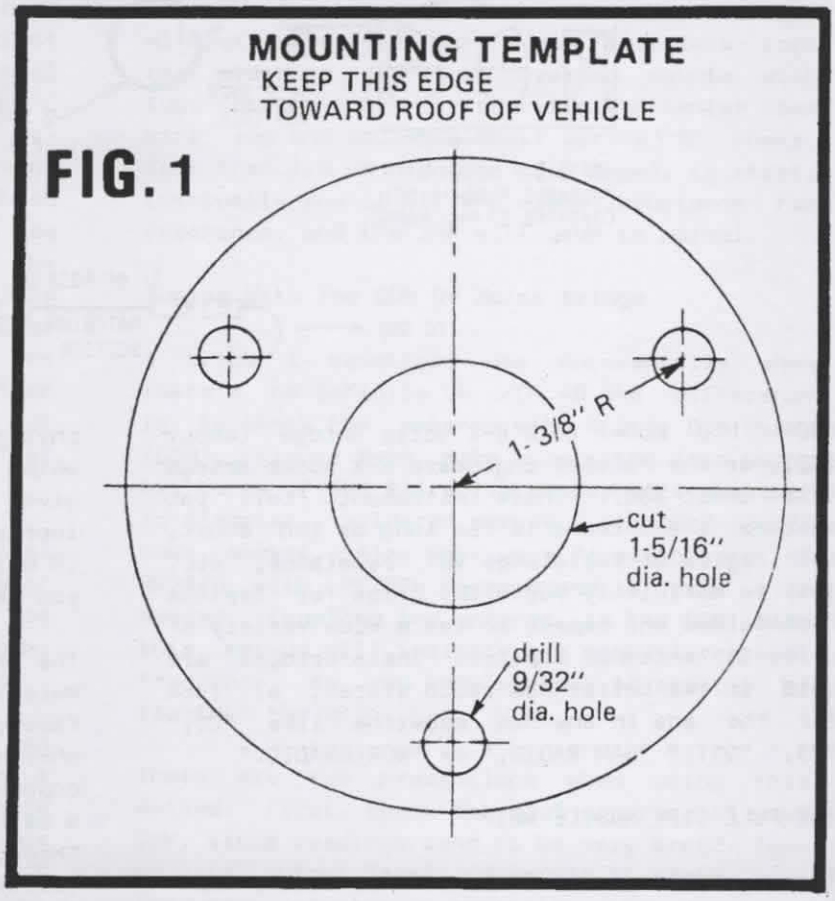
1) Place template (FIG. 1) at desired mounting location, drill holes as shown on the template. CAUTION: Attach to flat portion of body.

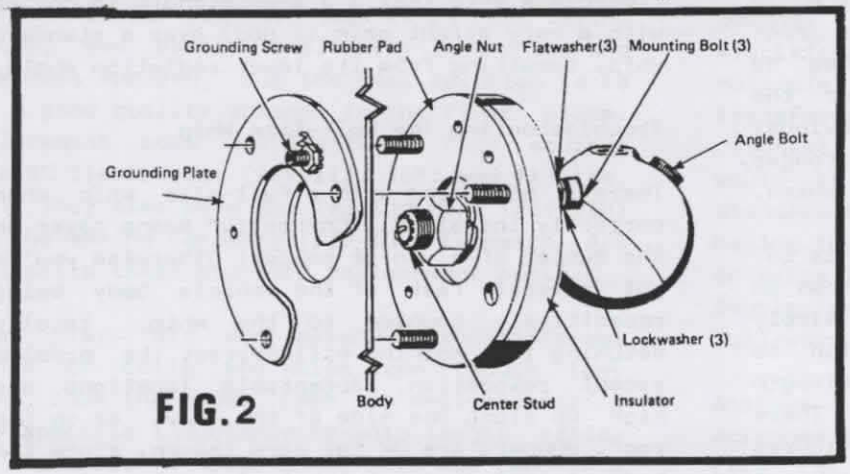
2) Assemble mount as shown in FIG. 2.

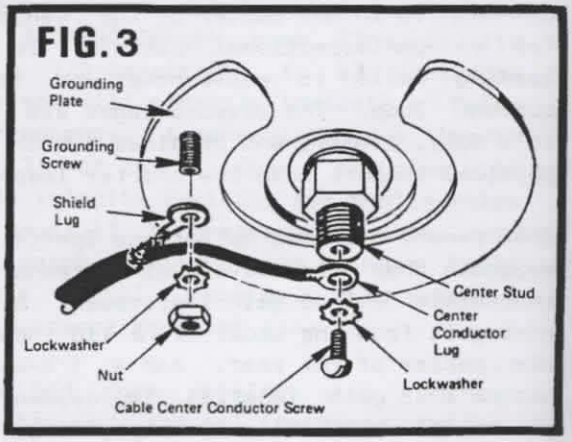
3) After the mounting screws have been tightened securely, the antenna receptacle in the upper hemisphere can be adjusted to a vertical position by loosening the angle bolt and angle nut. Tighten both after adjustment.

4) Tighten the grounding screw (FIG. 3) securely into the car body for a good ground. Attach the center conductor of the coax to the center stud and attach the shield braid to the grounding screw.

5) Fasten antenna and tighten.







the ratio of one impedance to another, this makes it 50 ÷ 36 = 1.389, which is a perfectly acceptable figure. Loaded whips are adjustable, and the feedpoint impedance can be raised above 36 ohms by proper coil design and tap location.

Besides improper location, there are several other reasons for a high SWR on full-size whips: the swivel ball mount may be shorted to the vehicle body (very common!), the coax braid or center conductor may have broken off from its mounting lug, or the shorting braid inside the shock spring may be broken or corroded.

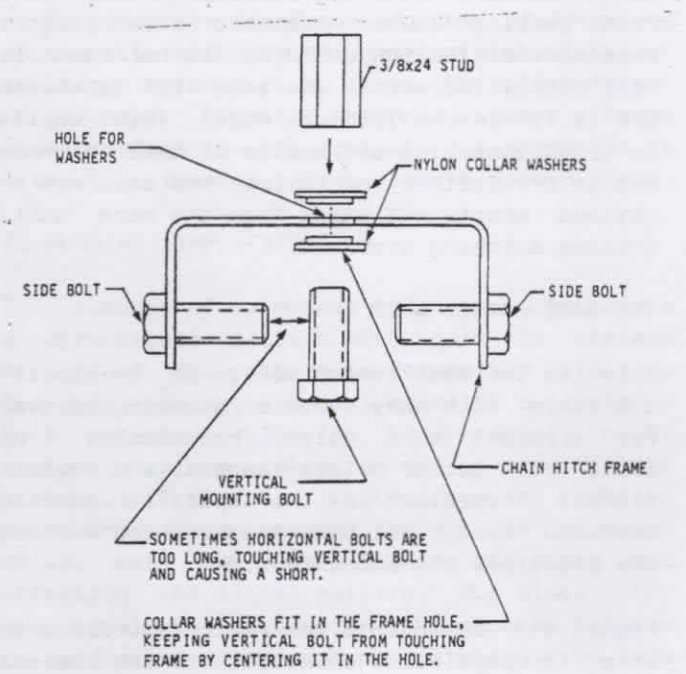
With a shorted or open coax conductor the SWR will measure the same on both the FORWARD and REFLECTED scales, and will peg the meter at full scale, since the VSWR is infinitely high. (Such readings are true for all antennas.) A quick test for shorts and opens is whether or not the receiver noise level increases when you connect the coax plug. If not, a DC ohmmeter across the PL259 plug will quickly confirm this problem. The wire on the center or shield lug sometimes breaks off from corrosion or vibration. Jumper a clip-lead across the whip and one of the swivel ball mounting bolts; an ohmmeter across the PL259 plug should then indicate a short, unless one conductor is open.

In the case of a short, you'll very often find the swivel ball/shock spring assembly shorted directly to the vehicle body; many amateurs install these wrong! The whip and spring are supposed to be supported only by the plastic mounting plate, which means a hole at least 1¼" in diameter. Many people drill this hole out just big enough to pass the threaded stud of the ball mount, effectively bolting the ball directly to the vehicle body! See Figure 8-37 for the correct installation technique.

When installing a chain or strap bumper hitch, make sure the horizontal bolts of the mounting plate don't protrude far enough inside to short to the vertical mounting stud. Also make sure that the nylon collar washers are properly seated; these must insulate the 3/8" x 24 stud and the whip from the vehicle body. People have been known to replace lost bolts with longer ones, or to forget the insulating plastic collar washers. Figure 8-38 shows this idea.

All the same tests for shorts and opens apply equally to center-loaded steel whips and loaded fiberglass rods. If standard 3/8" x 24 mounting

FIGURE 8-38
ASSEMBLY OF 3/8" x 24 WHIP STUD FOR CHAIN BUMPER HITCH



threads are used, these antennas can be checked just like the full-size threaded whips.

Don't overlook the possibility of a shorted or open PL259 plug either. The factory crimp-on plugs occasionally go bad. Even more common is improper installation of the standard PL259 and the associated UG175/U or UG176/U reducing adapter. When installing a preassembled cable, plan the cable run so you won't have to cut off the factory plug; thread the plain end through the vehicle first. If you must install the plug yourself, I highly recommend using the Amphenol 83-58FCP solderless coax plug instead. Other solderless PL259s include the GC Electronics #18-415 and Radio Shack #278-196. Review the correct plug/cable installations on Page 318.

When the SWR is about 3:1 in an otherwise good installation (or known to be good previously), the problem is usually a broken shorting braid inside the shock spring. Most people don't realize there is one! If you bend the whip over far enough to stretch the spring, you'll see it inside. Without this shorting braid, the spring acts like a base loading coil; this adds inductance to an already resonant antenna and detunes it. A broken braid isn't repairable and the spring should be replaced. The smaller springs on base-loaded whips also have shorting

braids. Replacement parts are sold by A/S, Radio Shack, Dick Smith, and GC Electronics.

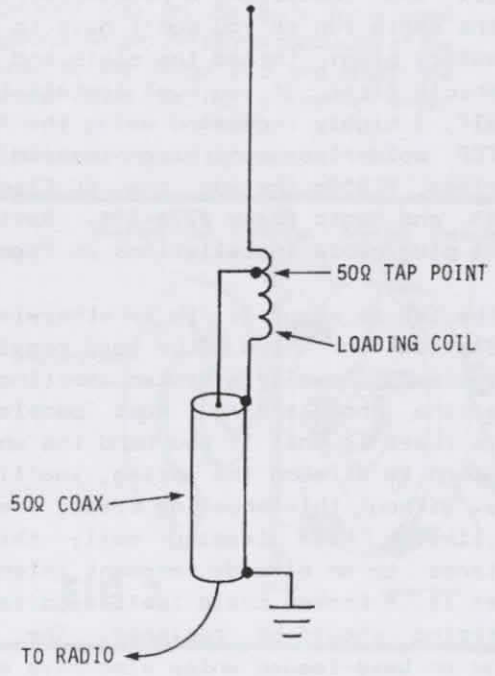
Any problem besides an outright short or open won't usually stop the receiver noise level from getting louder when the coax plug is reconnected. The SWR could be 3:1 but the noise will still increase. The true test is whether SWR is low in the Transmit mode. This applies to troubleshooting all mobile or base antennas, and is the fastest way to test and separate the obvious shorts and opens from the more subtle antenna matching problems.

THE BASE-LOADED WHIP

This is the most common mobile CB whip. It's available with many types of mounting hardware for straight roof holes, hatchbacks, trunk lids, rain gutter clips, campers, and magnetic clamps. Regardless of the specific mounting hardware used, all base-loaded whips work on the principle of "shunt feed."

Figure 8-39 shows this schematically. Since the whip is physically shorter than the correct electrical length, it has capacitive reactance. This is balanced out with an equal amount of inductive reactance shunted across its base terminals. At the same time, the proper 50Ω impedance point must be found. This point is located somewhere along the coil, which is tapped at that point. In commercial CB antennas the 50Ω point is permanently sealed inside the coil shell and connects to its center pin. Thus shunt feed works just like the tapping down of any other parallel-resonant circuit, where the higher tapped impedance is matched to the lower impedance of the total coil winding. Every installation is slightly different and the exact capacitive reactance can't be predicted, so the whip length must always be adjustable.

FIGURE 8-39
THE SHUNT-FED MOBILE WHIP USING BASE LOADING



The main advantage of shunt feed is that the antenna operates at DC ground potential and can be fed with unbalanced coaxial cable. Because of this, it provides a safety factor against lighting when used in base installations, and reduction of road static when used in mobile installations. The ball tip included on the end of the whip rod helps discharge road static too, since that end is a voltage loop and high voltage is usually attracted to sharp points.

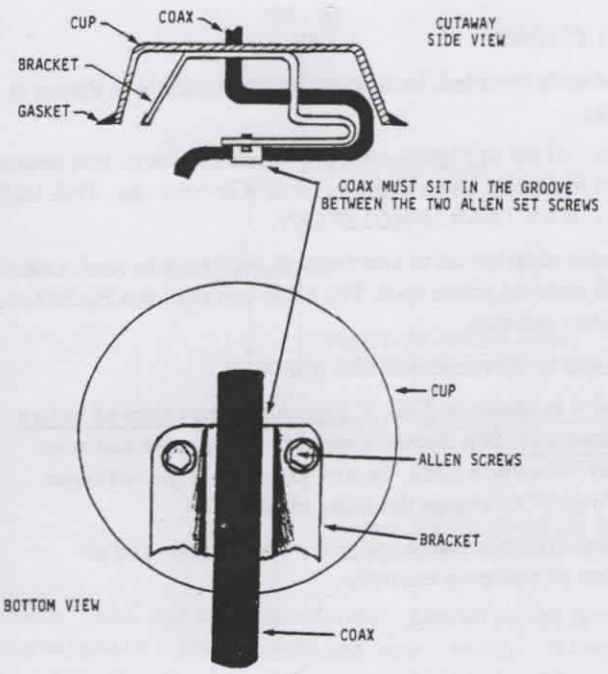
Troubleshooting The Base-Loaded Whip

Note from Figure 8-39 that your ohmmeter will always show a DC short between the coax center and shield when connected to any base-loaded CB antenna. This has misled countless amateurs who thought they had found a shorted antenna. DC resistance and RF impedance are <u>not</u> the same! An ohmmeter will show DC continuity from the whip to the center pin of the coil and center pin of the coax plug, <u>and</u> to the outer coil threads which are the vehicle ground. The better antennas rarely have coil problems, but there's still some junk around that actually uses conductive plastic; couple those with a 200-watt linear and high SWR, and the coil is guaranteed to burn open!

Poor grounding is a common cause of high SWR in trunk-lid mounts. Make sure there's always some metal-to-metal contact between mounting cup and vehicle body. The little Allen screws on the cup are supposed to break the paint, so make sure they do. When the mount itself isn't preassembled, make sure you route the coax correctly; it's supposed to fit in the groove between the Allen screws so there's some strain relief. Many installers incorrectly let it drop straight down, which strains the cable and may eventually pull it completely out of the cup. Figure 8-40 shows the proper cup assembly.

Most base-loaded antennas that are permanently installed on the roof or elsewhere use a

FIGURE 8-40
PROPER COAX ROUTING OF TRUNK LID MOUNT



standard 3/8" mounting hole for the 5/8" threaded base assembly which mates with the coil. (Hustler is one exception, having its own unique mounting method. The XBL-4 uses a 3/4" hole and the threaded base is preassembled, a good idea!) In such installations, make sure the center coax wire folds over into the groove of the center pin; people have been known to leave it sticking straight up, causing an intermittent or open circuit. Personally, I always solder the wire to the pin afterwards to prevent any possible corrosion or resistive connection to develop. Figure 8-41 shows the correct assembly procedure.

Magnetic Antennas

These are very convenient for people who don't want holes in their car, or who use one antenna on several vehicles. And it allows the superior rooftop location to be chosen. Any loaded antenna (base, center, or top) can be used with a magnetic base. You can buy either the base itself with 3/8" x 24 or 5/8" threads to mate with most popular whips, or complete magnetic antennas with oversize coils, like the K-40 or A/S Formula 1.

This antenna type is only capacitively coupled to the vehicle body via the magnet base, so its efficiency is less than a metal-to-metal ground. This weakness can sometimes be offset by rooftop mounting and its higher radiation pattern. Make sure the coax doesn't get mashed passing through the door or trunk lid, which would upset its impedance. Another disadvantage of magnetic whips is the greater probability of ignition noise pickup, since the antenna's not DC grounded. Magnetic antennas require a large steel surface to work against, so <u>never</u> use it without at least a 1/4-wavelength ground plane.

CO-PHASING SIMPLIFIED

The purpose of co-phased antennas is to create a directional pattern with gain in certain directions. The pattern is determined mainly by the whip spacing, assuming equal RF currents in both antennas. (They're always equal in CB systems, since there's no power divider circuit.) If the coax lengths from the radio to each whip were unequal there'd be a phase delay, with one signal leading the other and effecting the signal pattern. But since they are equal, we can assume the co-phase harness is used mainly for impedance matching. So it's more accurately called a "matching" harness than a "phasing" harness.

Since the transmitter has a standard 50Ω output impedance which must equal the load impedance for maximum power transfer, paralleling two antennas directly would yield 50 ÷ 2 = 25 ohms impedance. To end up with a <u>net</u> parallel impedance of 50 ohms at the PL259 plug, each antenna impedance must be raised to 100 ohms; 100 ÷ 2 = 50 ohms. Unlike a single whip that's already 50 ohms and connected to 50Ω coax, we now need two 50Ω whips stepped up to 100 ohms; when paralleled the result is 50 ohms. The coax that connects these unequal impedances together must have some intermediate value between 50 and 100 ohms. That can be calculated by,

$$Z_{avg} = \sqrt{Z_1 \times Z_2}$$
$$= \sqrt{50 \times 100}$$
$$= \sqrt{5000}$$
$$= 70.7\Omega$$

This value is conveniently close to the nominal impedance of RG59/U or RG11/U coax cable, which are 73 and 75 ohms respectively. That's exactly what <u>is</u> used for the co-phase harness.

FIGURE 8-41
INSTALLATION OF STANDARD 3/8" SNAP-IN ROOF MOUNT
(Courtesy Antenna Specialists Co.)

FIG. 1

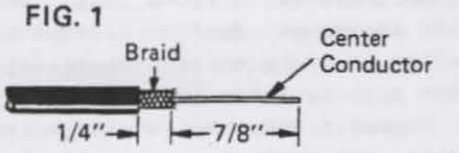


FIG. 2

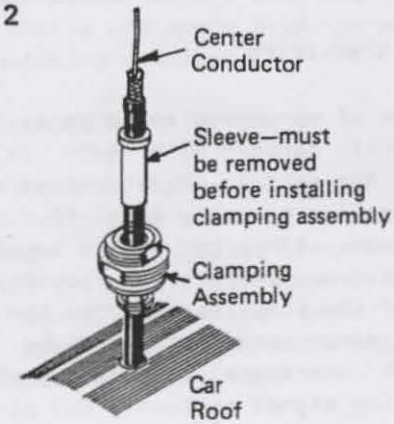


FIG. 3

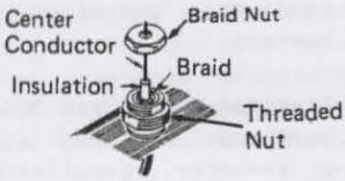


FIG. 4

FIG. 5

INSTALLATION INSTRUCTIONS

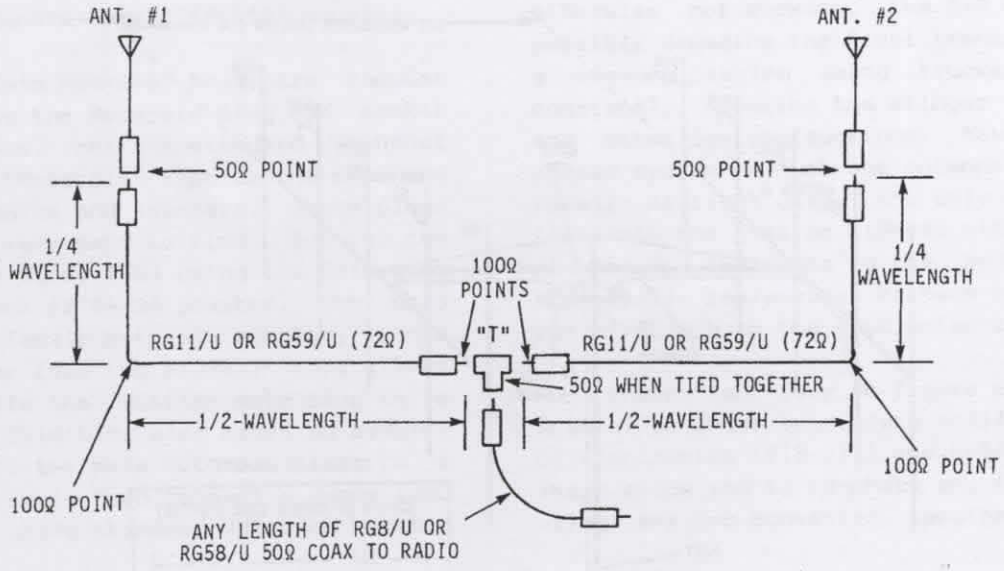
(If clamping assembly is already installed, be sure center conductor is as shown in FIG. 4 and begin at step 9.)

1. Drill 3/8" hole in roof of car at highest centrally located point so that antenna will be vertical when mounted. Use a sheet metal drill or hole saw. THE USE OF A TWIST DRILL MAY TEAR UPHOLSTERY.
2. Route cable from radio location up to and through 3/8" hole in roof. Leave a few inches of cable exposed above roof. The cable end with the PL-259 remains at the transmitter location.
3. Strip exposed cable end to dimensions shown in FIG. 1.
4. Disassemble the mount as shown in FIG. 2. Sleeve must be removed before installing clamping assembly. Slip clamping assembly over cable and snap "fingers" into hole in the vehicle body. Be sure assembly is pushed down far enough for all "fingers" to engage the body metal.
5. Insert sleeve, plain end first, over cable and press in until wide end of sleeve is flush with top of clamping assembly.
6. Holding clamping assembly on 1/2" flats, tighten threaded nut (with 3/4" flats) until clamping assembly is rigidly fastened to mounting surface. (FIG. 3).
7. Fan out 1/4" of exposed braid and push cable into clamping assembly until braid rests on top of clamping assembly (FIG. 3).
8. Extend insulation (1/4" long) through braid nut and thread it on clamping assembly until braid is securely clamped.
9. Place rubber pad over clamping assembly and flat against mounting surface (FIG. 4).
10. Screw mounting adapter snugly on clamping assembly (FIG. 5), threading center conductor through hole in adapter pin. DO NOT USE WRENCH LONGER THAN 6" to tighten mounting adapter.

NOTE! →

11. Bend exposed center conductor back along slot in side of adapter pin (FIG. 5). Center conductor must lay completely in slot.
12. Press eyelet into seal then press seal and eyelet assembly over adapter pin (FIG. 5).
13. Complete installation by following original instructions supplied with antenna.

FIGURE 8-42
IMPEDANCE MATCHING OF DUAL WHIPS USING TUNED CO-PHASE HARNESS
(Courtesy Antenna Specialists Co.)



To make the actual impedance transformation, 1/4-wavelength coax sections are used, since such a length is already a convenient impedance transformer; if high at one end it's low at the other, and vice-versa. In this case it's a 2:1 step-down transformer. A 1/4-wavelength will be about 6' using standard 66% Velocity Factor coax. Any odd multiple of a 1/4-wavelength can also be used, such as 1/4, 3/4, 5/4, etc. (Even multiples result in 1/2-wavelengths, which are impedance repeaters.) If the physical whip spacing exceeds the 12' of the two coax lines, 3/4-wavelength (or longer) cables must be used. This is the usual situation in an 18-wheeler and the excess cable is bundled up out of the way. Figure 8-42 shows the net result of using two phasing cables with 3/4-wavelength (17') coax transformers to feed each antenna.

Co-Phasing Base Antennas

The same principle can be used when feeding or stacking two base antennas. The antenna types really don't matter as long as they're normally 50 ohms at the feedpoints. For example, they could be two 1/4-wavelength ground planes, two 5-element Yagi beams, etc. Figure 8-43 shows the 1/2-wave stacking of two multi-element Yagi beams with a suitable phasing harness. Note this harness is virtually identical to the dual trucker phasing harness, except here the heavier low-loss RG8/U and RG11/U cables are used for the base installation.

Co-Phase Matching Tips

Matching phased arrays involves adjustment of two antennas rather than one, which complicates tuning. If you happen to get a reasonably low SWR right away, you can probably do the fine tuning with both antennas connected. When there's any significant reactance though, both antennas will interact with each other. You could spend all day running up and down ladders trying to match them.

Instead, try terminating one antenna plug in a 50Ω dummy load while tuning the other whip for lowest SWR. Then reverse the process, replacing the tuned antenna with the dummy load while tuning the second antenna. This way you've eliminated any secondary reactance before it affects the SWR readings. Figure 8-44 shows the general idea.

The same principle that's used on mirror-mount whips also applies to stacked beams or base verticals. Tune one antenna and then the other using suitable dummy loads. The disconnected antenna will probably have a small inductive effect on the hot antenna because of its close proximity, so some retuning afterwards may still be needed.

Never cut the coax cable of a commercially-made CB harness; they already figured out the correct lengths! If you do make your own

FIGURE 8-43
HOW TO STACK TWO (OR MORE) YAGI BEAMS USING CO-PHASE HARNESS
(Courtesy Antenna Specialists Co.)

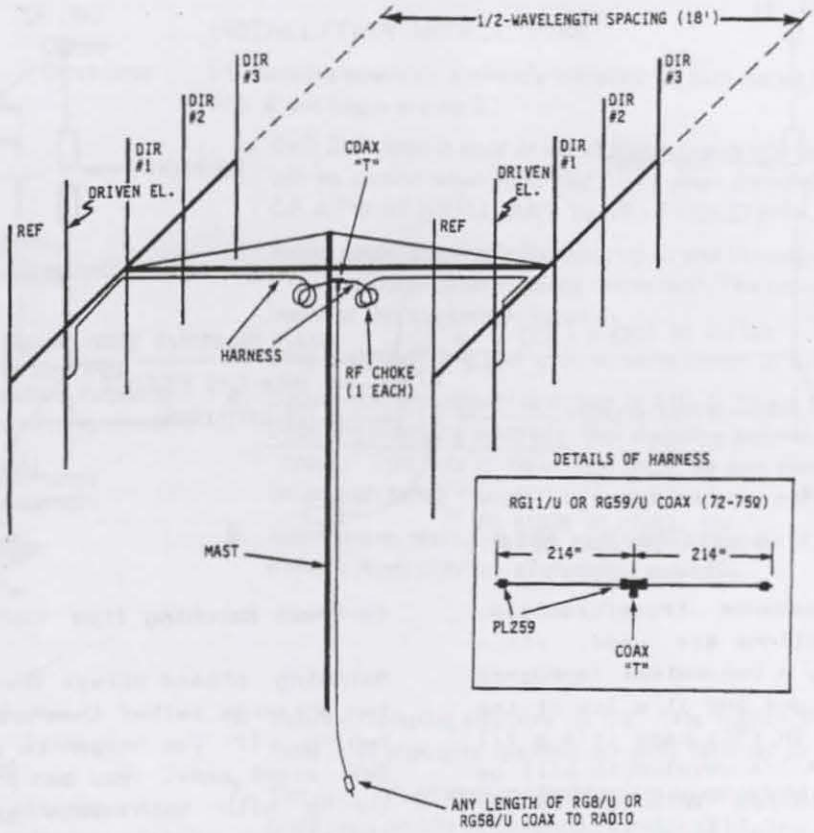
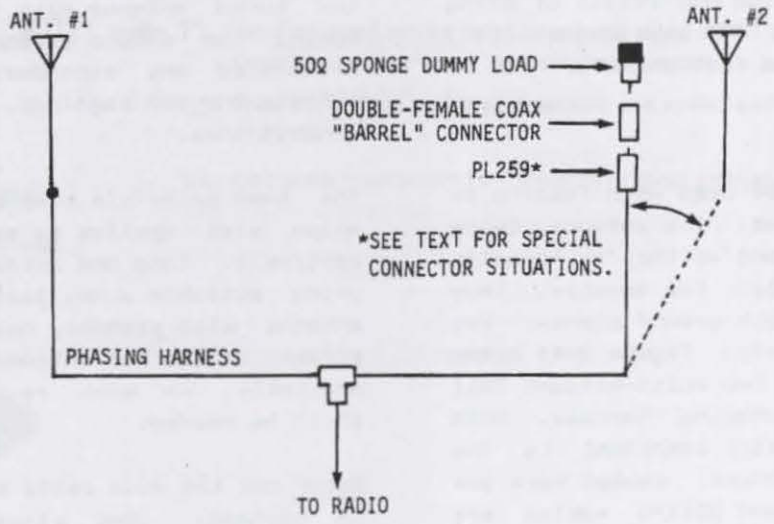


FIGURE 8-44
USE OF ALTERNATING DUMMY LOAD FOR TUNING CO-PHASED SYSTEM

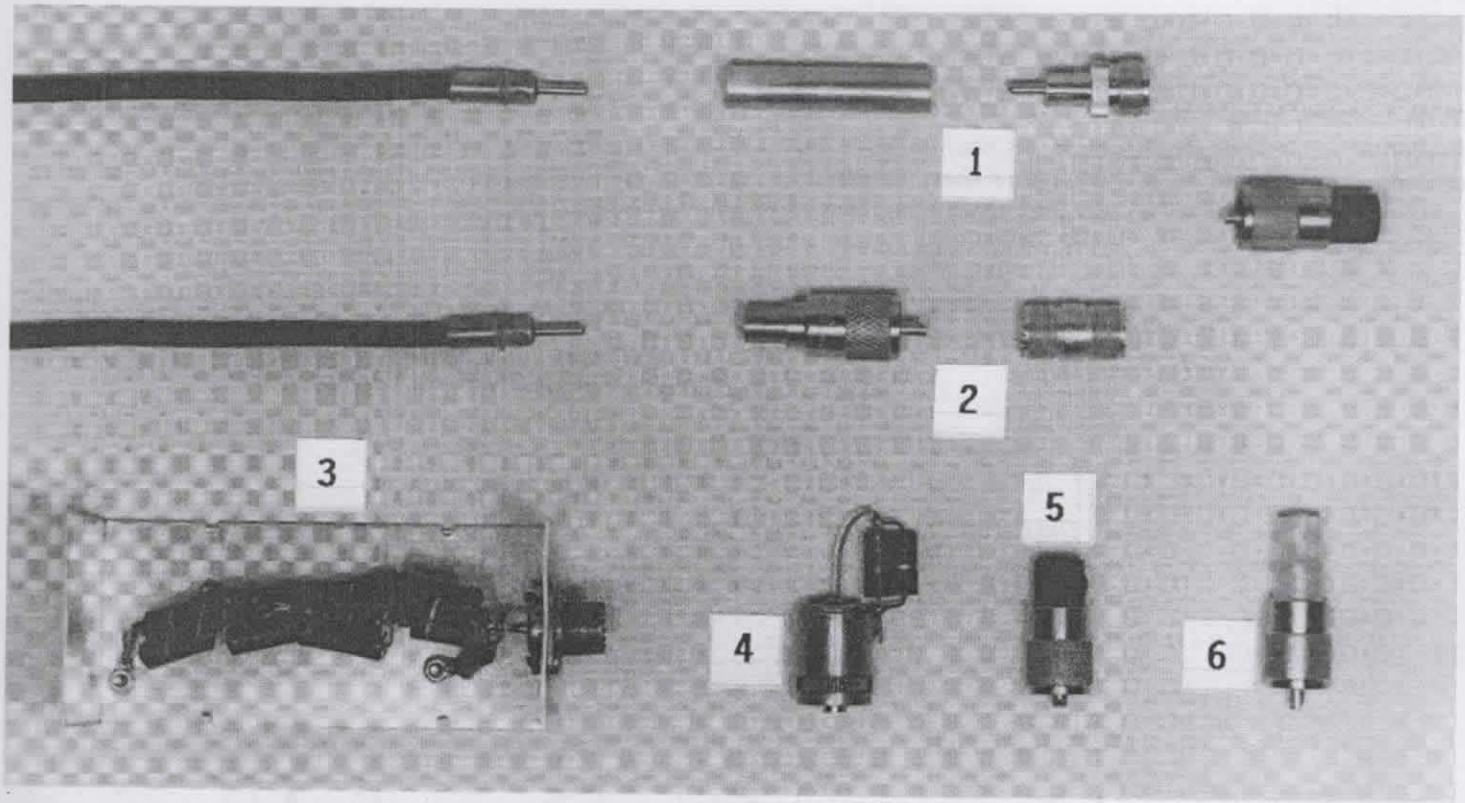


phasing harness, pre-test it by terminating both antenna ends with 50Ω dummy loads before connecting the actual antennas. In most cases this is very easy, since the antenna ends use PL259 plugs; you can connect a 50Ω sponge dummy load through a double-female (PL258) coupler.

The Hustler "Twin Huskies" that are popular with truckers use the Motorola plug and socket on their antennas, not the standard Amphenol UHF types. (The "Motorola" type is the same one found on car radios and scanners.) These plugs and sockets are very hard to find. But you can make a suitable dummy load using the Gold Line #95 or Radio Shack #278-208 adapter, the Gold Line #78 double-female Motorola adapter, and a sponge type dummy load (GL #1072); this allows you to terminate the Hustler male plug in a female UHF end. Gold Line also makes an adapter (#85) to convert the male Motorola plug to a PL259 end; you could then connect a dummy load to that PL259 using standard UHF-type mating hardware. (See the following photo.) Otherwise, you'd have to resort to a clip-leaded resistor for a dummy load when testing them.

If one antenna of a phased pair is broken or otherwise not working, the SWR will increase, possibly damaging the Final transistor. This is a common problem among truckers, who are constantly breaking the stinger tips on trees and other low obstructions. Never operate a phased system on just one antenna. If you can't repair it right away, the only options are to terminate the phasing harness with a dummy load at the end that goes to the bad antenna, or temporarily replace the harness with a straight run of RG58/U to the good antenna.

For those too lazy to figure all this out, special co-phase tuners are still being made by GC Electronics (#18-732) and Gold Line (#1098). These allow you to co-phase any two CB antennas using any two convenient lengths of 50Ω coax.



DUMMY LOADS: #1 and #2 show two possible ways to adapt the Hustler type Motorola coax plugs to female UHF ends for use with a dummy load when tuning co-phased whips. #1 uses a double-female Motorola adapter (Gold Line #78) with a Motorola-to-UHF adapter (Gold Line #95, Radio Shack #278-208). #2 uses a Gold Line #85 adapter with a standard PL258 coupler. Both result in a female UHF end for direct connection to a sponge-type dummy load. #3 is a homebrew 30-watt load using a network of seventeen 100Ω, 2-watt resistors, mounted in a Bud box with an SO-239 coax socket. #4 is made from the brass base of a standard 5/8" A/S type loading coil and two 100Ω, 2-watt resistors. #5 is the 4-watt sponge type load (Gold Line #1072), and #6 is the modulation light type (Gold Line #1057).

They're not made for high power though, and they also add some insertion loss. Replacement harnesses are still sold by Shakespeare: the #4048 has the lug terminals, and the #4173 has the PL259s for both common mirror-mount types.

Dummy Loads Aren't So Dumb

The use of dummy loads is a fast way to isolate coax vs. antenna problems in any installation. By replacing the antenna with a non-reactive 50Ω load, you'll know immediately where the problem lies. If you expect to do a lot of drive-in CB repairs, half the problems will be in the antenna and not the radio. Be prepared by having suitable dummy loads to fit all the most common connectors and mounting hardware.

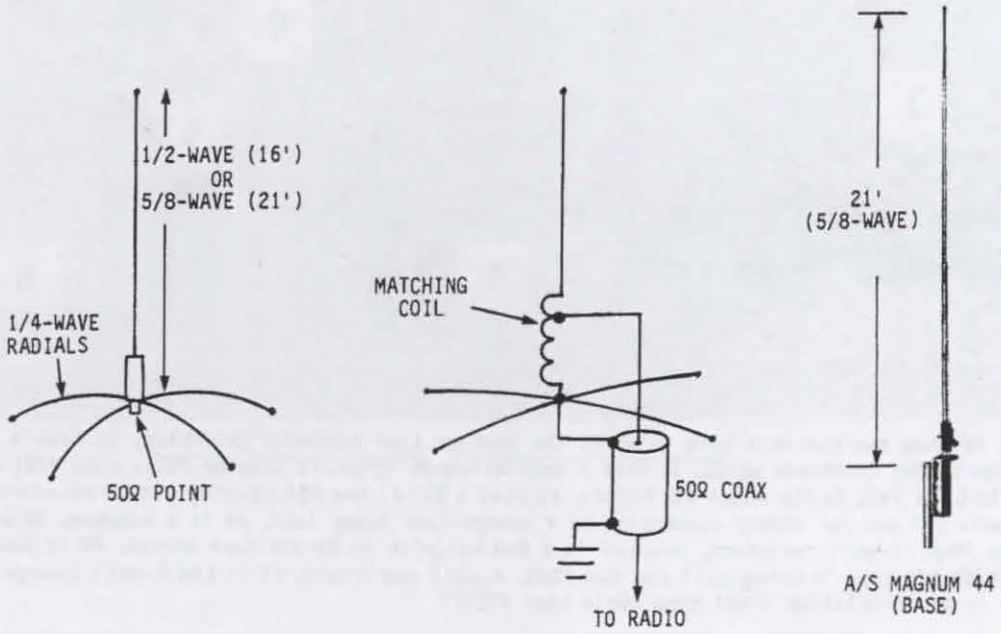
As shown in the photo, you can also make a dummy load to fit all the common 5/8" threaded base-loaded mounts by using a defective loading coil. Break it open and remove the wire, saving the threaded brass base. Then solder two 100Ω, 2-watt carbon resistors across this. Use it on any standard 5/8" base-loaded roof mount or trunk lid mount. You can even clip-lead such resistors directly across the antenna mount to test coax SWR, but keep the leads very short. Clip-leading these resistors is also useful for antennas with lugs on one end of the coax, like those with the 3/8" x 24 threaded stud mounts.

MATCHING HIGH-IMPEDANCE VERTICALS

The popular 1/2-wavelength and 5/8-wavelength omnidirectional CB verticals can't be connected directly to 50Ω coax like a 1/4-wave ground plane without special impedance matching. An example is the A/S Magnum 44, which is a 21' 5/8-wave radiator. Since the current loop or low-impedance point of a 1/2-wave antenna is at the center, a voltage loop or high-impedance point exists at the ends. This impedance can be as high as 2,000 ohms. Since you're feeding it at one of those ends, the high impedance must be transformed to 50 ohms. This is done using the same shunt feed method previously described for the base-loaded mobile whips.

Refer to Figure 8-45. A 1/2-wave radiator is naturally resonant, so adding base inductance would detune it. Therefore the manufacturer purposely shortens the vertical radiator slightly, creating capacitive reactance. Now the additional inductive reactance of the base coil can simultaneously tune it to resonance and transform the impedance. Somewhere along the coil there's a 50Ω point, which can be tapped for matching to 50Ω coax. In practice the 1/2-wave radiator is made about 16' long, slightly shorter than the true 17' electrical size. This antenna sometimes includes 1/4-wave radials, although they're not actually needed.

FIGURE 8-45
MATCHING SHUNT-FED 1/2- & 5/8-WAVE BASE VERTICALS



The 5/8-wave radiator (22') has a slightly lower radiation angle and slightly more gain. It's matched in exactly the same way. The feedpoint impedance will be different than the 1/2-wave vertical, since you've moved another 1/8-wavelength along the voltage loop. Again, ground radials are sometimes included. The shortened length is about 21'. The use of shunt feed in both these antennas simplifies feeding with coax cable, and grounds the antenna for DC which is very helpful for static discharge and lightning protection.

MATCHING YAGI & QUAD BEAMS

Both the Yagi and Quad antennas are matched using a similar technique, called a "Gamma" match for its similarity to that Greek letter. The methods are slightly different because each type is physically different; the Yagi has aluminum tubing and the Quad uses wire for the elements, but the principle is the same.

The impedances of Yagis and Quads are very different. A Yagi may be in the range of about 15Ω depending upon element spacing, where a Quad is typically 95-130Ω. But this makes no difference at all. The Gamma match is based on the fact there will always be two points on the driven element between which the radiation resistance equals 50 ohms. This point can be matched with 50Ω coax cable. See Figure 8-46A.

The coax can't be directly connected between these two points, since they're physically much farther apart than the spacing of the coax conductors, about 18-24" at 27 MHz. Spreading the coax conductors to reach these two points creates inductive reactance, which must be balanced out with an equal amount of capacitive reactance. An air-variable capacitor of about 50-75 pF in series is used, which is sealed in a weatherproof housing. Figure 8-46B shows the Gamma match for the Yagi and Quad antennas.

Either antenna is tuned by adjusting both the capacitor and the Gamma shorting point for lowest SWR. The SWR Meter should be placed at the antenna end, which means at least two people are needed to make the adjustments.

Preventing Coax Radiation

There's one other problem created by feeding a balanced antenna like a Quad or Yagi with unbalanced coax: RF current flows along the outer shield conductor. Normally with balanced feeders like "Twin Lead," whatever current is flowing in one conductor has a current of equal but opposite phase in the other conductor to cancel it. But with coax, the field from the inner wire can't escape the shielding effect of the outer braid for cancellation to occur. The result is radiation from the coax itself. This not only upsets the signal pattern and the impedance match as the coax becomes part of the total radiating system, but can also cause TVI. As shown in Figure 8-47, the RF can flow right back down into the transmitter and from there to the AC power lines. With poor grounding it may even be re-radiated all over the building.

FIGURE 8-46
MATCHING QUADS & YAGIS

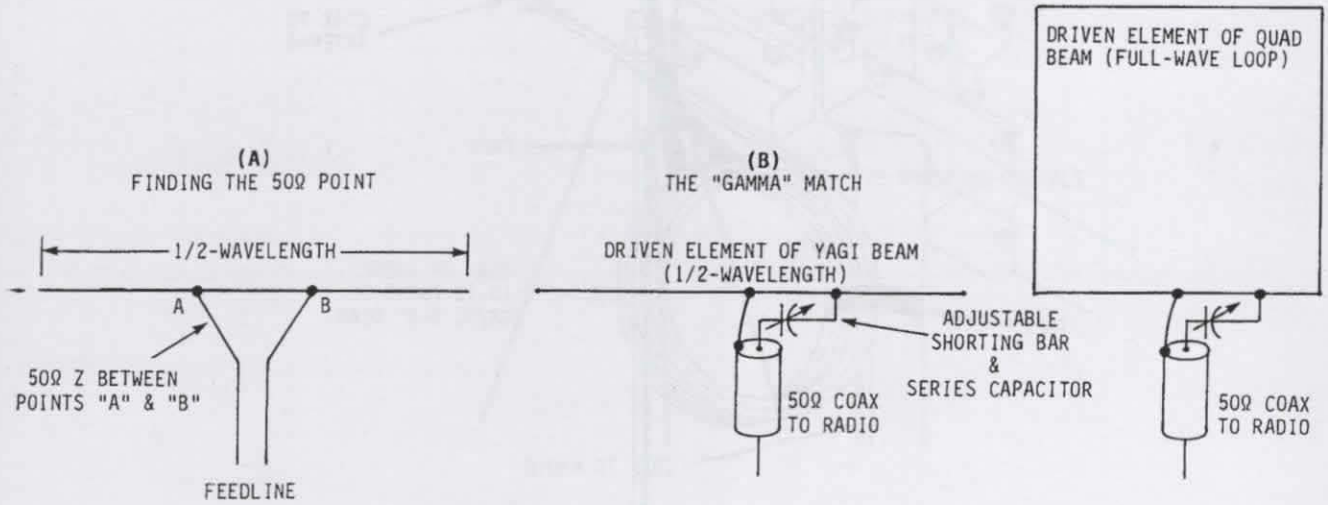
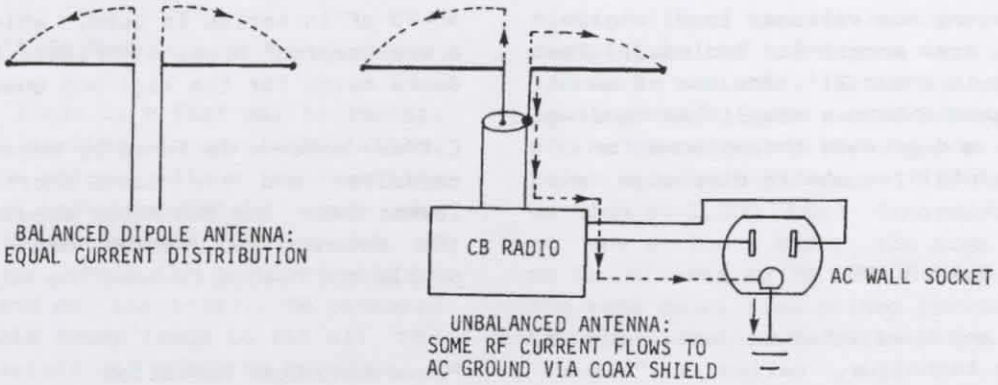


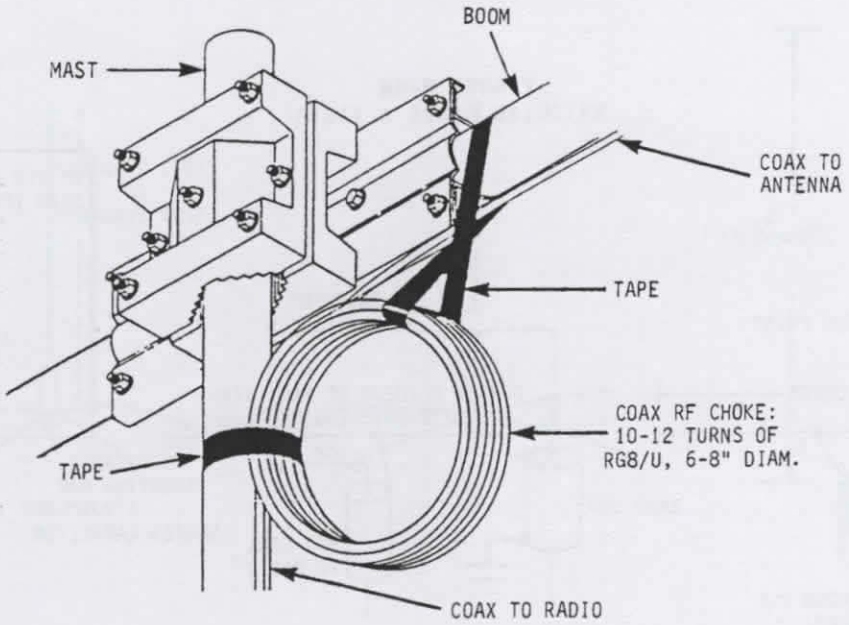
FIGURE 8-47
EFFECT OF USING UNBALANCED COAX FEEDLINE
(Courtesy RSGB RADIO HANDBOOK)



To prevent this, the balance must be restored. A "balun" or balanced-to-unbalanced transformer is one commonly used method. This is basically a tuned parallel stub across the coax at the antenna end. Commercial baluns are weatherproof units having coax sockets, and are sold in Ham equipment stores. Without a balun, you could use a large ferrite core at the antenna end, wrapping about three turns of coax around it.

The simplest and cheapest method is to make an RF choke using the coax feedline itself. Refer to Figure 8-48. (Also Figure 8-43.) Wrap 10-12 turns of the RG8/U at the antenna end into a coil about 6-8" in diameter and tape it to the mast or boom. This creates enough series reactance to minimize the shield current flow. Commercial antennas use similar isolation methods. Consider the RF unbalance possibility if TVI problems exist; the previous installer may have forgotten to include the RF choke, connecting the coax directly to the beam.

FIGURE 8-48
SIMPLE RF CHOKE MADE FROM THE COAX FEEDLINE.
(Courtesy Telex/HyGain Communications Inc.)



Guy Wire Effects

When guy wires are used to support the mast on base antennas like a Yagi, Quad, or ground plane vertical, they must be broken up into non-resonant lengths. Otherwise they'll detune the antenna, effecting SWR and the radiation pattern. Effective lengths might be 6' or 12', broken up by some plastic or porcelain egg type insulators. (Available from Dick Smith, Fair Radio Sales, Ham Radio Outlet, etc.) The first set should be placed within a few inches of the guy-wire ring; otherwise the metal-to-metal contact between the mast and the partial wire "radials" might form a capacity hat which loads the antenna. See Figure 8-49.

SPECIAL CB ANTENNAS

There are several popular CB antennas using 1/4-wave or 1/2-wave radiators, but having slightly different matching techniques than those discussed so far. The following is a quick summary of how they work.

FIGURE 8-49
GUY WIRE EFFECTS & PROPER INSTALLATION

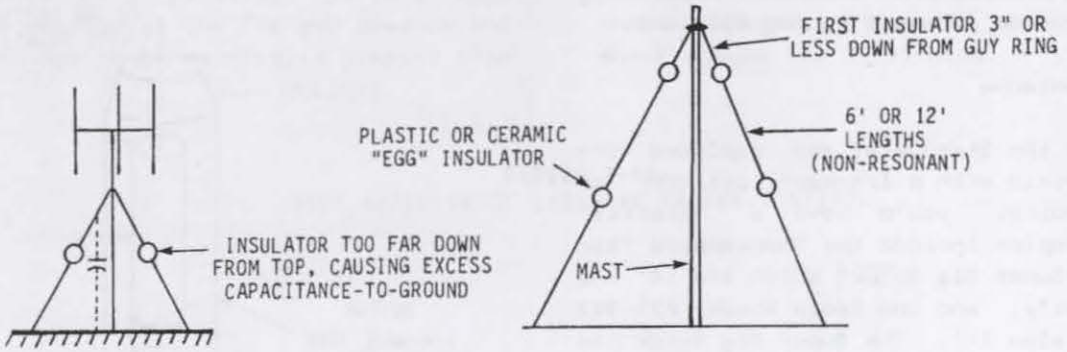
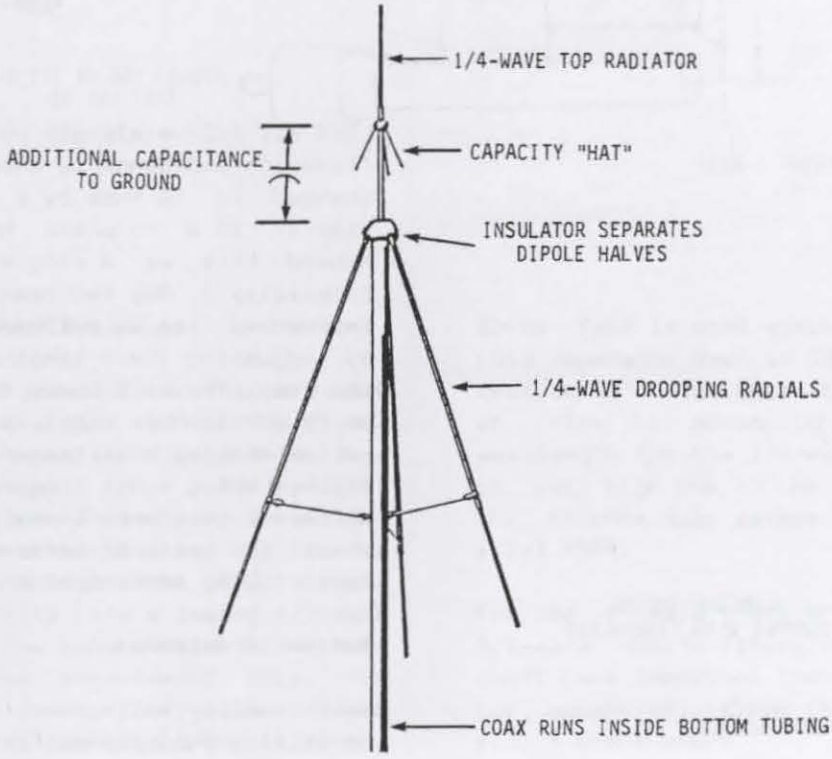


FIGURE 8-50
THE "STARDUSTER" OMNIDIRECTIONAL BASE ANTENNA
(Courtesy Antenna Specialists Co.)



The A/S Starduster

A variation on the common 1/4-wave ground plane vertical is the very popular A/S "Starduster," Figure 8-50. It combines both capacitive top loading and "drooping" radials. The small radials at the top add extra capacitance to ground, which raises the current loop. This lowers the radiation angle. And by allowing the radials to drop at a 45° angle, the radiation resistance is also increased, making it easier to feed RF power. Remember, a normal 1/4-wave ground plane is only about 36 ohms, so raising the impedance improves the match to 50Ω cable. The coax actually runs up inside the larger bottom section; there's an insulator separating the top and bottom 1/4-wave tubing sections.

The Coaxial Antenna

If you took the Starduster and replaced the drooping radials with a 1/4-wave cylinder of aluminum tubing, you'd have a "coaxial" antenna. Examples include the Shakespeare "Big Stick" and "Super Big Stick" which are 16' and 18' respectively, and the Radio Shack #21-967 "Crossbow," also 16'. The Super Big Stick has slightly better performance than the others, because of its lower radiation angle.

FIGURE 8-51
CONSTRUCTION OF THE COAXIAL ANTENNA

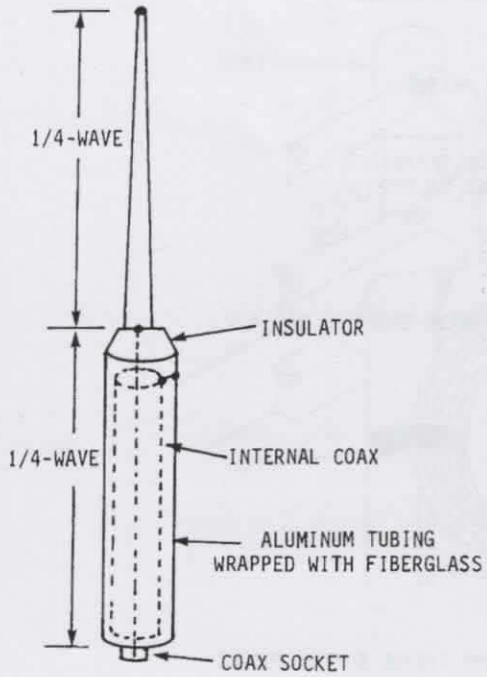
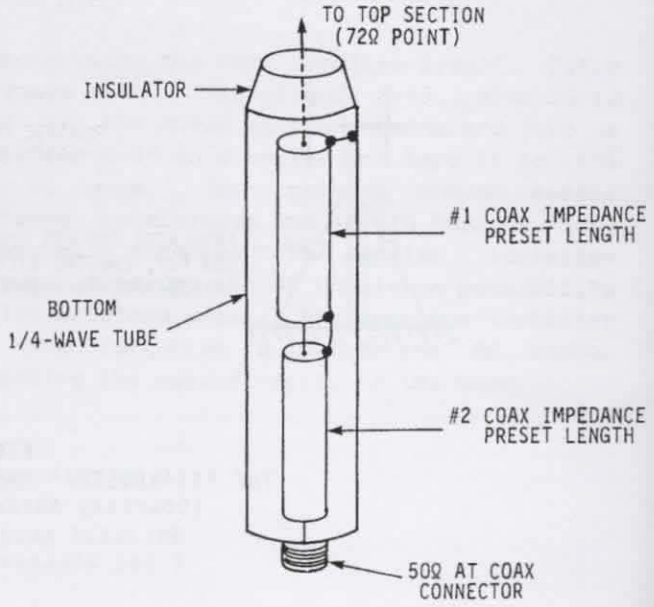


Figure 8-51 shows their construction. Although the coax plugs into the base, it's not actually fed there; there's more coax running up inside the tubing from the base to the center insulator that joins the two 1/4-wave sections. The coax center wire connects internally through the insulator to the top 1/4-wave section, and the coax shield to the bottom 1/4-wave tube. The effect is that of a vertical 1/2-wave dipole. The main advantage at 27 MHz is less wind drag, because it needs no radials.

FIGURE 8-52
SERIES-SECTION COAX IMPEDANCE TRANSFORMER



Like all 1/2-wavelength center-fed dipoles, the feedpoint impedance is about 72 ohms. This is changed to 50 ohms by a coaxial transformer, similar to a co-phase harness. (Figure 8-51 showed this as a single piece of coax for simplicity.) Any two coax cables of different impedances can be spliced together and matched by adjusting their lengths and distances from the load. The well-known "1/4-wave transformer" or "Q section" is simply a special case of the series-section coax transformer. The Super Big Stick, being a bit longer, requires a slightly different impedance transformation. Figure 8-52 shows the basic transformer placed inside the lower tubing section of the coaxial antenna.

Marine CB Antennas

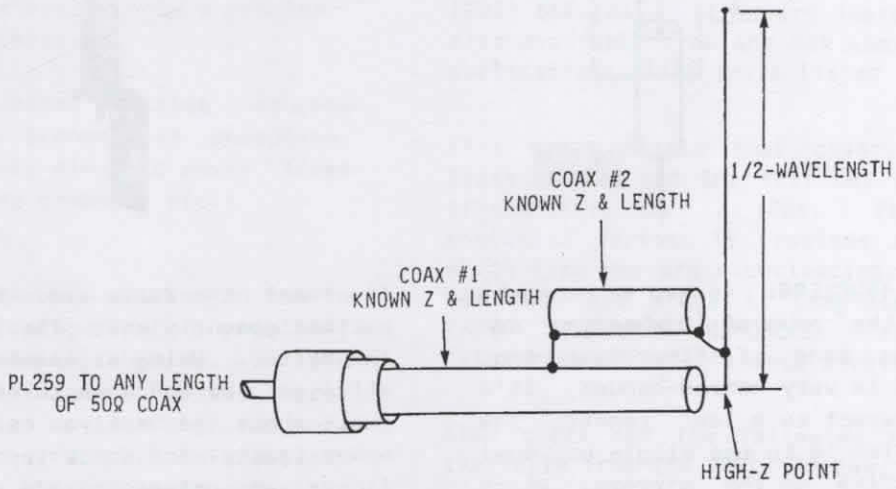
Many smaller boats have fiberglass hulls with no metal ground plane. For such installations a

1/2-wavelength vertical must be used, since it doesn't need a ground plane to work against. True 1/2-wave marine antennas are about 18' long. Shortened models include the Shakespeare 4050-B (3') and 388 (7'), which are both loaded and therefore quite narrow-banded. The problem again is the high base impedance of a 1/2-wave vertical antenna. A shunt-fed transformer could be used, but salt air would quickly corrode the coil and destroy its effectiveness.

Figure 8-53 shows a simpler matching method using a coax "stub" to transform the high base impedance down to 50 ohms. This is similar to the previous series-section coax transformer, with the cables now in parallel. In this case the stub is shorted at the far end because the antenna impedance to be matched is greater than the feedline impedance; when the antenna impedance is lower than the feedline impedance (like the shortened marine whips), the stub would be open at the far end. By using different coax impedances and lengths, a point can eventually be found where the correct impedance transformation occurs. The stub is terminated in a PL259 plug.

The advantage of this method is that the stub connection can be tightly sealed inside a PVC jacket for protection against the sea air. This special coax matching section must never be cut. Any convenient length of RG58/U or RG8/U can be spliced on with coax connectors to reach the radio location. Like shunt-fed antennas, these types will normally show a DC ohmmeter short across the PL259 plug.

FIGURE 8-53
STUB MATCHING OF 1/2-WAVE MARINE VERTICAL

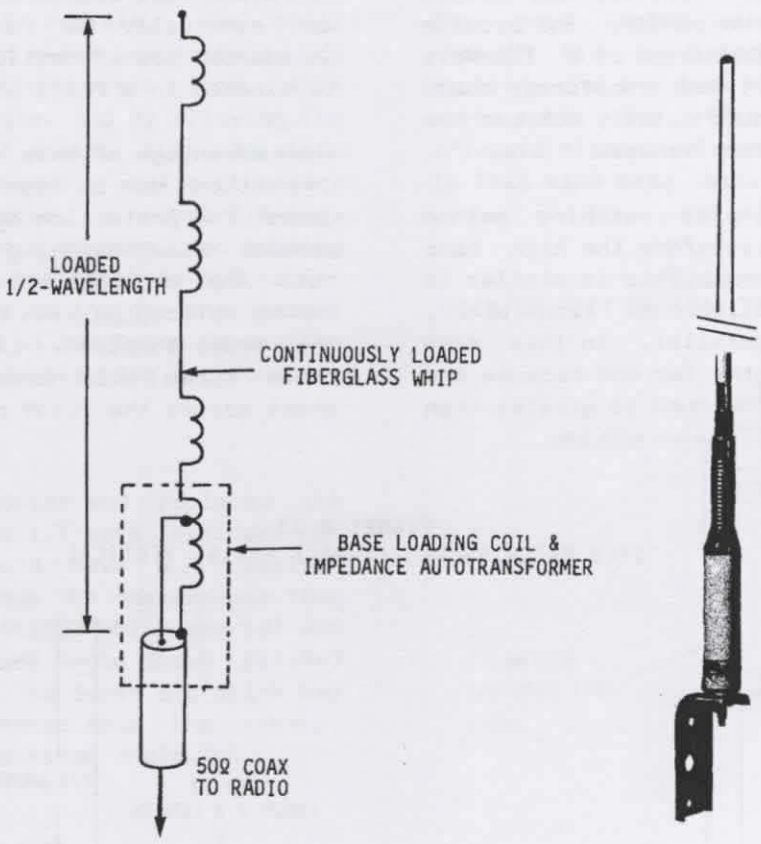


Other "No Ground Plane" Antennas

Working on the same principle as the 1/2-wave marine antenna is the A/S MR306 "No Ground Plane" mobile whip, shown in Figure 8-54. This was designed especially for vehicles like boats, motorcycles, snowmobiles, camper shells, Corvettes, or any other mobile application where there's not enough metal for a good ground plane. Basically it's a loaded 1/2-wave fiberglass whip in the same physical length as the standard 1/4-wave base-loaded whip. The combination of the loaded fiberglass rod and loading coil makes the complete 1/2-wavelength. Shunt feed is used again to transform the high base impedance down to 50Ω. The fiberglass rod section is continuously loaded. It takes a lot of wire to accomplish this, about one wavelength for the 1/2-wave effect. Thus the Q is very high due to the large L/D ratio, and the antenna only covers about 15 channels with a 2:1 VSWR.

Earlier I said there are no true 1/2-wave or 5/8-wave mobile fiberglass whips because they don't have impedance transformers. This one's the exception, since the base loading coil is also a transformer.

FIGURE 8-54
THE A/S MR306 "NO GROUND PLANE" MOBILE WHIP
(Courtesy Antenna Specialists Co.



A SPECIAL NOTE TO TRUCKERS: As you've no doubt already learned, the cabs of 18-wheelers are increasingly being made of fiberglass too. Because the MR306 is very narrow-banded, it's not recommended except as a last resort. The best overall solution is to use single or dual 5' or 7' PAL Firestiks on the mirrors, which do have adjustable tuning tips to compensate somewhat. (Some other brands are also tunable.) At least the doors are still metal to form a partial ground plane. The longer the whip(s), the better. Using at least a 5' whip, you can still get the SWR down to about 1.5:1. This is just about the best you can hope for in these newer trucks. And don't try compensating with a linear amp unless there's a low SWR; chances are you'll fry the Final transistor and/or the linear's power transistor(s)!

NOTES

APPENDIX A
SOLVING NOISE & INTERFERENCE PROBLEMS

There are two major types of interference that can have a great effect on CB radio operation:

1) Interference which the CB transmitter causes to other electronic equipment like TVs, stereos, telephones, VCRs, etc. (TVI and RFI.) This is generally only a problem with base station operation.

2) Interference <u>from</u> other outside sources that affects proper transceiver reception. (Automobile ignitions, electric power lines and motors, lightning crashes, etc.)

A great deal has already been written on how to locate and solve both categories of problems, mostly by guys a lot smarter than me. So I'm not going to repeat it in great detail here. Instead, we'll briefly review the subject, giving you sources for further information. It's up to you to study the reference material. Also included are pictures of the more common filter devices you should know about.

Perhaps your single best information source for the first type of problem is:

RADIO FREQUENCY INTERFERENCE: HOW TO IDENTIFY AND CURE IT. Published by the American Radio Relay League, 225 Main St., Newington CT 06111. (203) 666-1541. It's very inexpensive and it's also available from any Ham store carrying ARRL publications, like those listed in CHAPTER 1.

This great little book covers virtually all types of TVI and RFI that may be caused by HF transmitters such as CBs. It even includes photos of various TV problems so you can tell which type you are experiencing. I urge you to get this and study it completely! The ARRL RADIO AMATEUR'S HANDBOOK also covers both categories of interference problems.

Also check out the following title, which is available from the ARRL, Amazon, and others:

THE INTERFERENCE HANDBOOK, by William R. Nelson and William Orr. (1981)

INTERFERENCE FROM CB TRANSMITTERS (TVI, RFI)

There are two types of TVI: harmonic radiation, and front-end overload. Each requires slightly different filtering methods for good reduction.

Harmonic Interference

Certain American TV channels are harmonically related to the CB channels. Specifically, these are Channel 2, 5, and 9. TV Channel 2 is near 54 MHz and causes the worst problems, which is why a 54 MHz TVI trap is always included in the Final output coupling stage of a CB. The third harmonic is 81 MHz, Channel 5. And the seventh harmonic (Ch.9) falls close to 189 MHz. The strength of CB harmonics rapidly decreases with the distance from the 27 MHz fundamental.

Harmonics are reduced by placing a low-pass filter in series between the transmitter output and the antenna. This filter passes frequencies

like 27 MHz, while attenuating those signals that are above it. Hence the name. They're made with power ratings from 5-1000 watts.

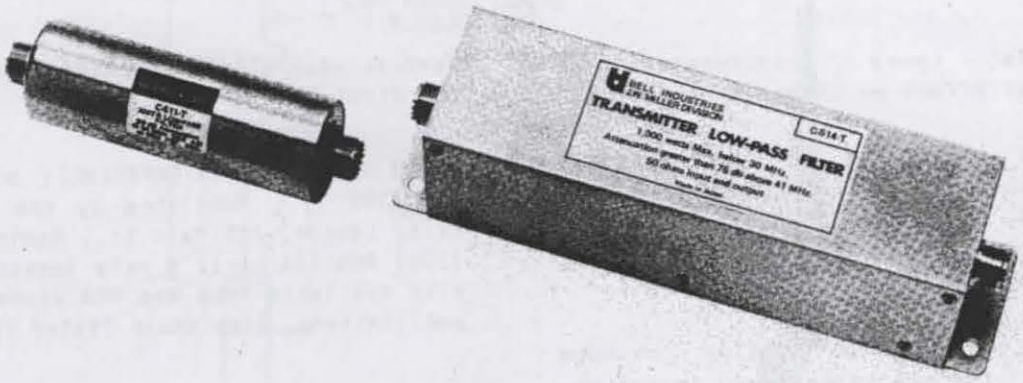
Suppliers of all types of CB filters can be found searching Google and include companies like J.W. Miller, Mouser, Digi-Key, Drake, Bencher, Kenwood, and others listed in Chapter 1, or from any good Ham dealer.

You can order directly from most of these. J.W. Miller only sells through distributors.

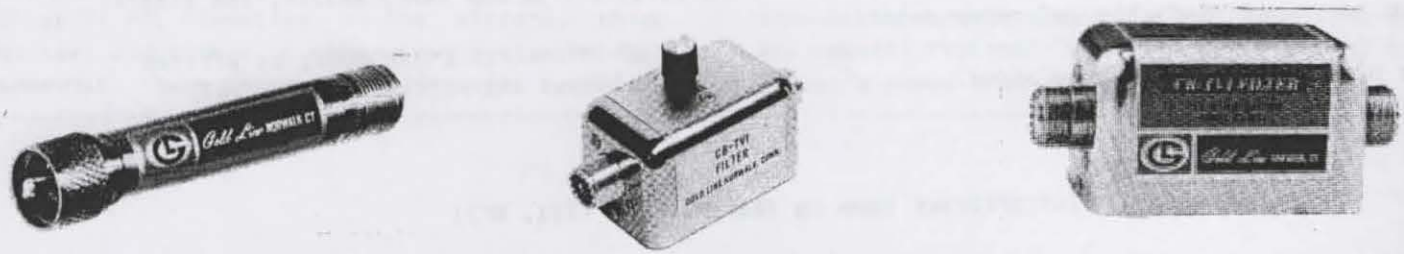
There are two very important precautions when installing any external filter:

1) Keep the connection <u>short</u>, under 4". The best way is through a double-male coax connector. This prevents coax radiation

2) The filter should be the last item in series between the CB and the antenna. Any other accessories like an SWR meter, antenna switch or matcher should be placed between the filter and the radio.



MILLER C-511-T (25 W) & C-514-T (1 KW) LOW-PASS FILTERS
(Courtesy J.W. Miller div. Bell Industries)



LOW-PASS FILTERS: #1118 (4 W, STACKABLE), #1051 (TUNABLE), #1077 (100 W)
(Courtesy Gold Line Inc.)

TV Front-End Overload

When you get interference on other channels that aren't harmonically related, the problem is usually front-end overloading. Remember, a TV channel is 6 MHz wide and its receiver is very broadbanded. Use of a linear amp or close proximity between CB and TV antennas can cause non-linear mixing, similar to IMD.

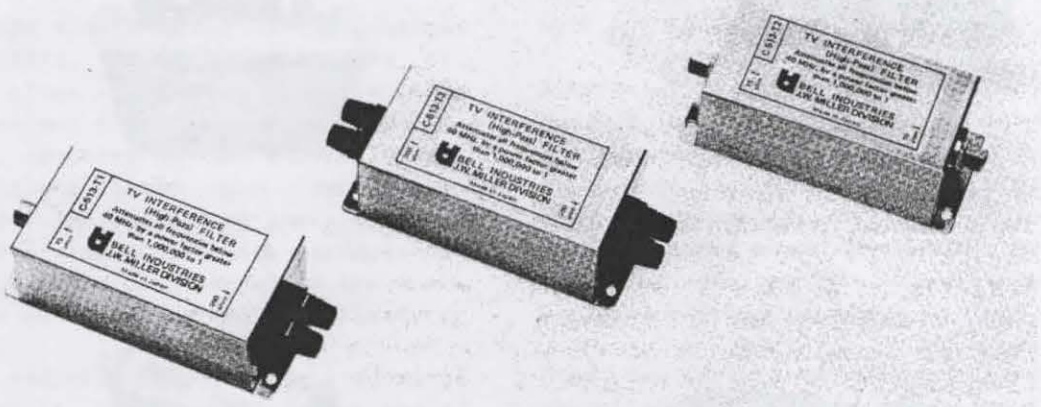
The usual cure is a high-pass filter, which is placed at the TV antenna terminals and has the opposite effect of the low-pass filter; i.e., any signals below its cutoff frequency (about 40 MHz) are attenuated. Again, keep the leads very short. Ground the filter case to the TV when applicable. CAUTION: Many TV sets have a hot chassis, so determine this first!

Another possible cure is a notch filter tuned to 27 MHz. You can make a simple LC circuit using formulas in the ARRL HANDBOOK and place it in series with the TV antenna at the set. But they're much harder to adjust, making the high-pass method more popular.

You can also try a different orientation or spacing between each antenna. Place the CB and TV antennas at different horizontal elevations above ground, and as far apart as possible.

RF can also get into the TV via the AC power lines. There are also filters made for this purpose. If the combination of CB/low-pass and TV/high-pass doesn't completely solve the problem, consider this possibility. Remember the coax isolation choke decribed on Page 348? You can make a simple AC line filter from the circuits in the ARRL books. Commercial examples are the J.W. Miller C-508-L and C-509-L.

The advent of cable has solved many of these problems because shielded coax is used. However cable TV often causes new and unique problems, especially at the individual home drop. Most CB operators seem to live in small towns or rural areas where cable isn't available. Converting the standard 300Ω twin lead over to 75Ω coax often helps. Parts are sold at do-it-yourself home building suppliers, Radio Shack, etc.



MILLER C-513-T1 (300-TO-75Ω), C-513-T3 (300Ω), & C-513-T2 (75Ω)
HIGH-PASS FILTERS
(Courtesy J.W. Miller div. Bell Industries)

Radio & Audio Interference (RFI)

This problem is caused either by overloading or mixing in the RF stages of FM tuners, or by audio rectification. The overload is very similar to TV overload. Rectification causes the CB signal to be heard in such things as speakers, telephones, or even your teeth!

Poor solder joints and poor grounding are major causes of RFI. Example: My first CB shop was in Monterey, California, in an old tin shed. And I had the incredible bad luck to be right next door to a recording studio. Combined with the salt air corrosion, guess what? My building was basically one big semiconductor, and the RFI was too hard to cure. I had to agree to do my DXing only at night, when the studio was closed.

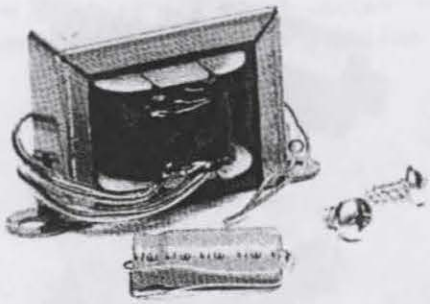
Remember that ground loops (Page 278) can be formed by using multiple grounding points. Try moving these around or changing their lengths.

I had an interesting RFI problem when moving into my current house. A leg of my 40/75 Meter dipole is stretched across the roof. The house had an AC-powered smoke detector. Every time I keyed up on 75M only, the alarm sounded. Great for group code practice! Obviously the AC wires

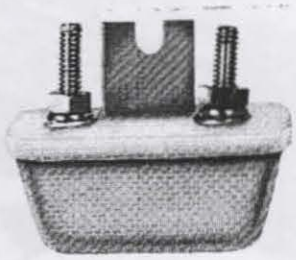
run through the attic and were overloading with RF. None of the usual filter methods worked, and I finally had to replace the smoke alarm itself with a battery-powered type.

Anything that's not absolutely at ground potential looks like a conductor to RF. For example, old electrolytic capacitors that dry out develop high internal resistance and will drop large RF voltages. Bridge a new one across anything suspicious. And don't overlook the AC power mains either. You'll often need a combination of these methods before the problem is solved. See the ARRL book for filtering examples used in many other electronic devices.

In FM tuners, determine if the RFI is before or after the VOLUME control. Rectification points before it may be a mike, tape deck, phono cartridge, etc. Points after the VOLUME control include long and/or unshielded speaker wires, which may be resonant. An 8' length is 1/4-wavelength! In any case, LC filters are usually effective. Commercial audio filters are made by J.W. Miller for stereo amp inputs (#C-505-R) and speaker lines (C-506-R). In tough cases you may actually have to get inside an amp and put ferrite beads and/or bypass capacitors right at the appropriate transistor or IC.

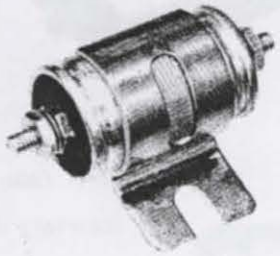


HOT LEAD IGNITION NOISE FILTER
(Courtesy Gold Line Inc.)



FEED-THRU TYPE SUPPRESSOR FILTER
(Courtesy Gold Line Inc.)

ALTERNATOR & GENERATOR FILTER
(Courtesy Gold Line Inc.)



COAXIAL TYPE BYPASS CAPACITOR
(Courtesy Gold Line Inc.)

INTERFERENCE TO CB RADIO RECEIVERS

This problem can be very annoying because it masks weak signals, especially on AM or SSB. FM reception has the advantage of amplitude noise reduction so it's not as noticeable. One of the best preventative measures is to start with a good radio having an RF/IF type Noise Blanker.

Automotive Ignition Noise

The hissing, "frying eggs" sound heard in many AM mobile receivers is ignition noise. It gets louder with higher engine RPM and is caused by the high-voltage discharge of the spark plugs

as they fire. The reason it can be so irritating to CB operation is because such noise is broadbanded in nature, having its maximum energy around 35 MHz. Not very far from the CB band! This explains why your AM/FM car radio works fine but the CB may not; broadcast signals are much further removed from 27 MHz.

Ignition noise can get into the CB either by conduction in the vehicle's electrical system, or by radiation. Conduction is the most common. The way to determine this is to simply replace the CB antenna with a dummy load; if the noise is still present, it's being conducted.

You can pinpoint the noise source with a simple RF probe. Take a length of RG58/U coax with a PL259 at one end, and long enough to reach from the radio to the engine. Strip a few inches of the shield away from the other end. Use this center conductor end to probe around the engine compartment for the point of loudest noise.

Most vehicles had simple inductive discharge systems before 1975. In such cases the use of resistive spark plugs and wires could cure the problem. You can buy these at most auto parts suppliers. Newer vehicles now use sophisticated electronic ignitions based upon capacitive discharge action. The wires must therefore be relatively low resistance or engine performance suffers. Don't replace plugs or wires in such vehicles without consulting a mechanic first.

In the case of radiated noise, good grounding will usually stop it. First make sure the radio and antenna are properly grounded. Then get some heavy ground braids, or make your own using the shield of old RG8/U coax with its center removed. Bond all the major metal surfaces together, such as the hood to the firewall and the exhaust pipes to the frame. Replace any wire that seems to be radiating with a shielded one. Any poorly grounded metal of the right length can resonate, generating RF noise. And don't overlook a possible bad plug, dirty rotor, or cracked distributor cap.

Poor grounding is the main reason why magnetic CB antennas don't work well. Changing from a mag mount to a grounded type can be all that's needed to eliminate ignition noise in a CB.

Many people try to eliminate ignition noise by using a coax cable for the DC power to the radio, running it through the firewall directly to the battery. This sometimes works but often does not, because the noise is being radiated, not conducted. Besides, with a constant DC power source like this you must always remember to turn the radio off manually or it could wear down the battery. Conducted noise can only be stopped at its source, as described next.

Other Automotive Interference

Any electrical device on a car can cause noise, such as the fuel pump, gauges, wiper or blower motors, voltage regulator or alternator. These sources can generally be controlled with bypass capacitors and series chokes, but first you must identify the sources.

Alternator or generator whine is a high-pitched musical sound that increases with engine RPM. Voltage regulators make a ragged or raspy noise which is irregular. Gauge sending units and fuel pumps make an irregular clicking noise. "Switch pops" can be caused by switching electrical devices like brake lights, seat belt buzzers, electric windows, or turn signals.

Once you isolate the source, install a bypass capacitor at its power leads. The coaxial type is more effective at HF and VHF than standard disc types, so invest the extra money. If the problem persists, add series inductance of a suitable current rating, or shield the wire. The same type bypass capacitor can also be used on the radio's positive DC power lead.

Good sources for multi-stage DC power line filters include Radio Shack, most good computer stores, and many others.

APPENDIX B

FCC FREQUENCY CHART

The following shows channel assignments and their ±.005% tolerances.

CHANNEL	FREQUENCY (MHz)	LOWER LIMIT	UPPER LIMIT
CH. 1	26.965	26.963651	26.966348
CH. 2	26.975	26.973651	26.976348
CH. 3	26.985	26.983650	27.986349
CH. 3A*	26.995	27.993650	26.996349
CH. 4	27.005	27.003649	27.006350
CH. 5	27.015	27.013649	27.016350
CH. 6	27.025	27.023648	27.026351
CH. 7	27.035	27.033648	27.036351
CH. 7A*	27.045	27.043647	27.046352
CH. 8	27.055	27.053647	27.056352
CH. 9	27.065	27.063646	27.066353
CH. 10	27.075	27.073646	27.076353
CH. 11	27.085	27.083645	27.086354
CH. 11A*	27.095	27.093645	27.096354
CH. 12	27.105	27.103644	27.106355
CH. 13	27.115	27.113644	27.116355
CH. 14	27.125	27.123643	27.126356
CH. 15	27.135	27.133643	27.136656
CH. 15A*	27.145	27.143642	27.146357
CH. 16	27.155	27.153642	27.156357
CH. 17	27.165	27.163641	27.166358
CH. 18	27.175	27.173641	27.176358
CH. 19	27.185	27.183640	27.186359
CH. 19A*	27.195	27.193640	27.196359
CH. 20	27.205	27.203639	27.206360
CH. 21	27.215	27.213639	27.216360
CH. 22	27.225	27.223638	27.226361
CH. 23	27.255	27.253637	27.256362
CH. 24	27.235	27.233638	27.236361
CH. 25	27.245	27.243637	27.246362
CH. 26	27.265	27.263636	27.266363
CH. 27	27.275	27.273636	27.276363
CH. 28	27.285	27.283635	27.286364
CH. 29	27.295	27.293635	27.296364
CH. 30	27.305	27.303634	27.306365
CH. 31	27.315	27.313634	27.316365
CH. 32	27.325	27.323633	27.326366
CH. 33	27.335	27.333633	27.336366
CH. 34	27.345	27.343632	27.346367
CH. 35	27.355	27.353632	27.356367
CH. 36	27.365	27.363631	27.366368
CH. 37	27.375	27.373631	27.376368
CH. 38	27.385	27.383630	27.386369
CH. 39	27.395	27.393630	27.396369
CH. 40	27.405	27.403629	27.406370

*Unassigned "A" channels; not legal CB frequencies. See CHAPTER 3.

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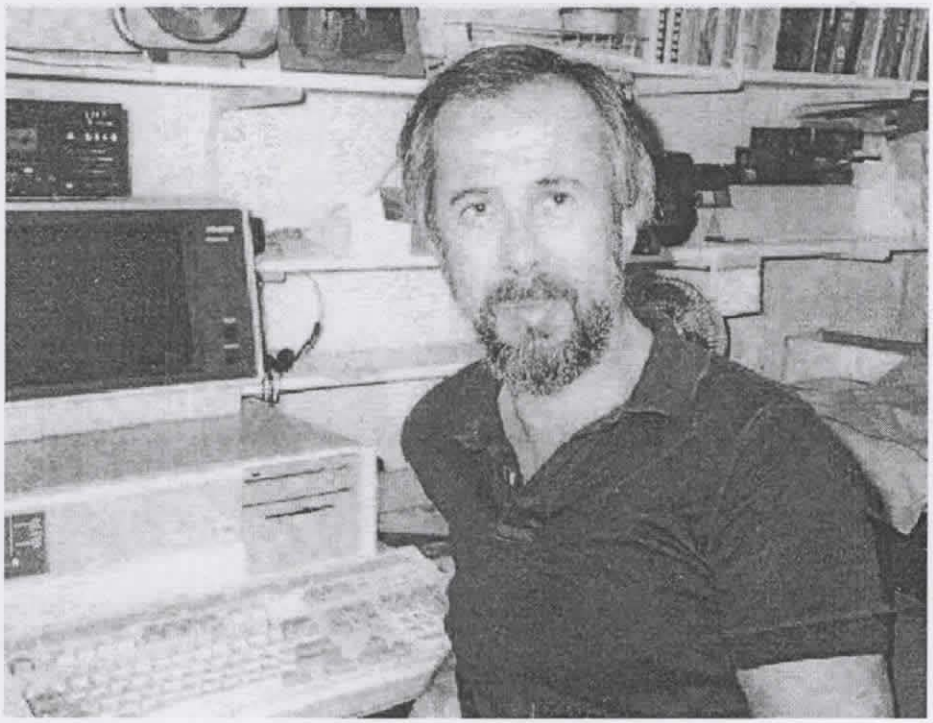

ABOUT THE AUTHOR

Lou Franklin is a radio nut. He began at age five with two tin cans and a string, but soon discovered his range was very limited. "I need more power!" he cried. It was at his first AM broadcast job that Lou discovered "skip." He would hang around there alone late at night after signoff, firing up the 10KW daytime transmitter. When letters from Broadcast DXers poured in from all over the country asking for QSL cards, the management got suspicious, so Lou moved on. He tried his hand at more broadcasting, Ham radio, and commercial mobile radio, and still has the RF burn scars to prove it. Then came that fateful day in 1974 at a large California truck stop, where Lou discovered CBs, 100-Mile Coffee, cowboy boots, and cordless soldering irons. His last try at a real job was repairing satellite navigation equipment, but he got horribly seasick the first time out of port. This ended yet another promising electronics career, so he decided to just write about it instead.

UNDERSTANDING & REPAIRING CB RADIOS

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Lou Franklin writes in a very informal, down-to-earth style which has made his previous CB technical publications the "bibles" of this field. There's no complicated math or electronic theory here; just practical, common CB circuits explained in the simplest possible way. Hundreds of schematics, charts, and drawings help make this the most complete reference available on the subject.

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USA $69.95
ISBN 0-943132-24-X