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:

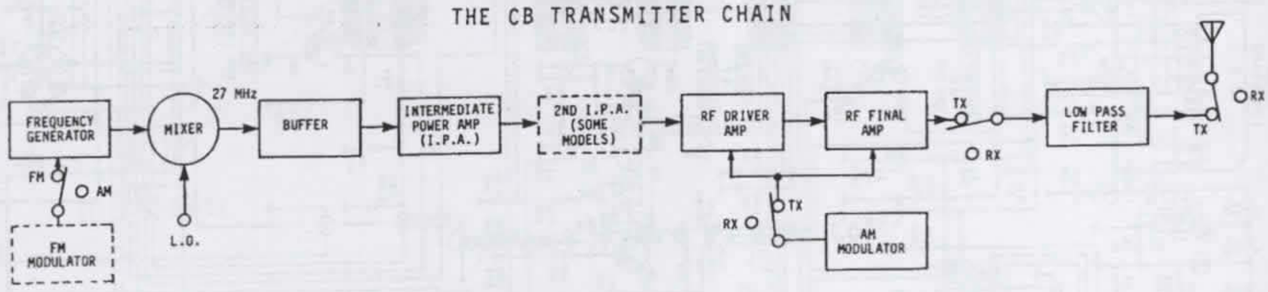
1. No RF output.
2. Weak RF output.
3. Intermittent RF output; quits when warmed up (or cold).
4. Unequal RF power output progressing across the CB frequency band.
5. Blows fuses.
6. Self-oscillation or instability.
7. Interference to other electronic equipment or nearby CB channels (RFI), or television 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)

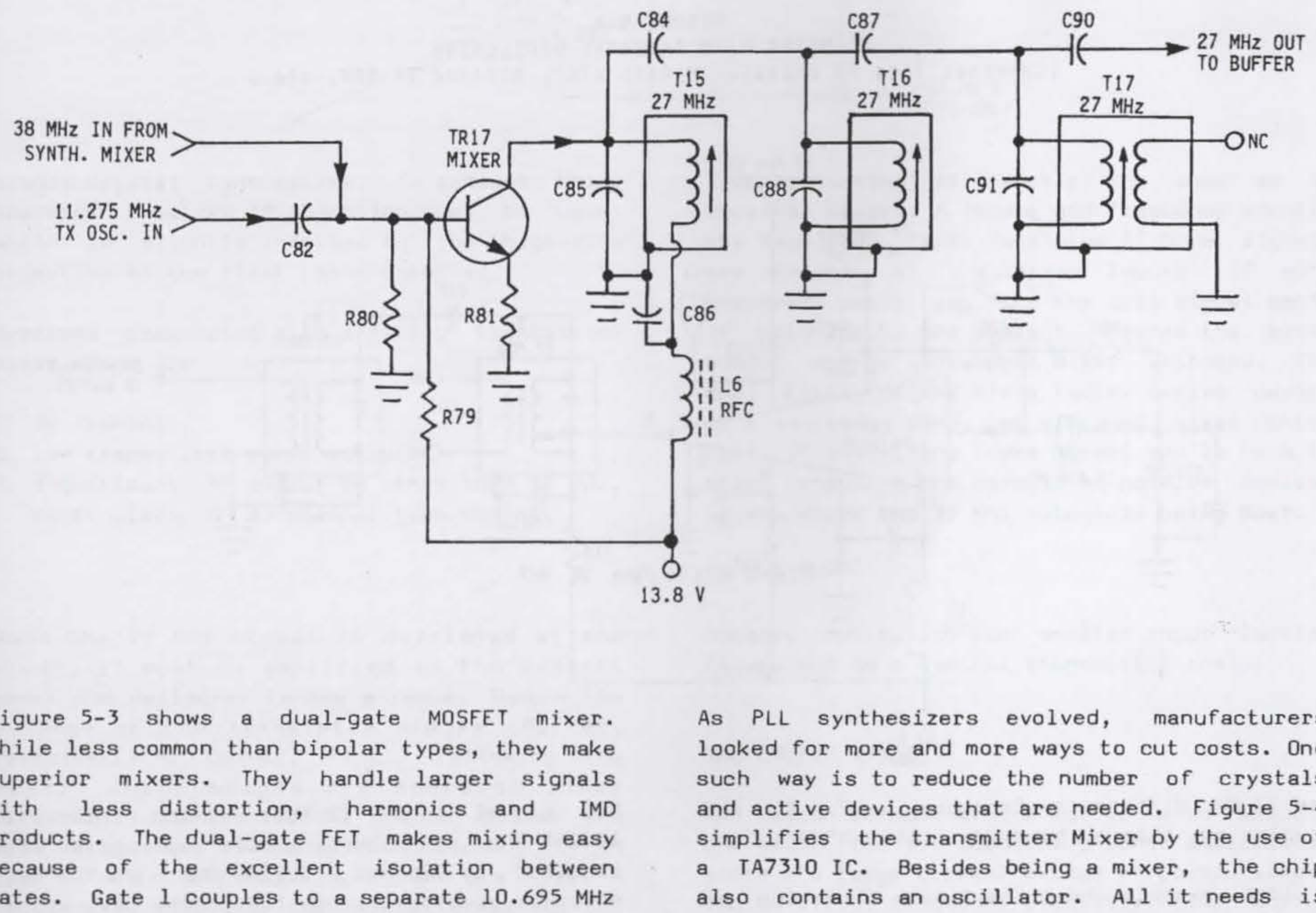


Figure 5-3 shows a dual-gate MOSFET mixer. While less common than bipolar types, they make superior mixers. They handle larger signals with less distortion, harmonics and IMD products. The dual-gate FET makes mixing easy because of the excellent isolation between gates. Gate 1 couples to a separate 10.695 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.)

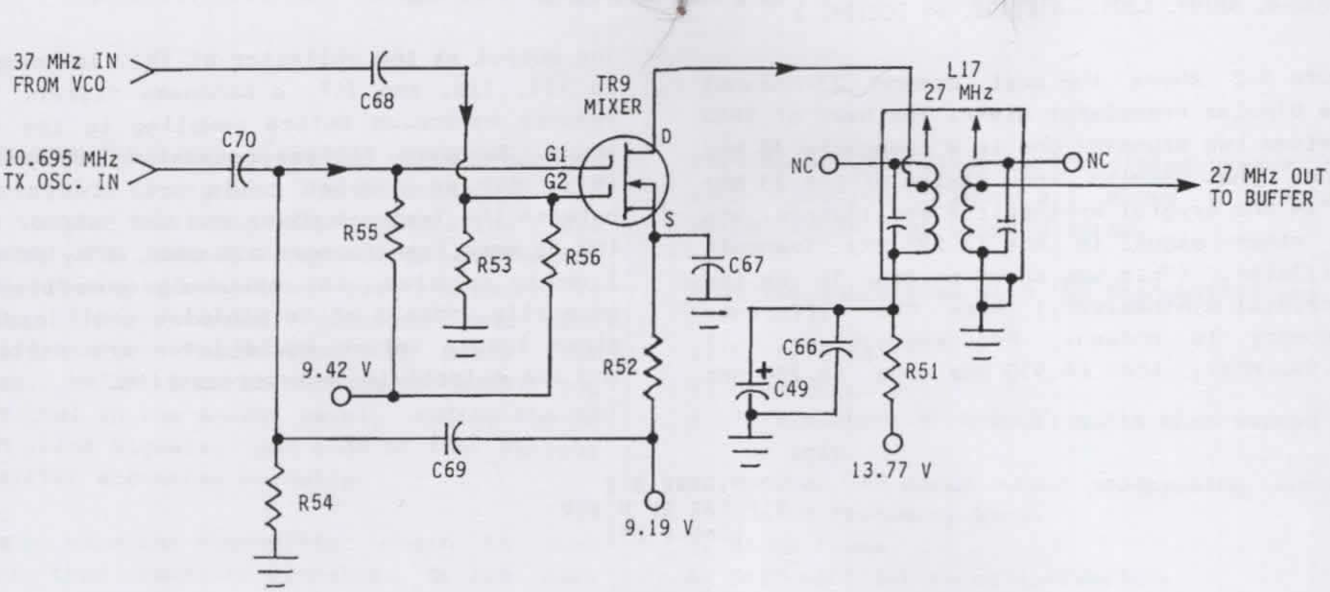
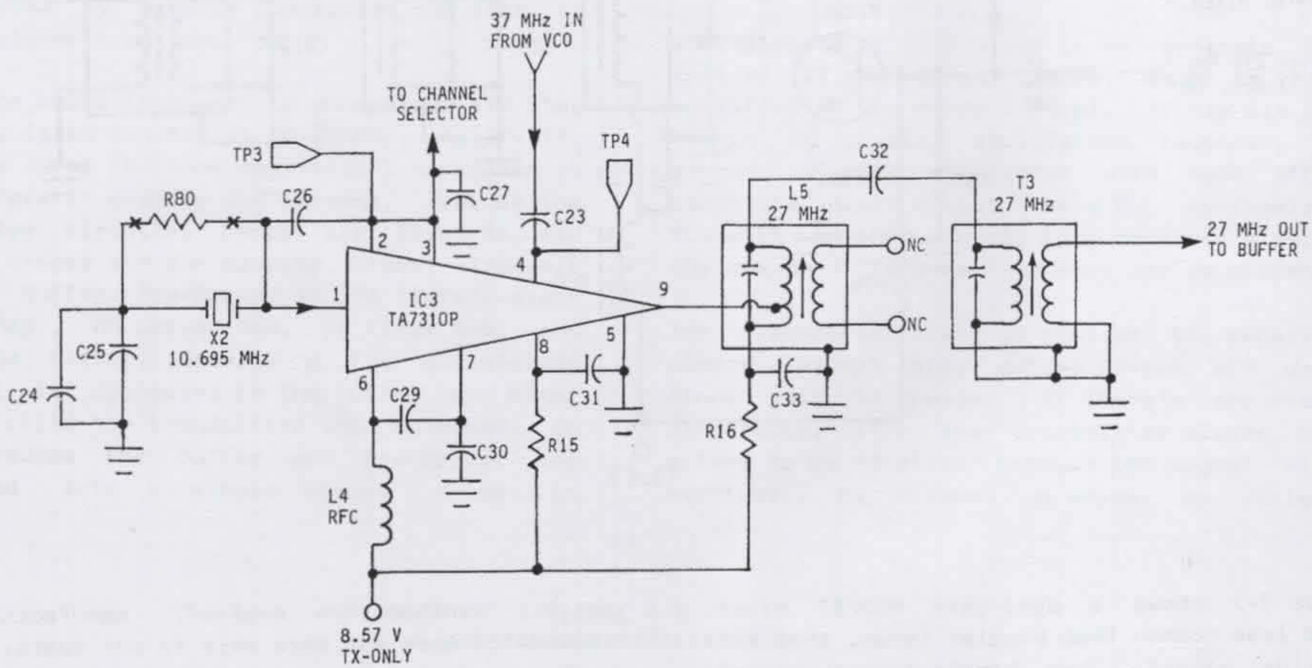


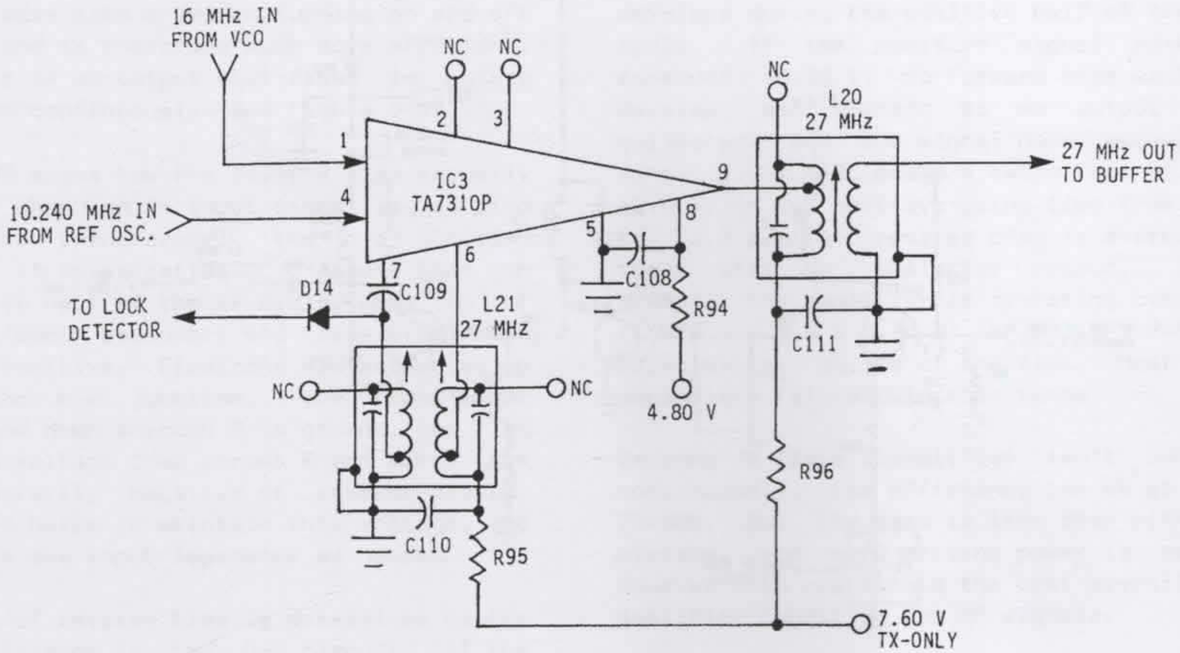
FIGURE 5-4
IC MIXER WITH INTERNAL OSCILLATOR
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)



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.

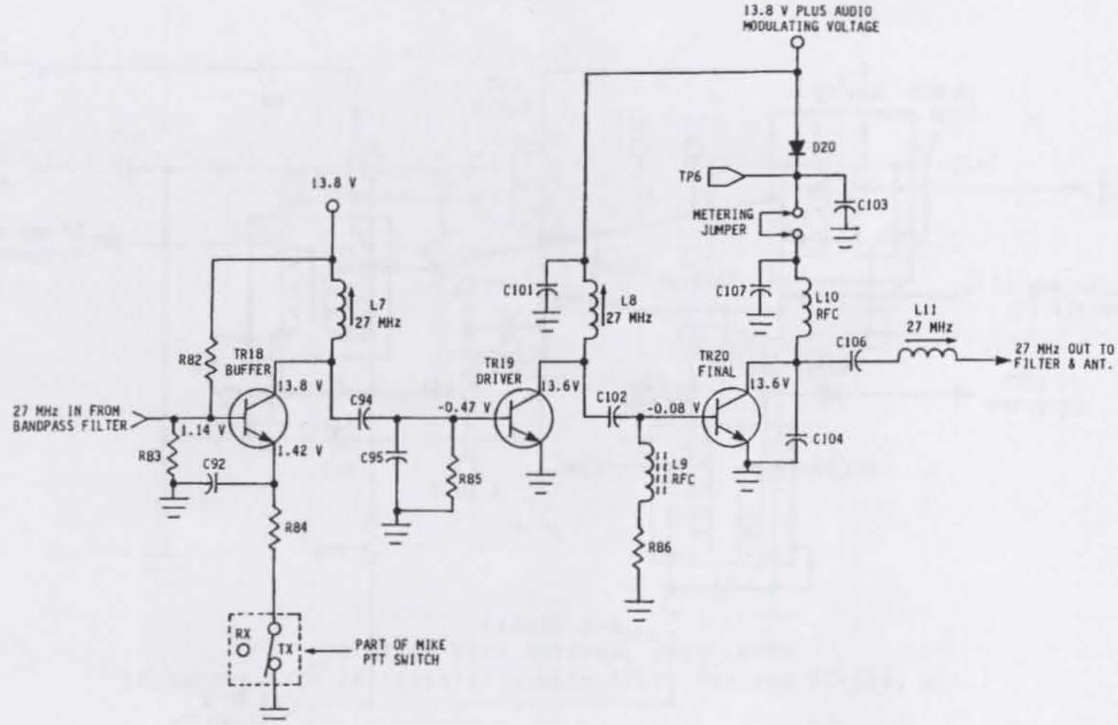
THE RF AMPLIFIER CHAIN

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.)

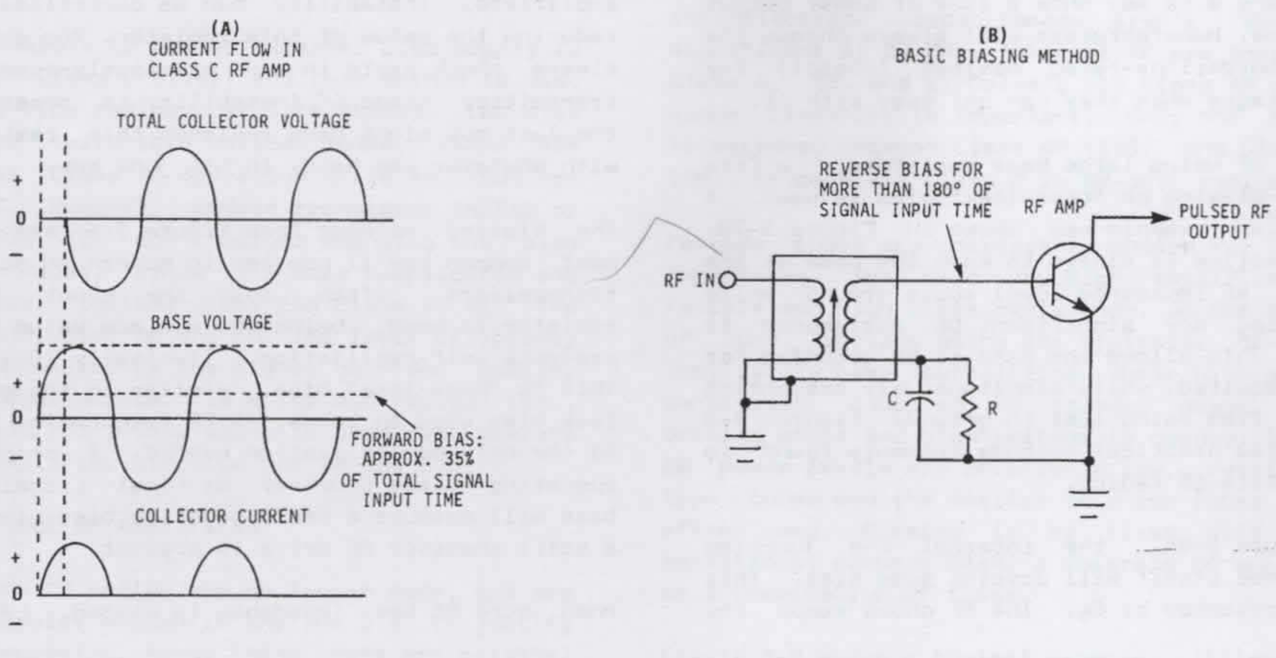
For example, assume a 2.0 V P-P RF signal is applied to the b-e junction, and the b-e resistance is such that a bias of -0.30 V develops during the positive half of the input cycle. If the positive signal peak never exceeded +0.30 V, no forward bias would ever develop and there'd be no output at the 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 <u>continuous</u> 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.)

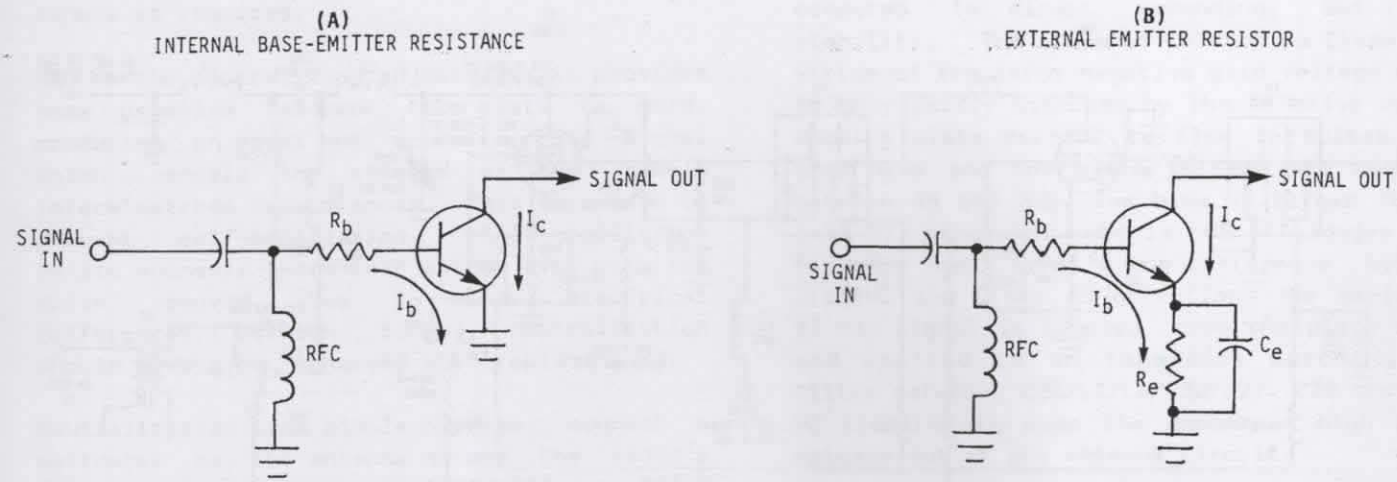


Figure 5-6 could be (and often is) replaced with a ferrite bead directly on the base lead of TR20 before soldering into the PC board. Beads are used for neutralizing at power levels over about 0.5 watt (Driver and Final), since they don't add any significant DC resistance to these high-current stages. 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

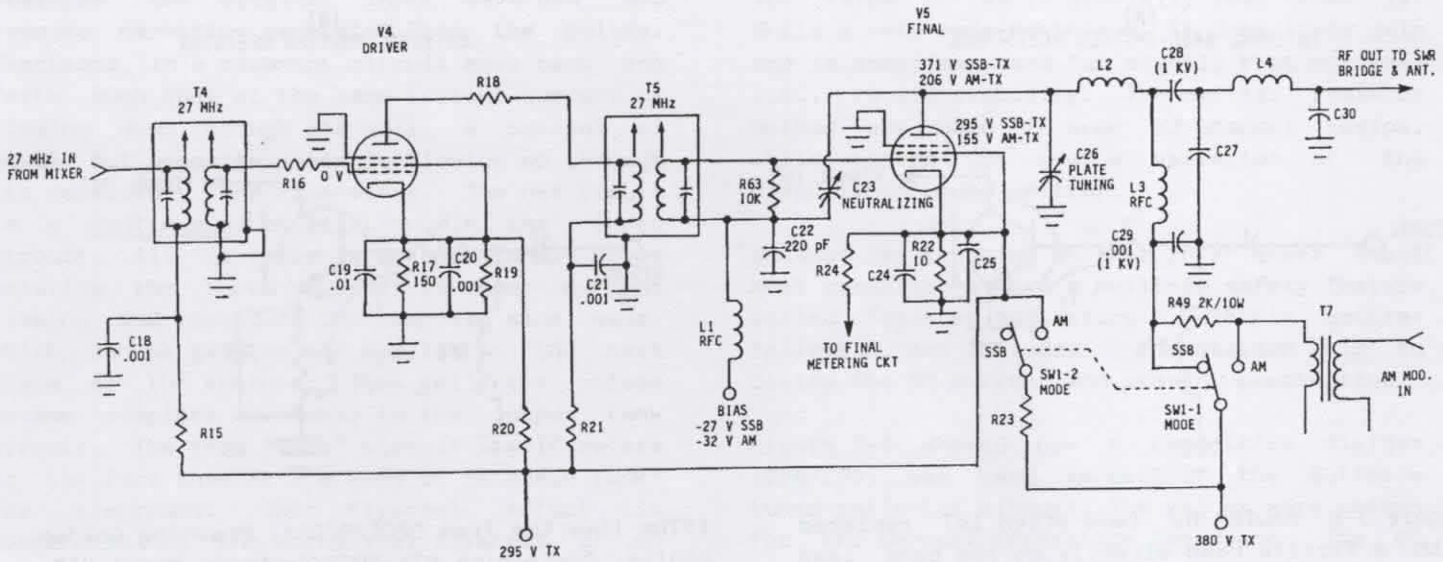
Tube-type CB radios are no longer made, but are still popular enough in the the U.S. to justify some discussion. Among these types are original 3- and 6-channel models from the 1960s, and the synthesized 23-channel radios from the 1970s like the Tram D201/D201A, Browning Golden Eagles, Gemtronics GTX-5000/Teaberry 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.

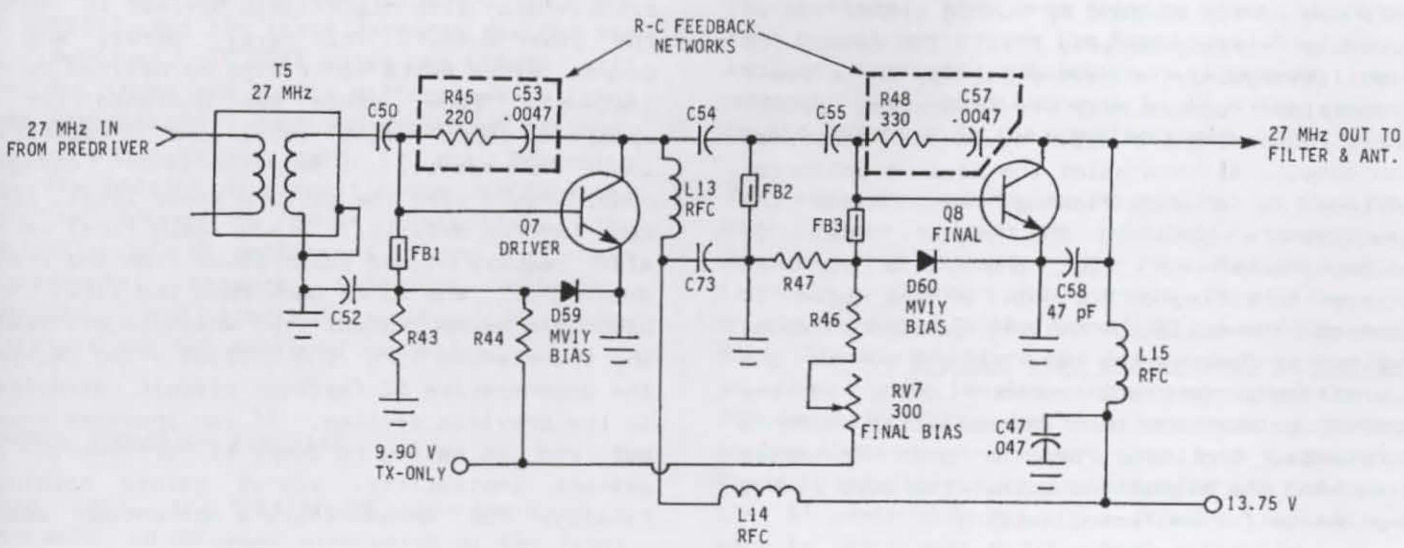
C23 is the neutralizing adjustment; it provides some negative feedback from plate to grid, producing an equal but opposite-phase signal which cancels the effects of the tube's interelectrode capacitances. This is needed to prevent self-oscillation. Self-oscillation exists whenever there's RF output even 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 <u>fatal</u>! 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 <u>shortest</u> 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, <u>but not as fast as the base current</u> 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 <u>rarely</u> 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 <u>identical</u> 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 <u>not</u> 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

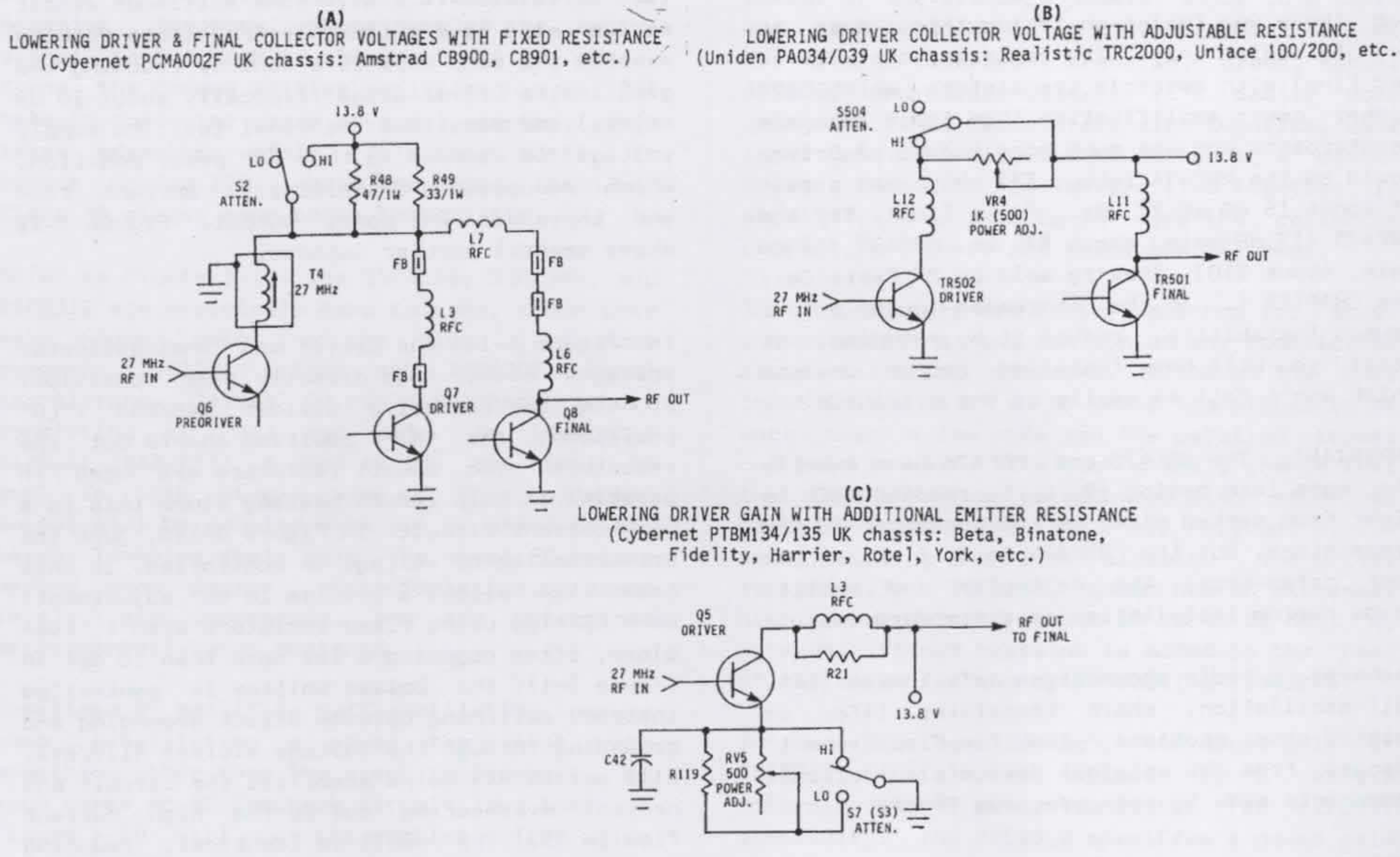
Before 1987, the British CB specs required a switchable 10 dB power attenuator at the front panel. (The new FCC-channel UK radios don't.) So older UK-FM equipment is switchable from LOW (0.4 W) to HIGH (4.0 W). Some multimode export radios also have switchable RF outputs working exactly the same way. 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



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 <u>specific</u> input impedance, which obviously changes with changing radio power output.

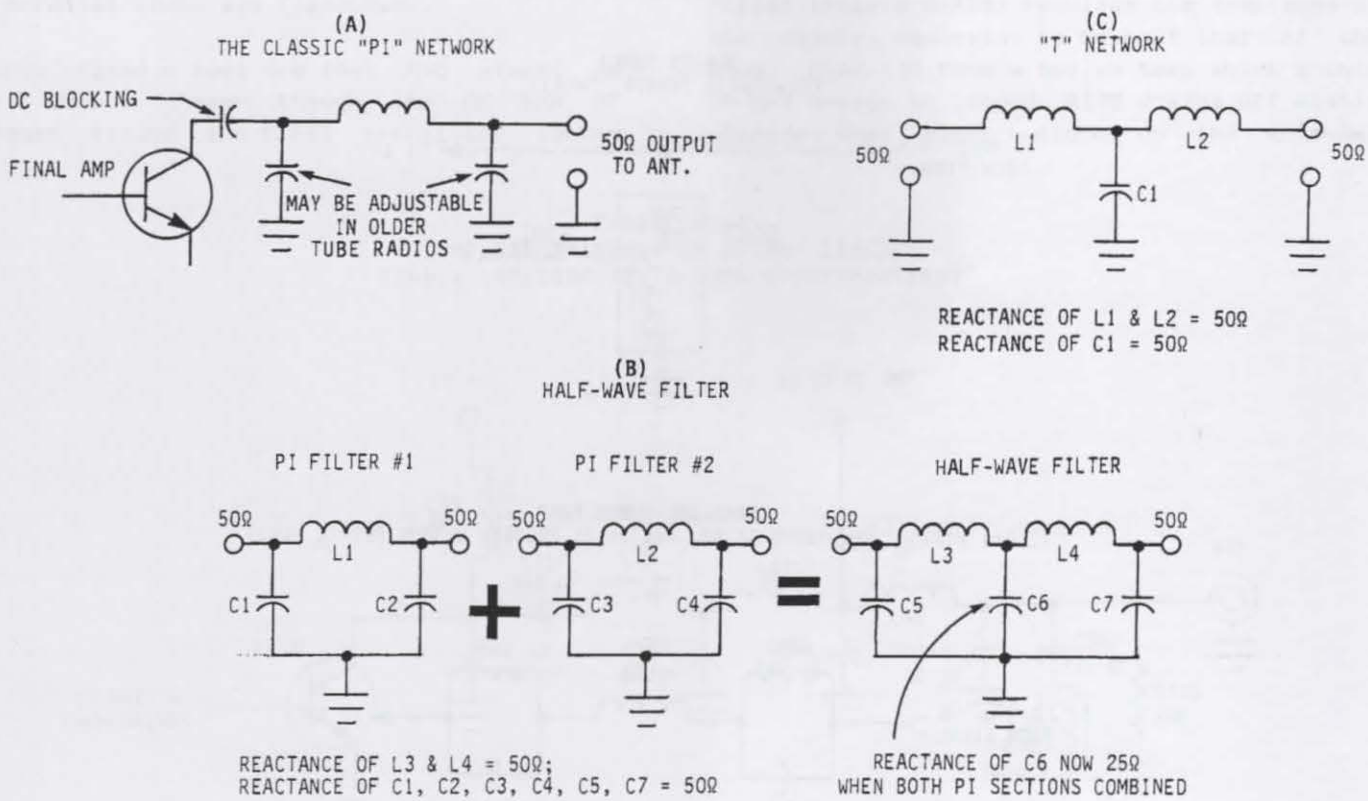
The Pi Network

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.

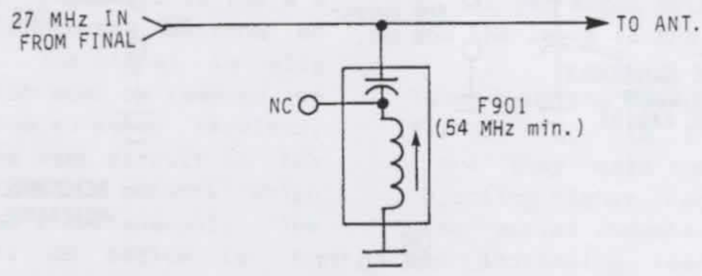
It's important to understand the subtle meaning of this idea. If a load (like the antenna) has any reactance, this effects the performance of any accessory items that may be in series between it and the radio. Add-ons like external low-pass filters or SWR meters will not work right and will actually 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.

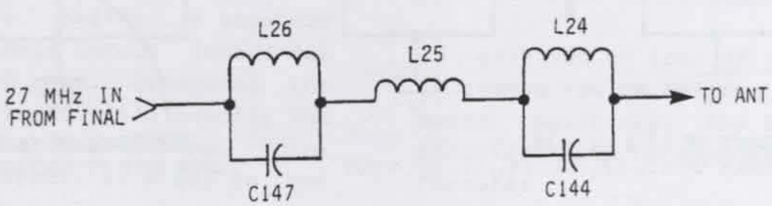
Because filter inductors require small values, they're air-wound; using magnetic cores would increase the inductance. Low-permeability tuning slugs are sometimes included though to optimize impedances and power transfer. Whether or not a coil is adjustable really depends upon its loaded Q, which when 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

SERIES TUNED
(Realistic TRC424, TRC431)



PARALLEL-TUNED TRAP
(Cobra 146GTL, President AR144, Realistic TRC451, Uniden PC244, etc.)



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.

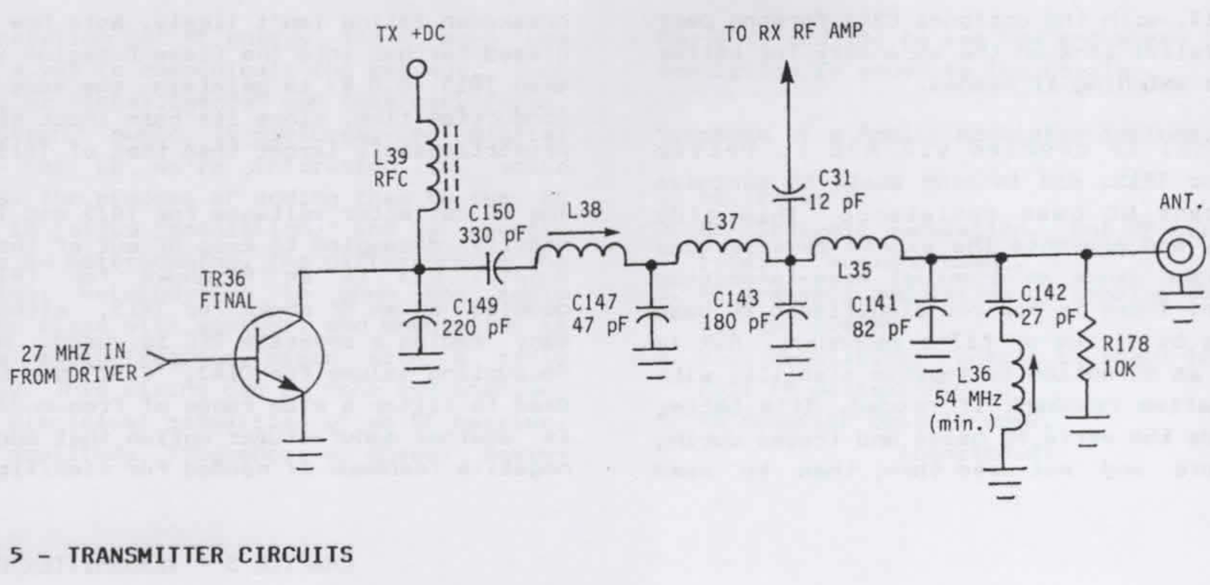
As shown in Figure 5-13, the trap may be either a series or parallel type. A series circuit presents a very low impedance at resonance and a parallel circuit a very high impedance. The series circuit will therefore shunt the 54 MHz energy to ground, while the parallel circuit blocks it from passing to 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 <u>double</u> 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.

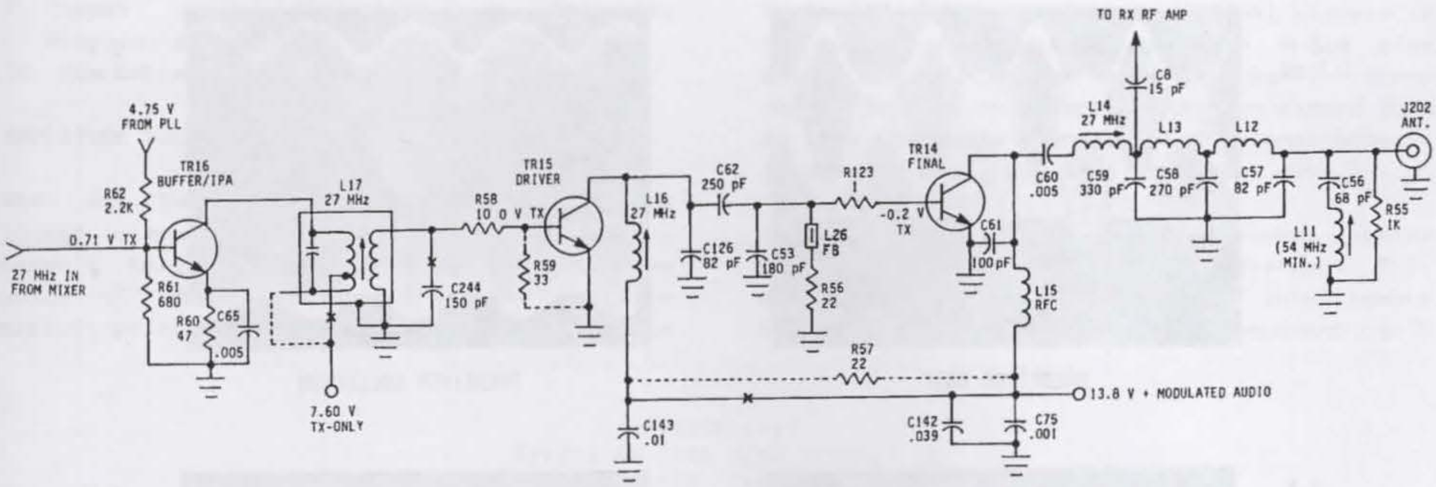
The signal is coupled via R58 to Driver transistor TR15. R58 is made small to minimize significant DC base resistance. This aids stability and prevents the excess reverse bias that might cause an eventual base-to-emitter breakdown. There is however significant RF base impedance by virtue of L17's secondary. 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

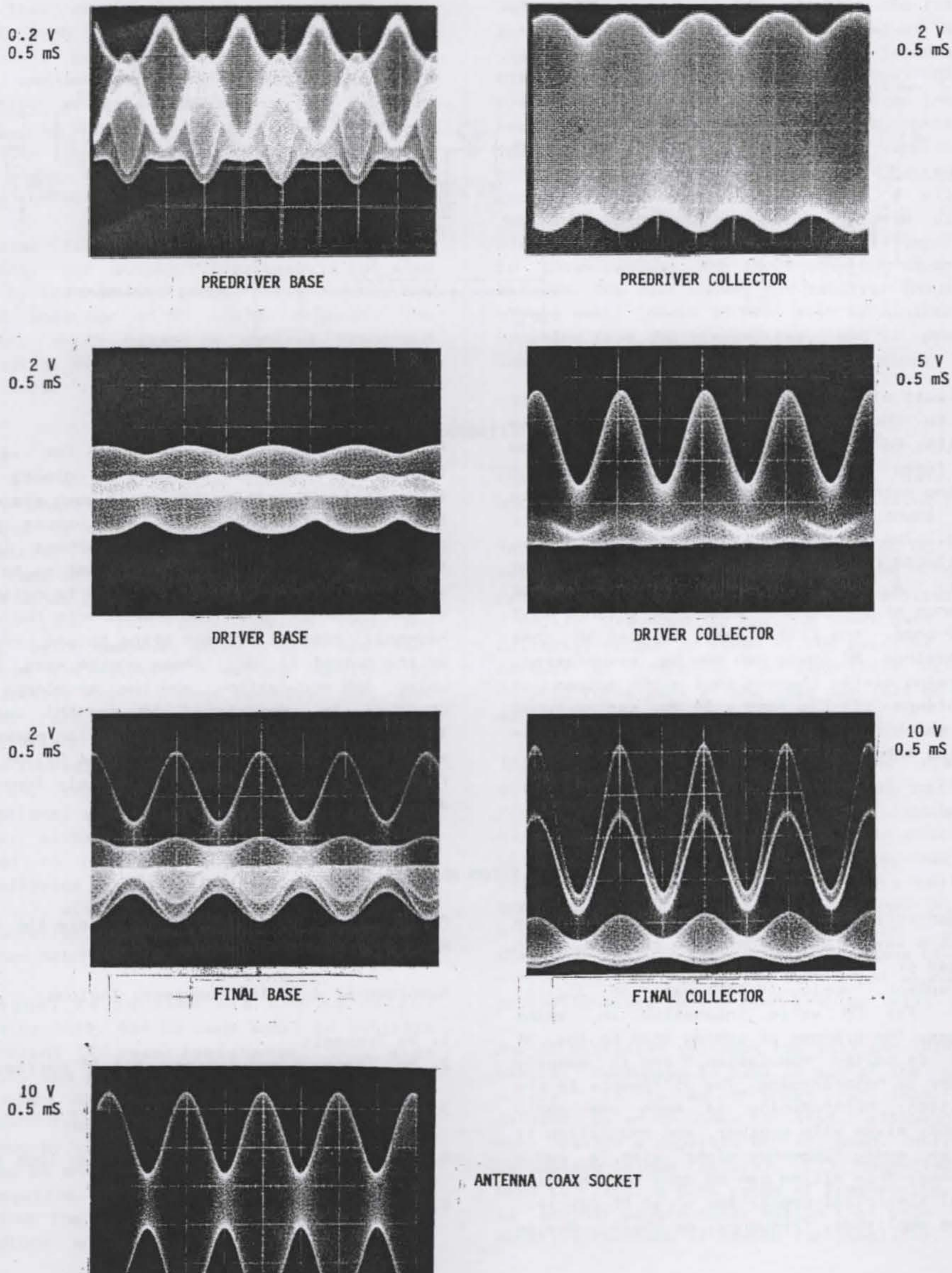
The generation of RF energy isn't much use without a way to communicate the message. Such messages or "intelligence" can take many forms, like speech, music, TV pictures, or digital data. For CB we're interested in voice messages. The process of adding them to the RF signal is called "modulation," and 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 <u>audio</u> 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)



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.

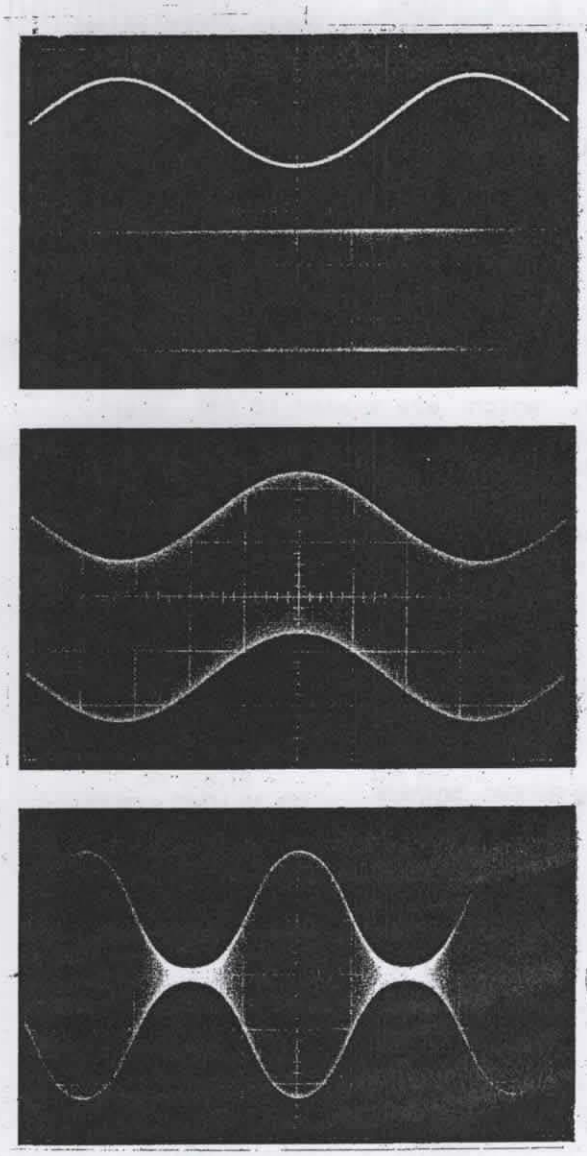
AMPLITUDE MODULATION

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.

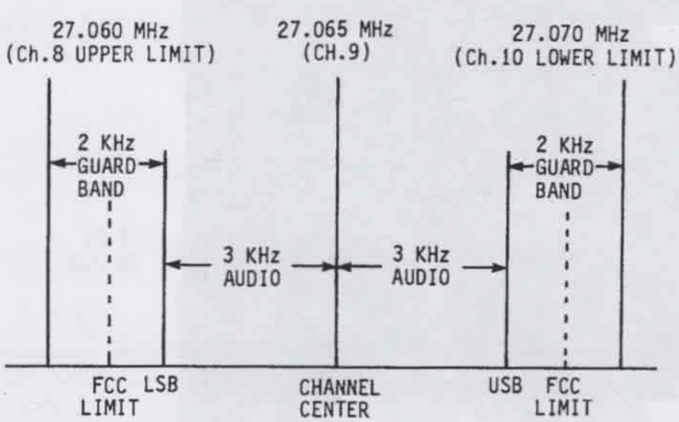
By mixing these two signals in a non-linear device like a Class C amplifier instead, the result is Photo "C." This is the familiar AM modulation envelope. The signal is now entirely at radio frequencies, but its strength or amplitude is changing at an audio rate. When an audio frequency controls the 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

FIGURE 5-18
SPECTRUM DISTRIBUTION OF AM CB SIGNAL



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.

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.

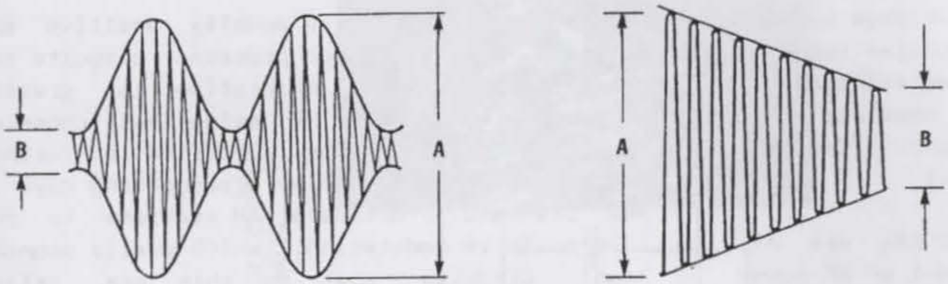
It's possible to increase the current flow indefinitely, up to the limit of the circuits to handle this extra power. But you can never decrease it to less than zero. Thus the modulated RF signal can be increased beyond 100% positive modulation, but negative modulation of more than 100% is impossible.

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.

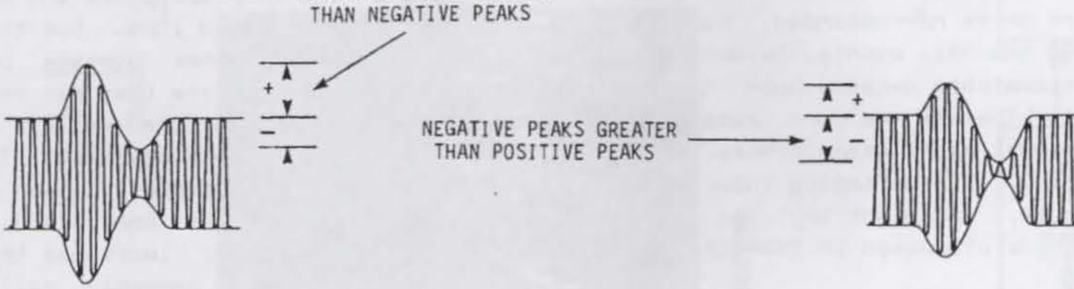
FIGURE 5-19
MEASURING MODULATION PERCENTAGE
(Courtesy McGraw-Hill Book Co.)



ENVELOPE METHOD TRAPEZOIDAL METHOD

$$\%MODULATION = \frac{A - B}{A + B} \times 100$$

FIGURE 5-20
CARRIER SHIFT
(Courtesy McGraw-Hill Book Co.)



POSITIVE CARRIER SHIFT NEGATIVE CARRIER SHIFT

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 <u>very</u> 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, <u>not</u> 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 <u>maximum</u>, 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. <u>Don't</u> rely on the radio's S/RF or SWR meter (or external SWR meter), since these circuits can't show modulation properly.

Speech Processing

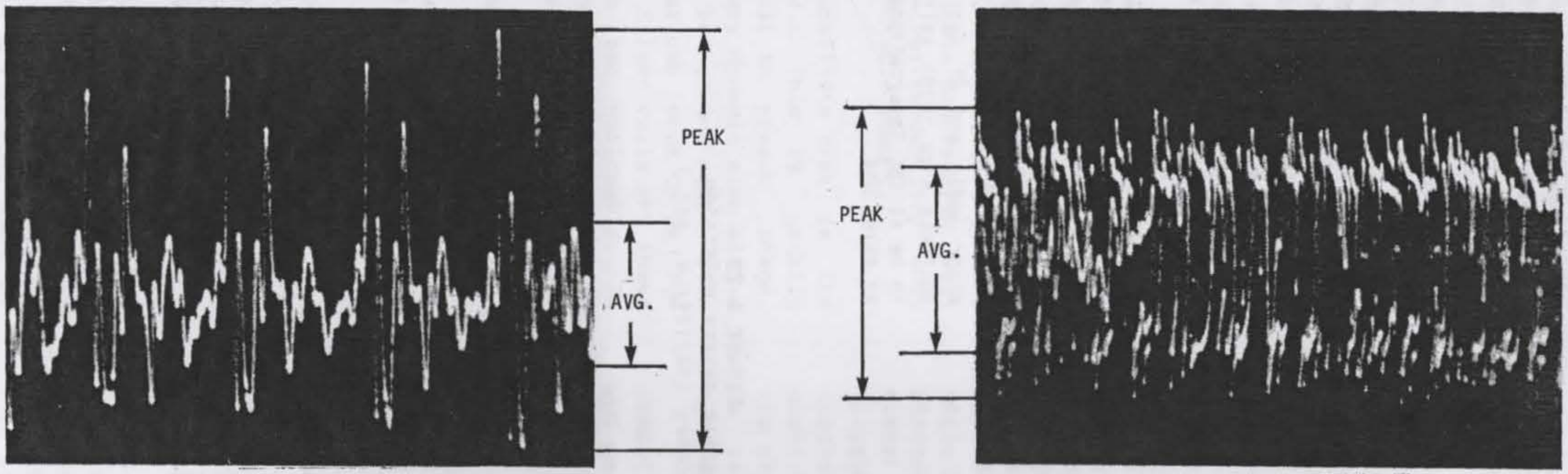
Normal AM signals are equally positive and negative. Special speech processor circuits can produce asymmetrical modulation to greatly increase signal power. By selectively choosing the frequencies to be amplified a further improvement is made. In my broadcasting days it was standard practice at AM stations 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 <u>ratio</u> of the envelope peaks and valleys so the peaks never exceed 100%, but the valleys have considerably higher <u>average</u> 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

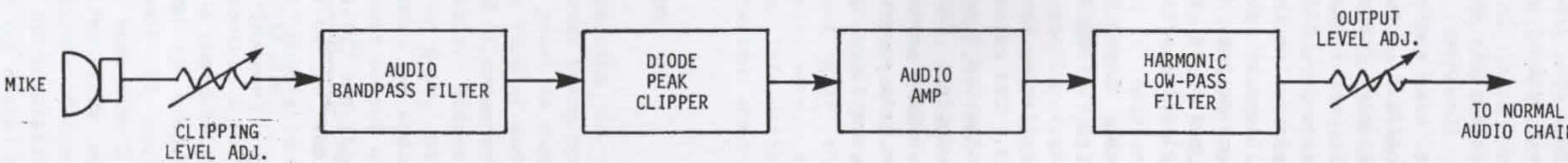
FIGURE 5-21
SPEECH PROCESSING

(A)
GRAPHIC ILLUSTRATION OF HOW AUDIO (OR RF) CLIPPING
LOWERS AVERAGE-TO-PEAK POWER RATIO



BEFORE PROCESSING **AFTER PROCESSING**

(B)
BLOCK DIAGRAM OF AUDIO CLIPPER CIRCUIT



of handling the increased duty cycle and current drain without overheating.

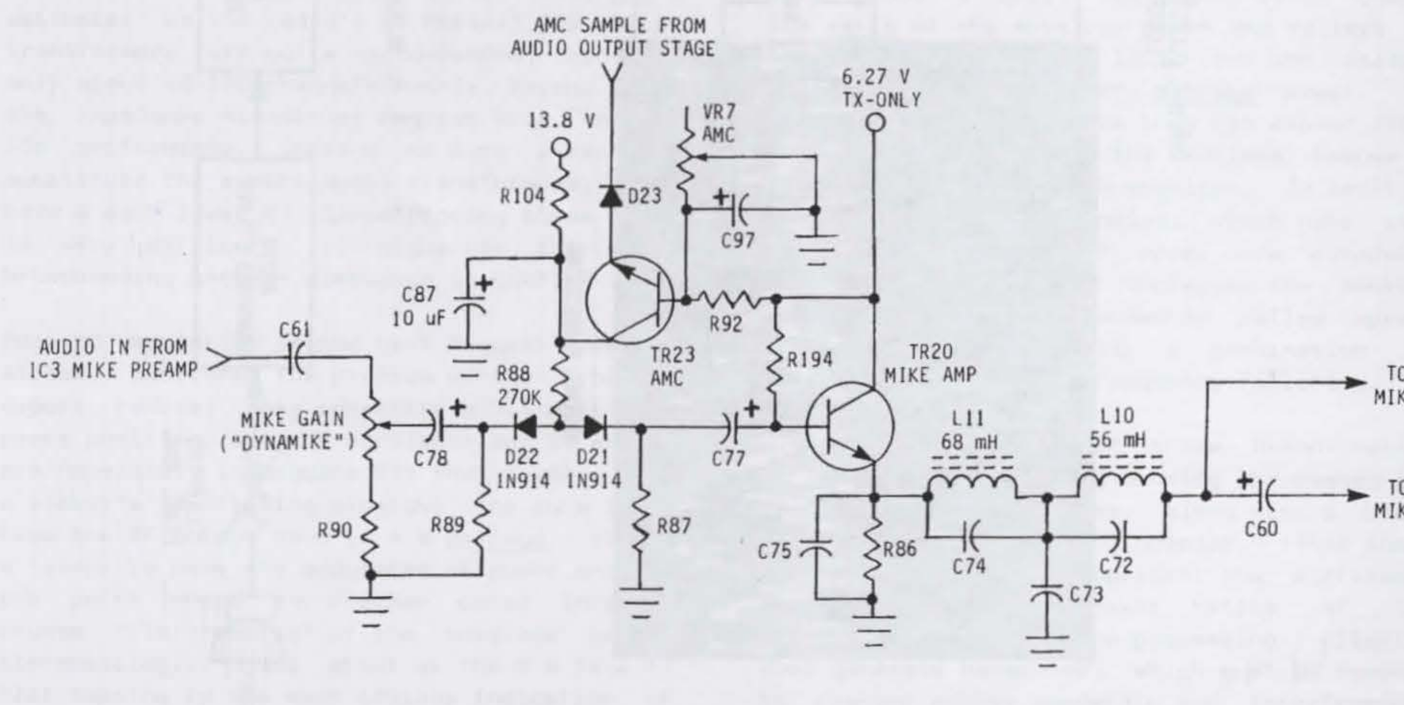
A clipper circuit is shown in Figure 5-22. The MIKE GAIN (DYNAMIKE) sets the input clipping level; the mike audio at this point has been greatly amplified. Audio is applied to a pair of fast switching diodes, D21/D22. D22 conducts on negative modulation peaks, developing a voltage across R89. D21 and 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: $1/2 \times 1/2 = 1/4$. 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 × 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.

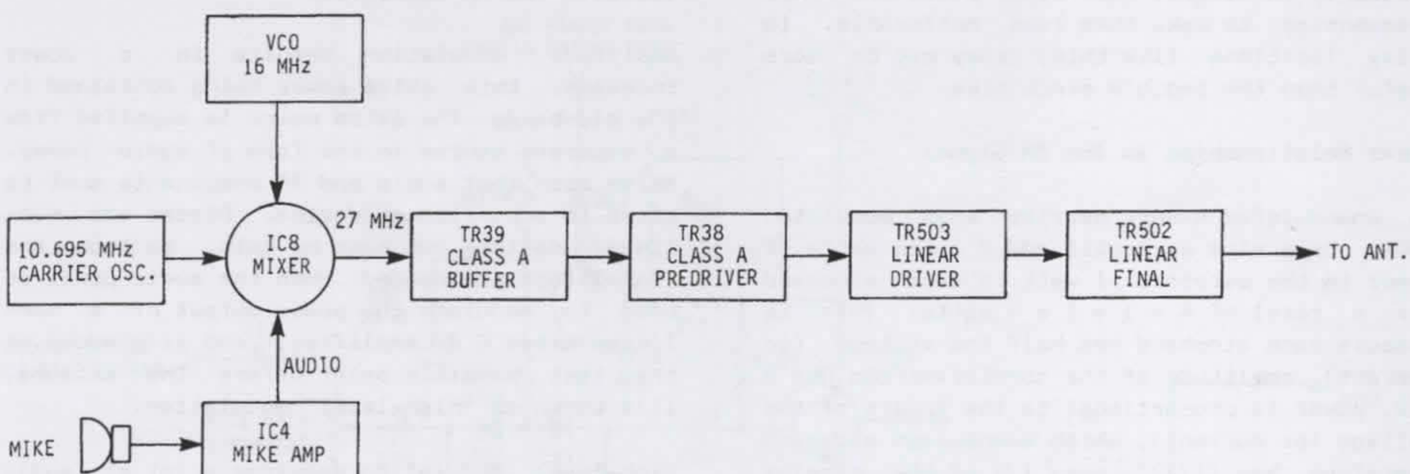
About the only CBs using this method are the CPI types (CP2000, CP300/400) and the Uniden President Jackson. The CPI chassis were designed from the ground up. They used very sophisticated audio circuits, for which they charged a premium price and put themselves right out of business. However Uniden found 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 <u>and</u> 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)

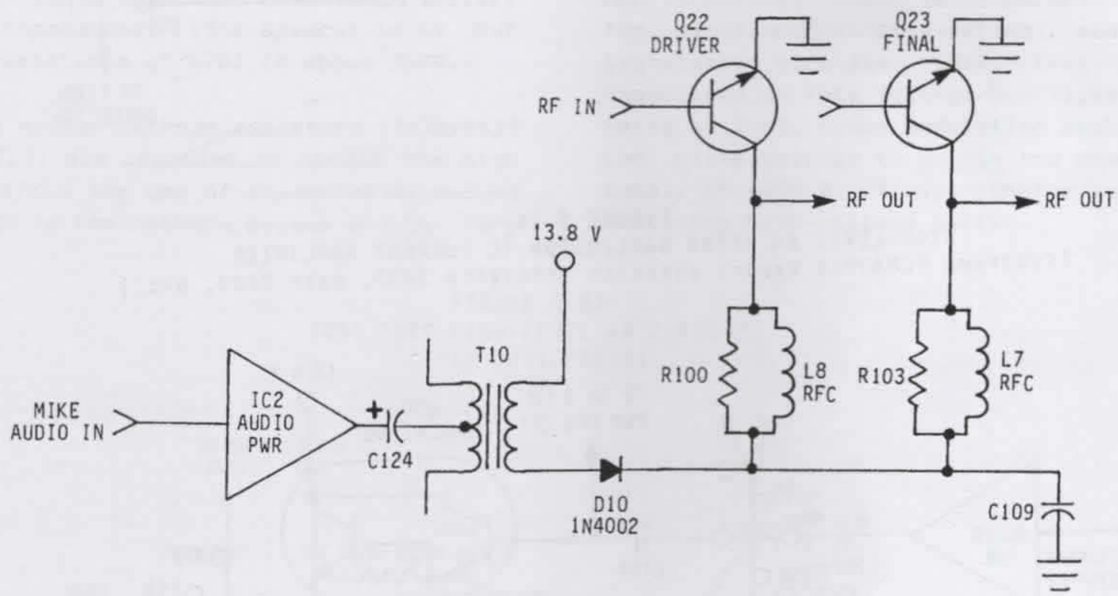


Figure 5-25 shows another common AM modulator circuit in which the output transformer has been completely eliminated. Amplified audio from IC6 is coupled through C174 and used to control the conduction of Darlington amp TR42/TR41. Thus the DC voltage to the RF stages will change at the audio rate. In 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)

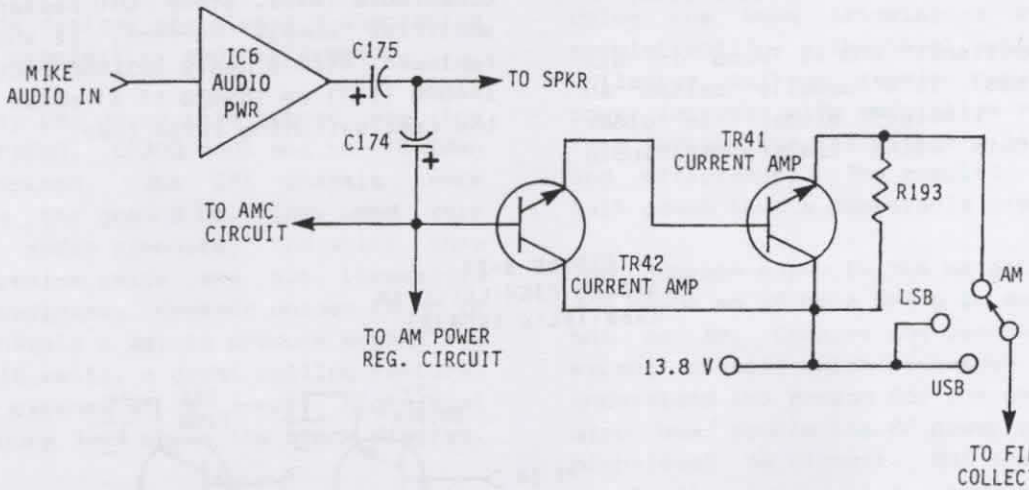
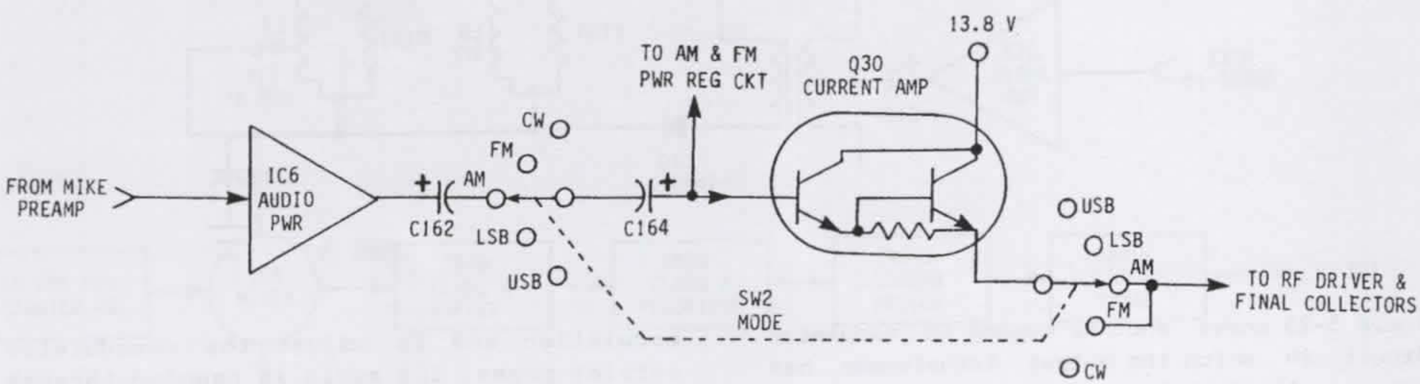


FIGURE 5-26
HIGH-LEVEL AM USING DARLINGTON IC CURRENT AMPLIFIER
(Cybernet PCMA001S export chassis: Lafayette 2400, Nato 2000, etc.)



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.)

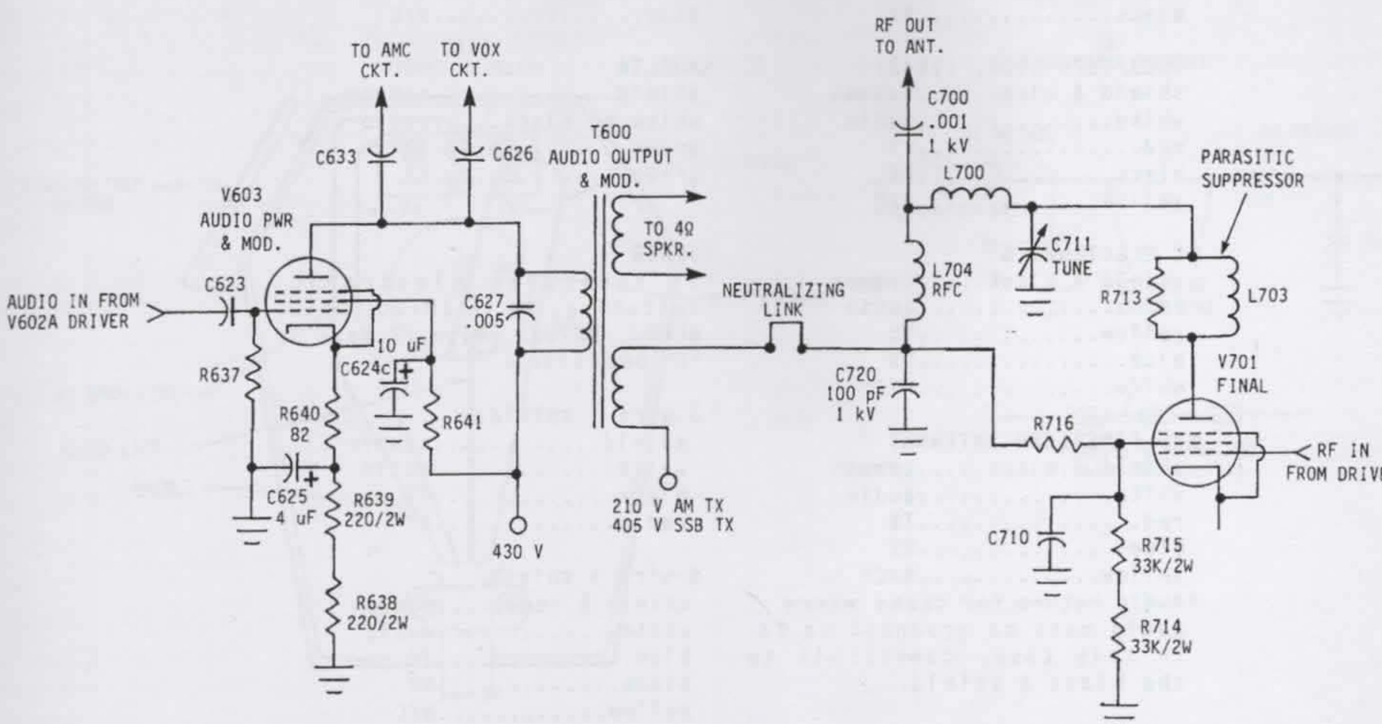
Unlike transistor RF amps, in tube circuits the net plate current of the modulated stage appears to be constant. That's because each increase in plate current is cancelled out by an equal decrease on the negative half of the audio cycle. The net result is a steady plate current which can't be seen on 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.

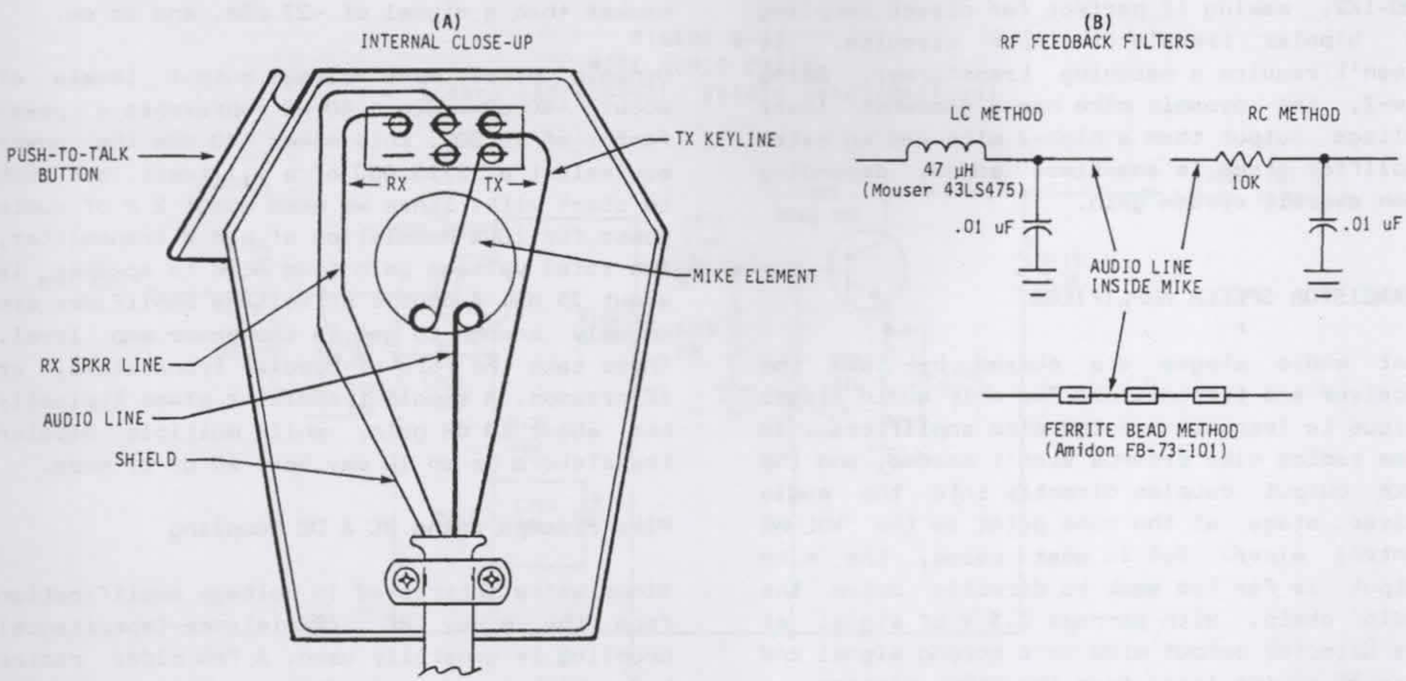
Figure 5-28 shows the functional cable color codes for many common mike brands. By combining the listed functions with the known functions on the radio's mike socket pins, you can wire any repaired or replacement mike to any radio.

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.

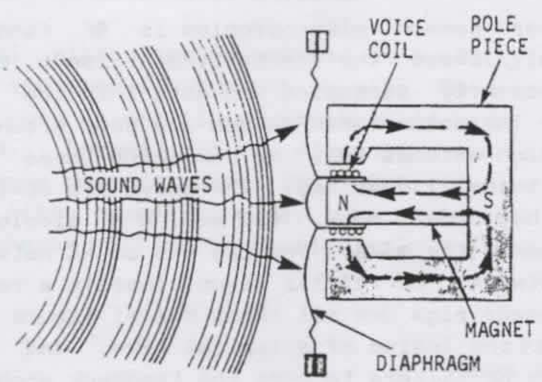
FIGURE 5-29
SOLVING MIKE FEEDBACK



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)

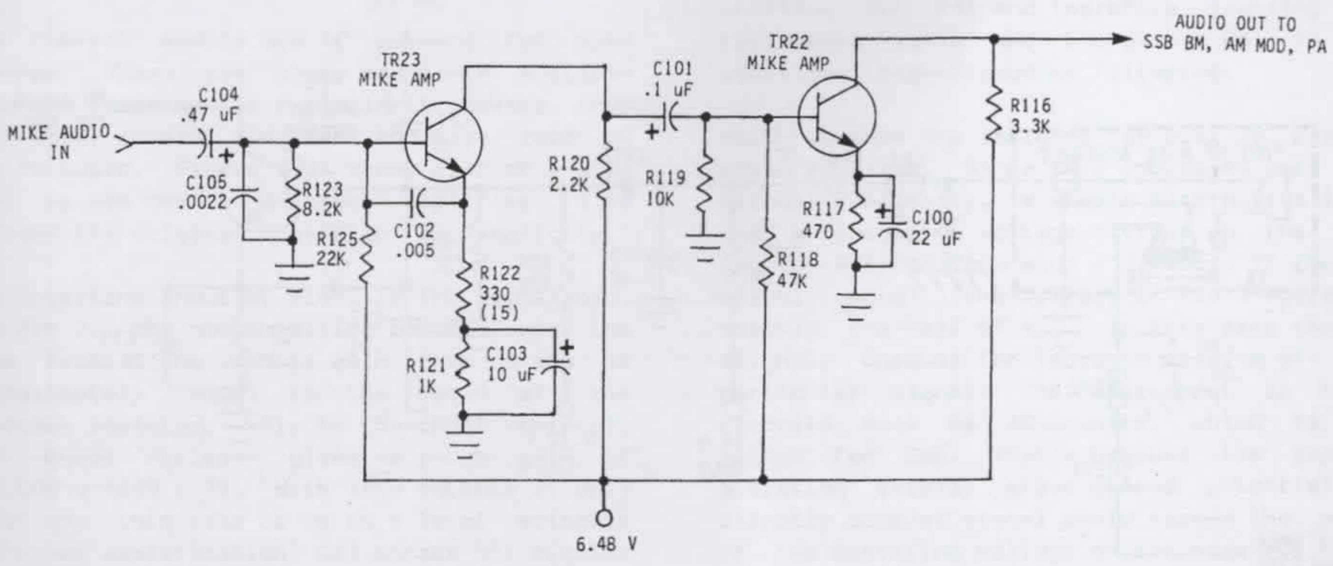


Figure 5-32 shows another common Uniden method. The difference here is the use of direct (DC) coupling between TR29 and TR28. There's no fixed resistor bias on TR29. Since emitter resistor R93 isn't bypassed at all, the voltage drop across it and hence the base bias is not constant; it changes at the 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.)

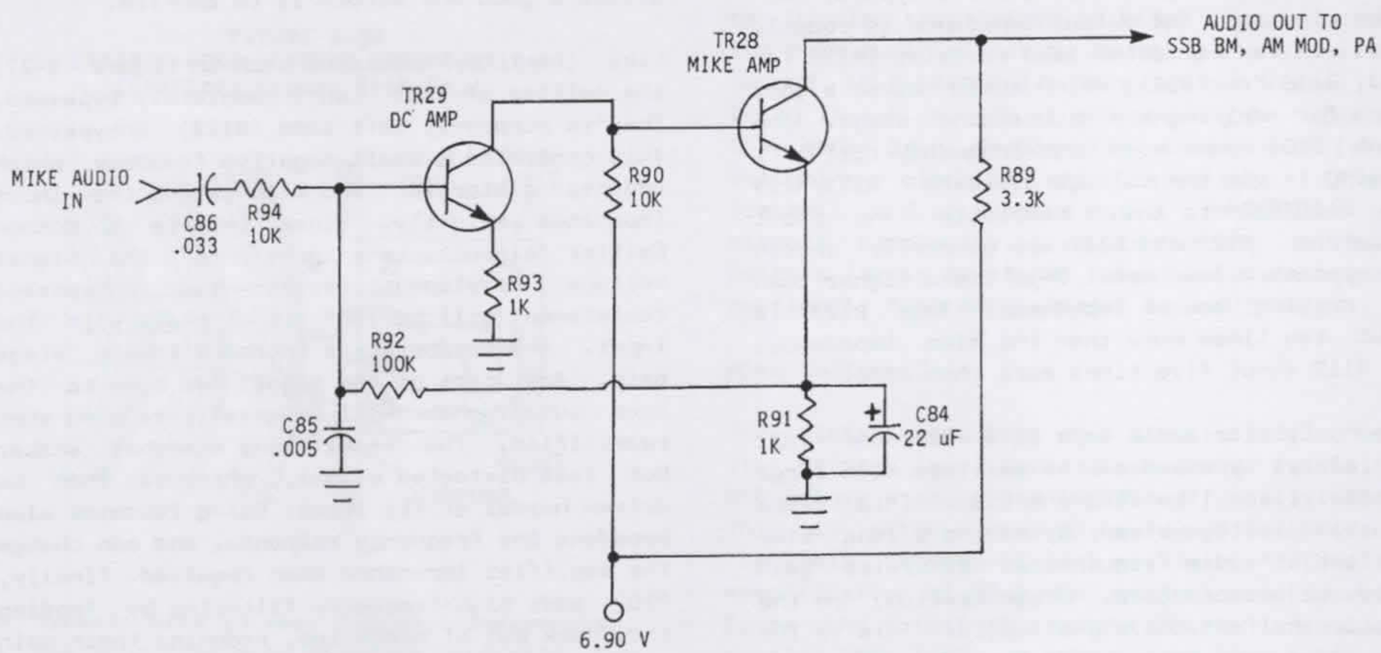


FIGURE 5-33
HIGH-IMPEDANCE MIKE INPUT CIRCUIT
(Johnson Messenger 4120, 4135, 4140, 4145, 4230, 4250)

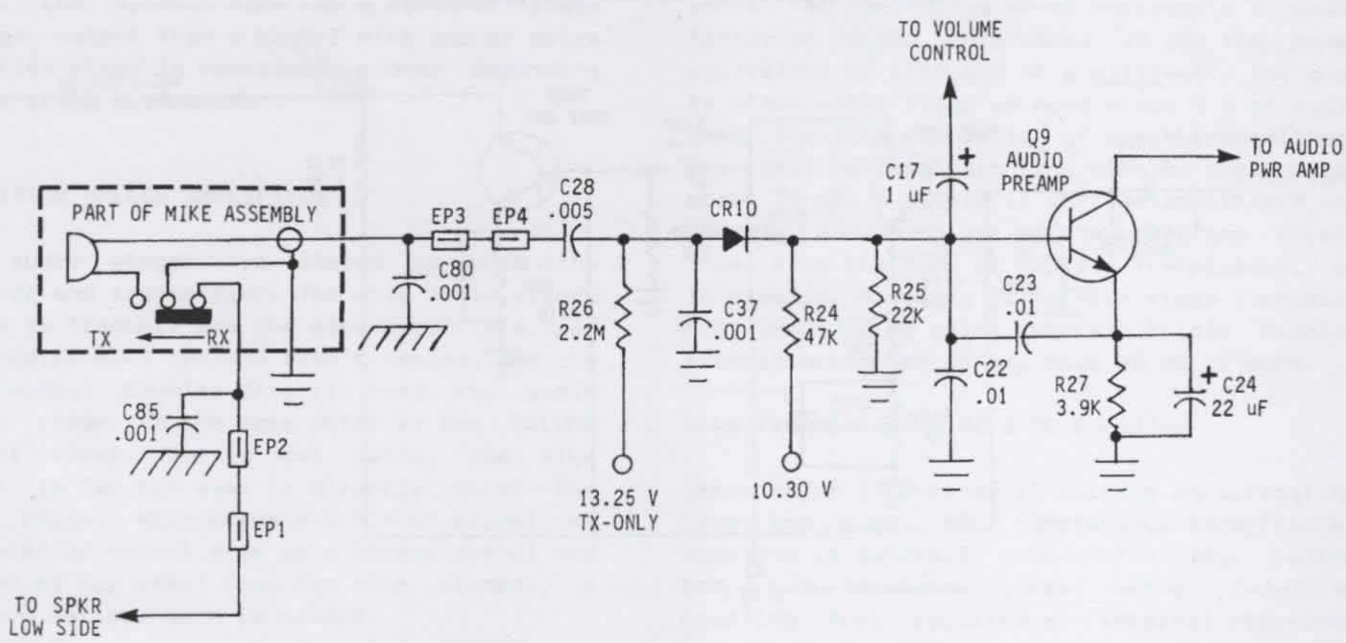
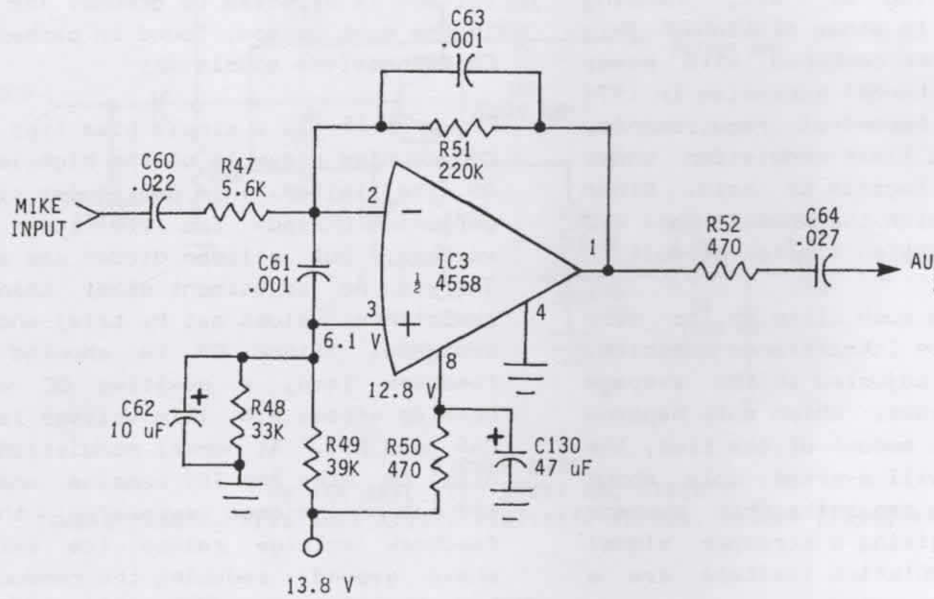


Figure 5-33 is a high-impedance input circuit, typical of Johnson radios with ceramic mikes. The higher output of a high-impedance mike eliminates one extra preamp stage, and less input coupling is needed as seen in the low value of C28. The large value of R26 is another high-Z indicator. Note the generous 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)

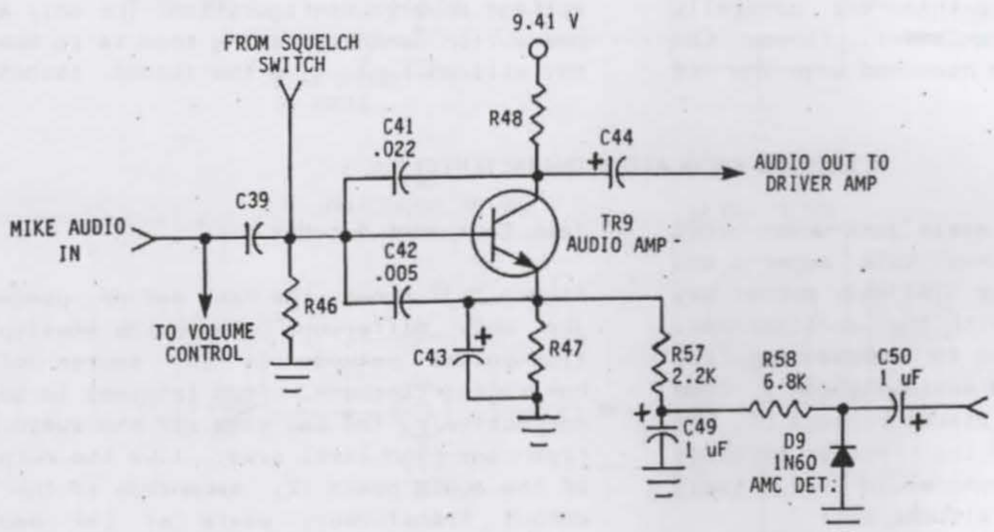
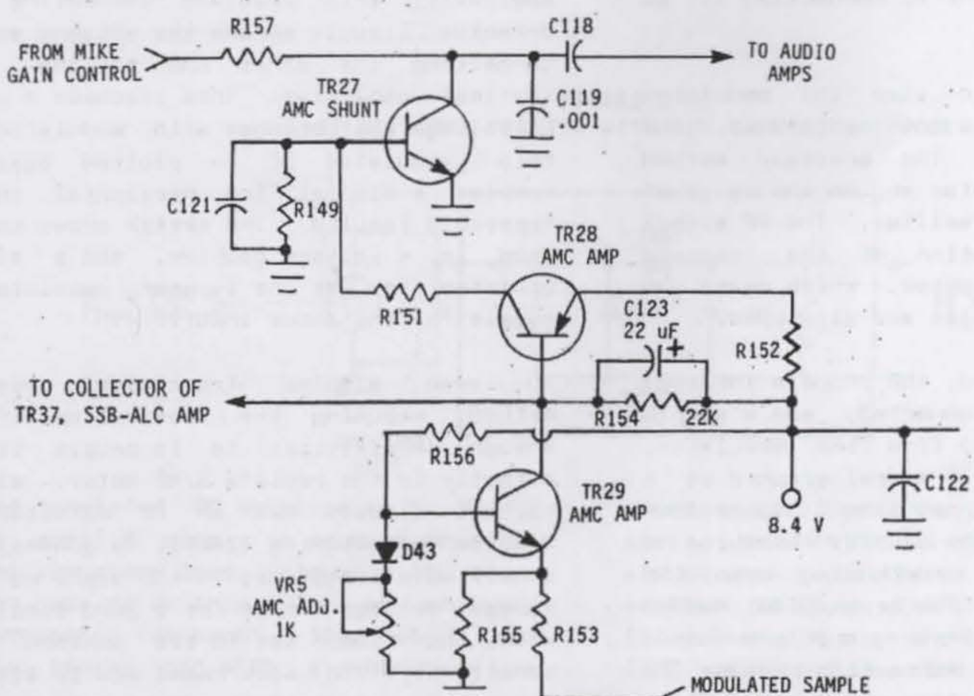


FIGURE 5-36
UNIDEN AMPLIFIED SHUNT AMC CIRCUIT
(Cobra 146GTL, President AX144, Realistic TRC451, Uniden PC244, etc.)



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

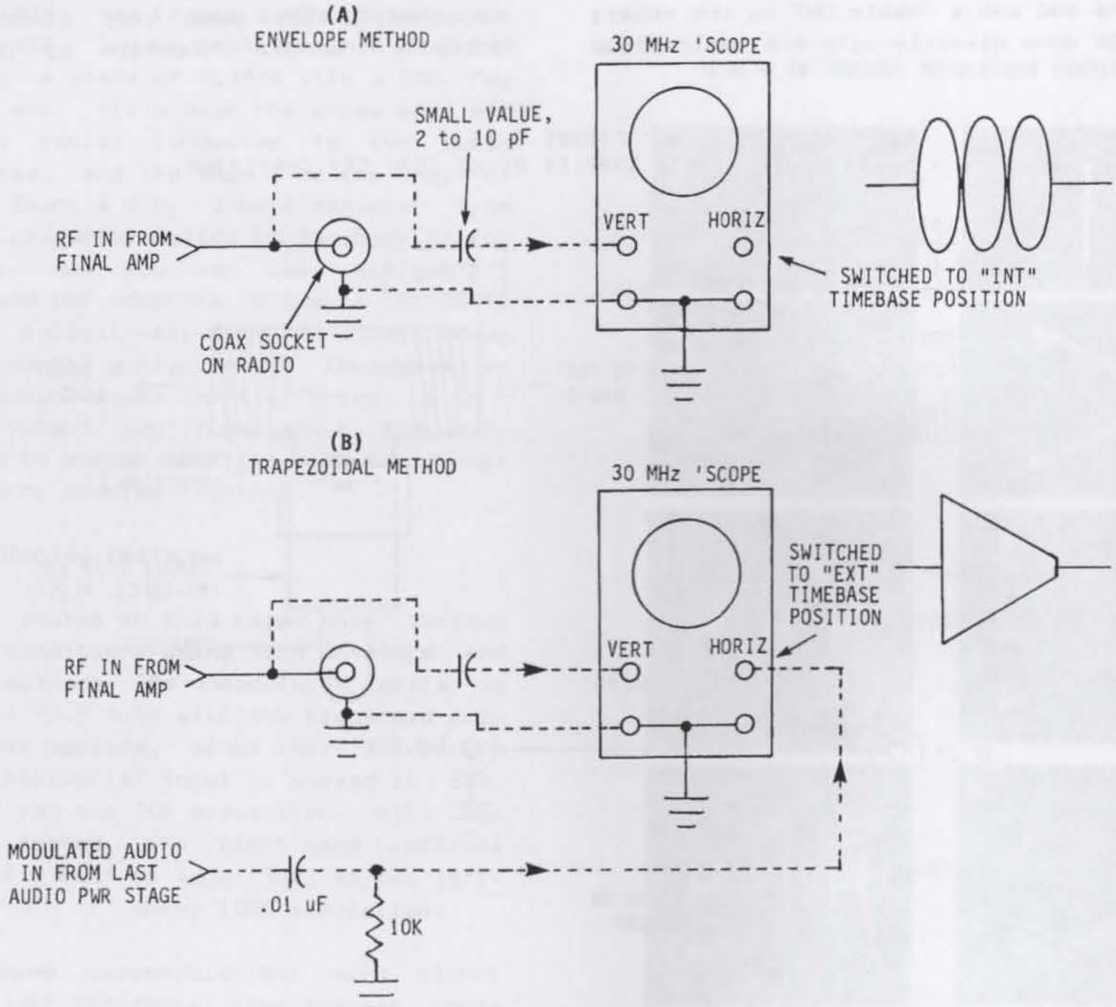
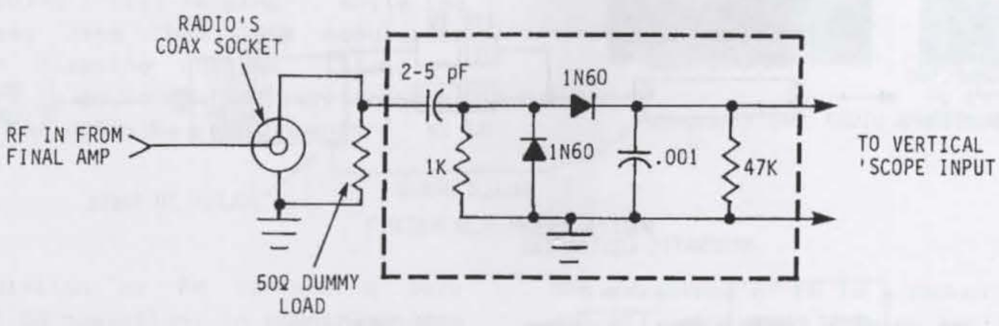


FIGURE 5-38
RF DETECTOR FOR USE WITH LOW BANDWIDTH 'SCOPE



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

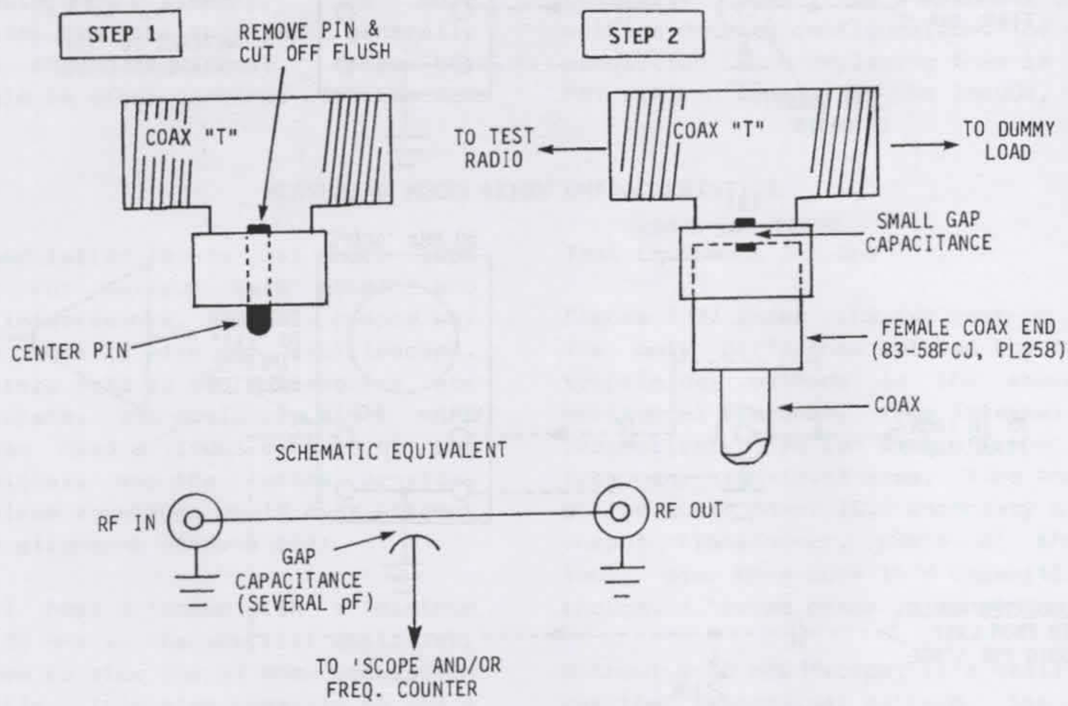
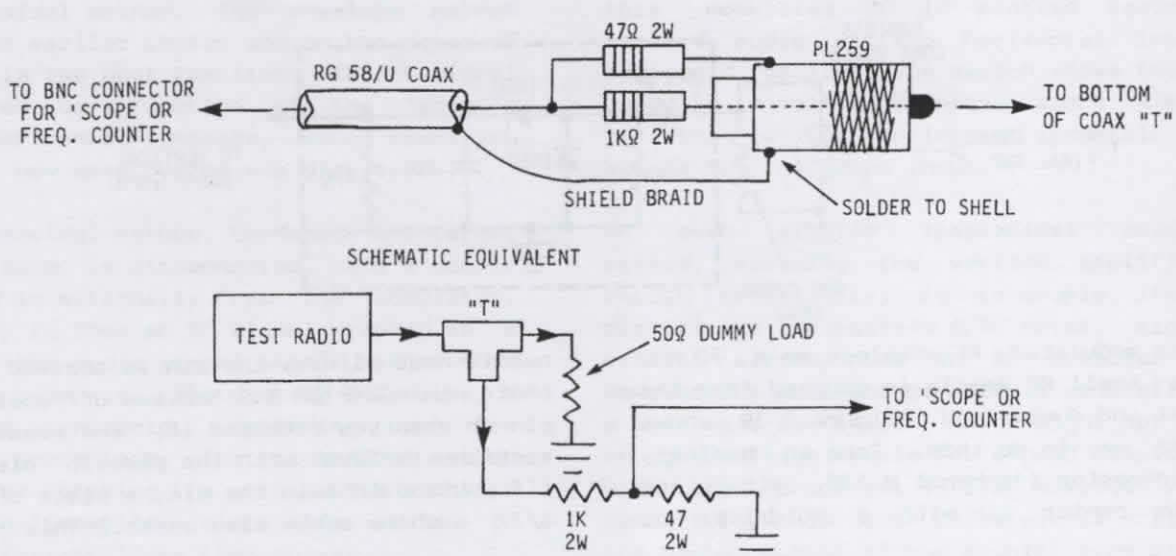


FIGURE 5-40
20:1 VOLTAGE DIVIDER RF SAMPLER



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.

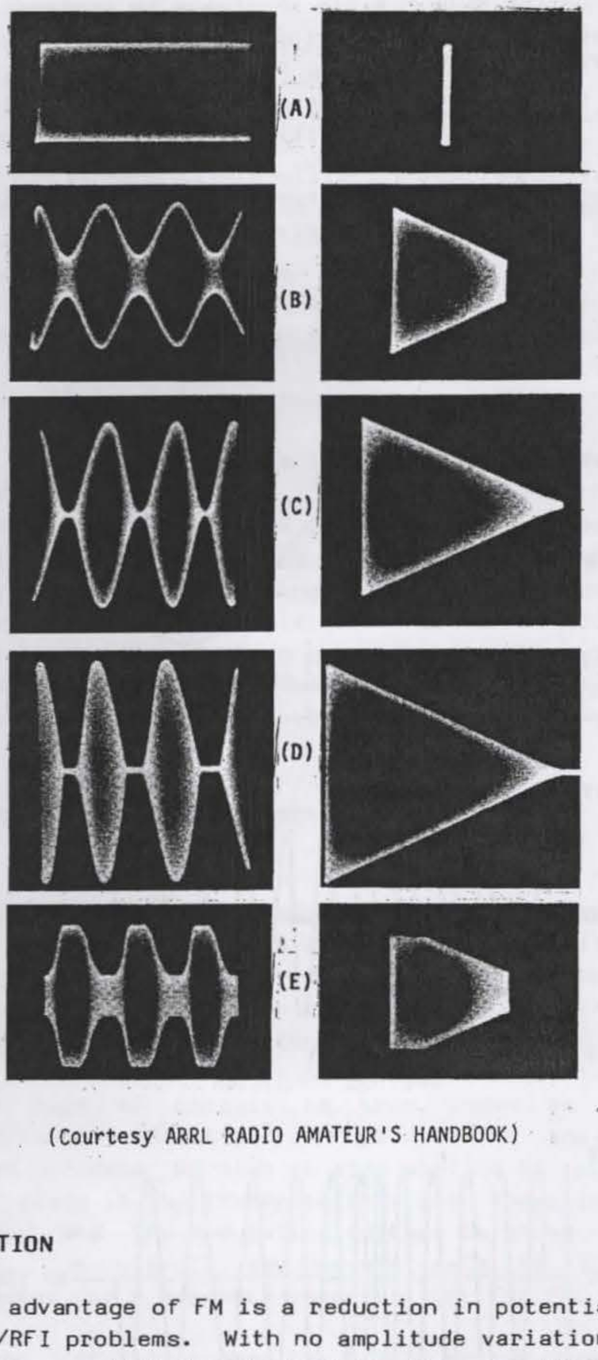
Modulation Display Patterns

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

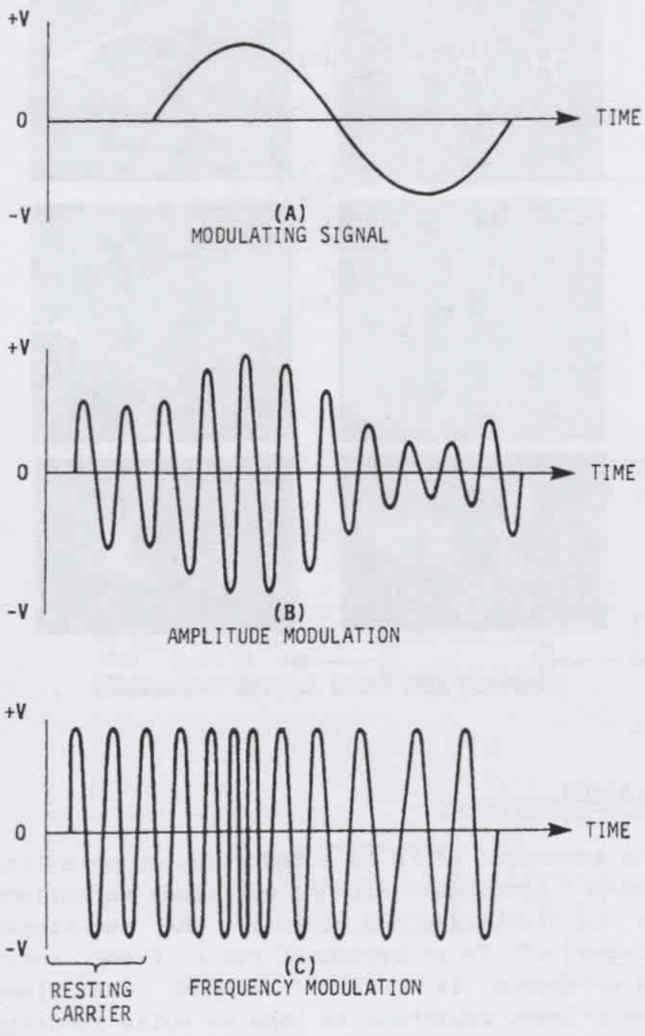
Frequency Modulation or FM is now a very popular form of CB operation. In countries like Britain, Holland, and Germany it's the only legal system. In the U.S. it's not "officially" legal, but is nevertheless widely used due to the popularity of the European type multimode export radios here. Figure 5-41 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.

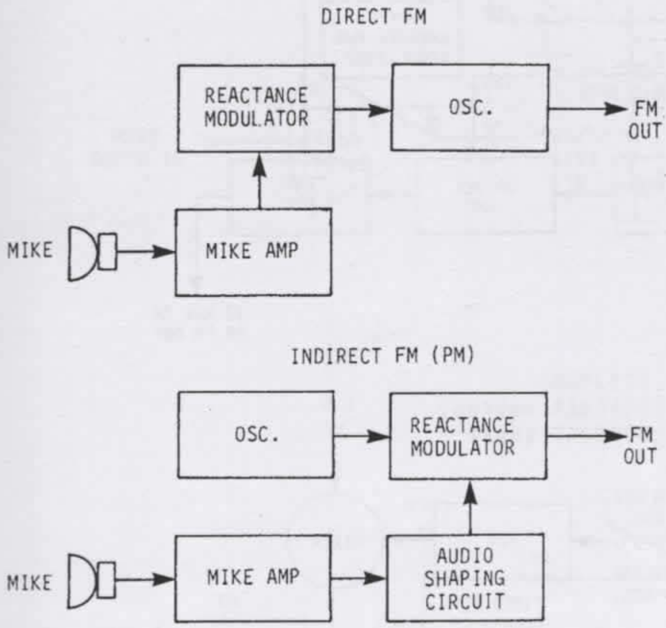
The differences have to do with the amount of "deviation" or frequency shift from the center unmodulated carrier. With FM, deviation is proportional only to the amplitude of the audio signal regardless of its frequency, while in PM the deviation is proporional to both the amplitude and the frequency 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 (PCMA001S, 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.

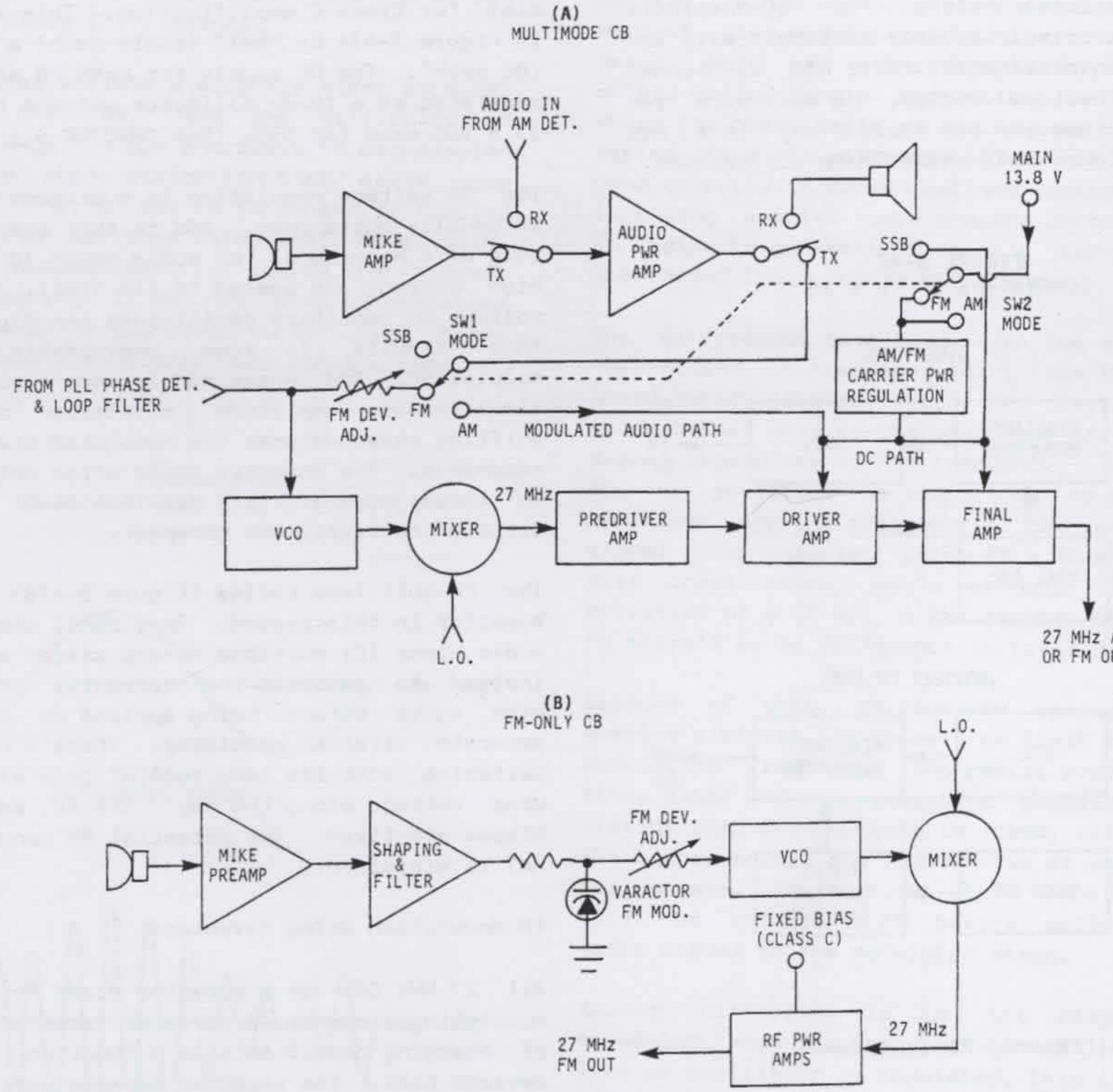
The FM-only type radios (Figure 5-43B) are far superior in this regard. They don't share the audio power IC; multiple op-amp stages are used instead to generate the correctly processed mike audio before being applied to its own separate varactor modulator. There's no mode switching with its long runs 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)

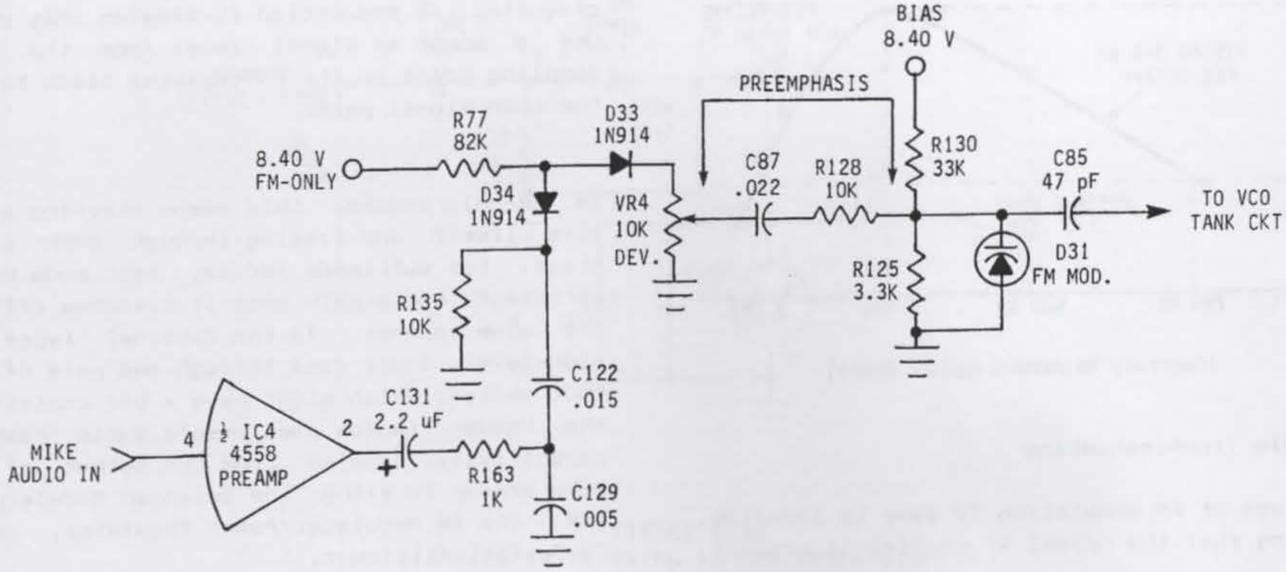
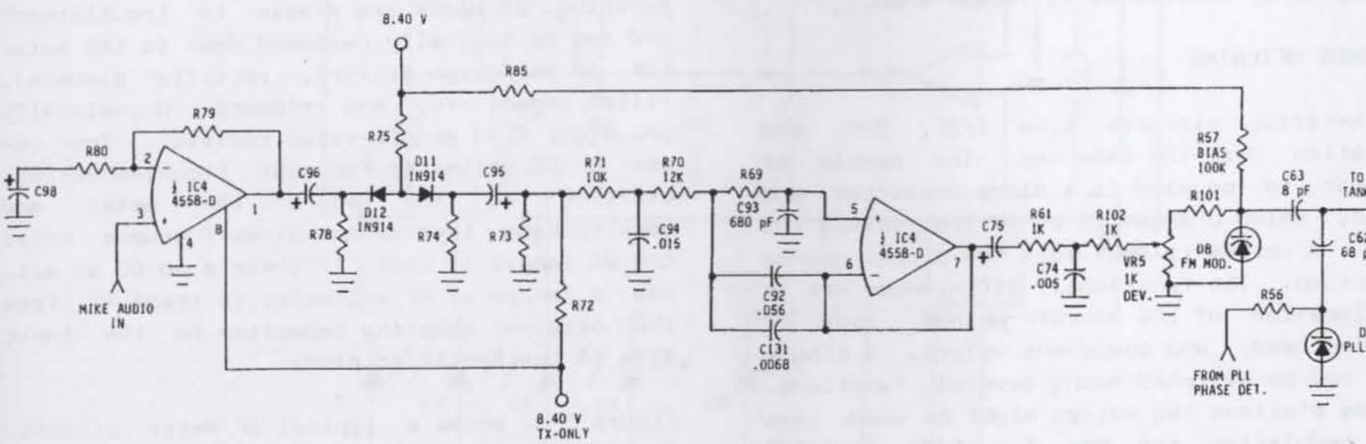


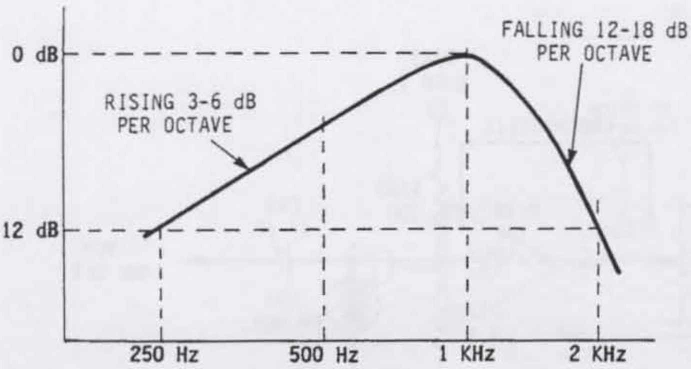
FIGURE 5-45
COMPLETE FM-ONLY TX AUDIO CHAIN
(Uniden PA034/039 chassis: Audioline 340/341,
Tandy TRC2000/2001, Uniace 100/200, etc.)



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.)

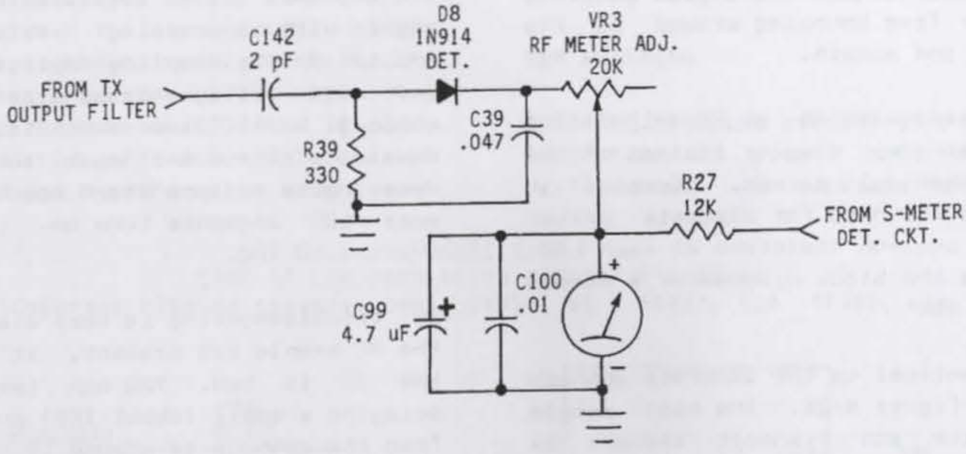
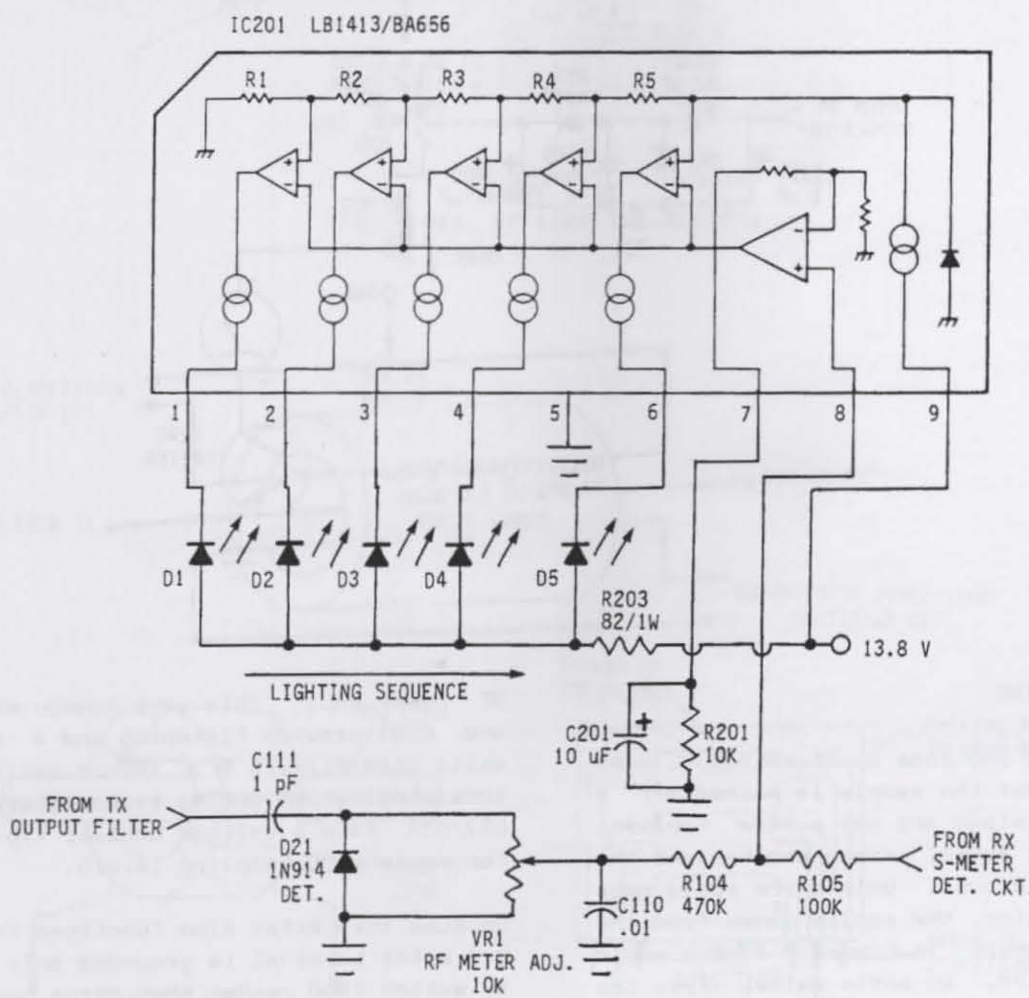


FIGURE 5-48
S/RF INDICATOR USING IC BAR/GRAPH DISPLAY
(Realistic TRC433)



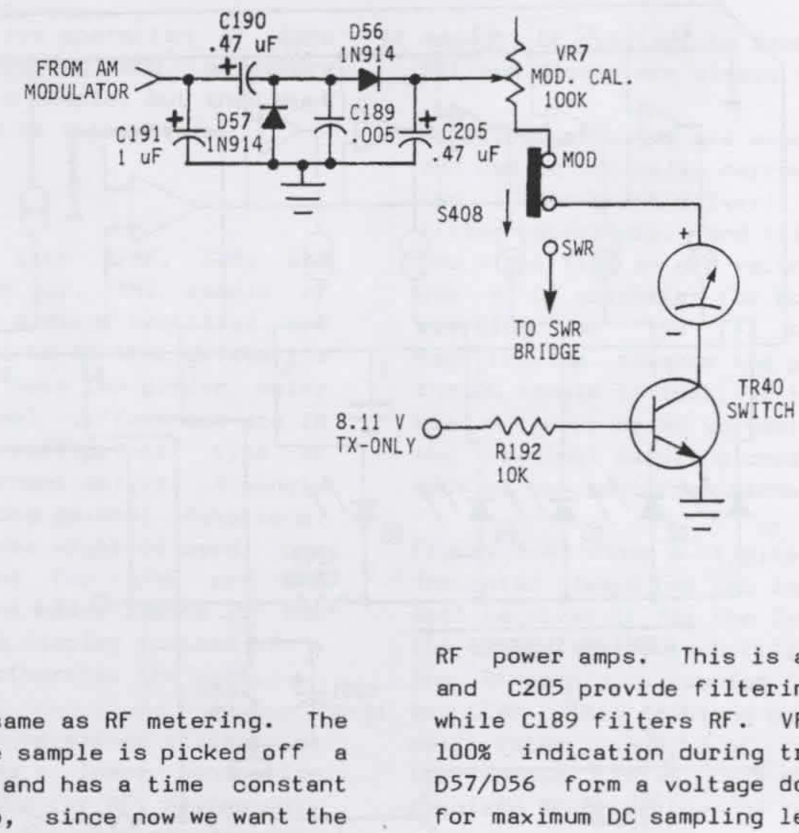
the DC drive to the meter. VR3 sets the desired meter deflection, with C100 for additional RF filtering. C99 is a large value used mainly for the S-Meter part of the input; there's mostly audio at that point, and the long time constant keeps the meter from bouncing around so the movement is slow and 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.)

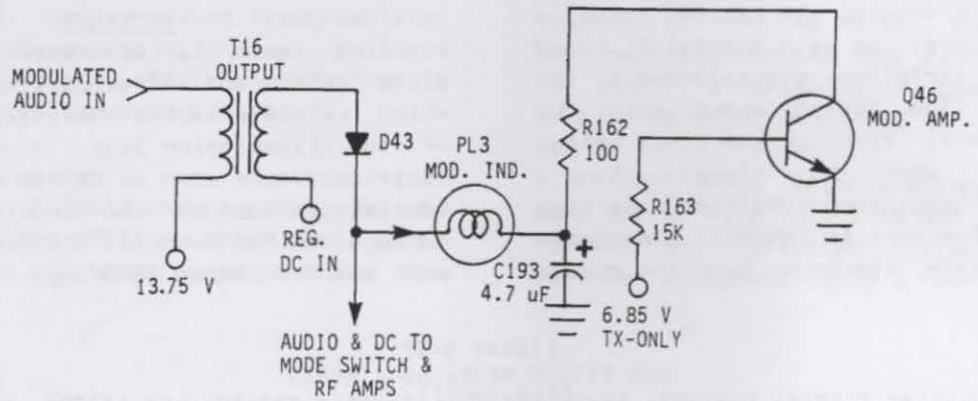
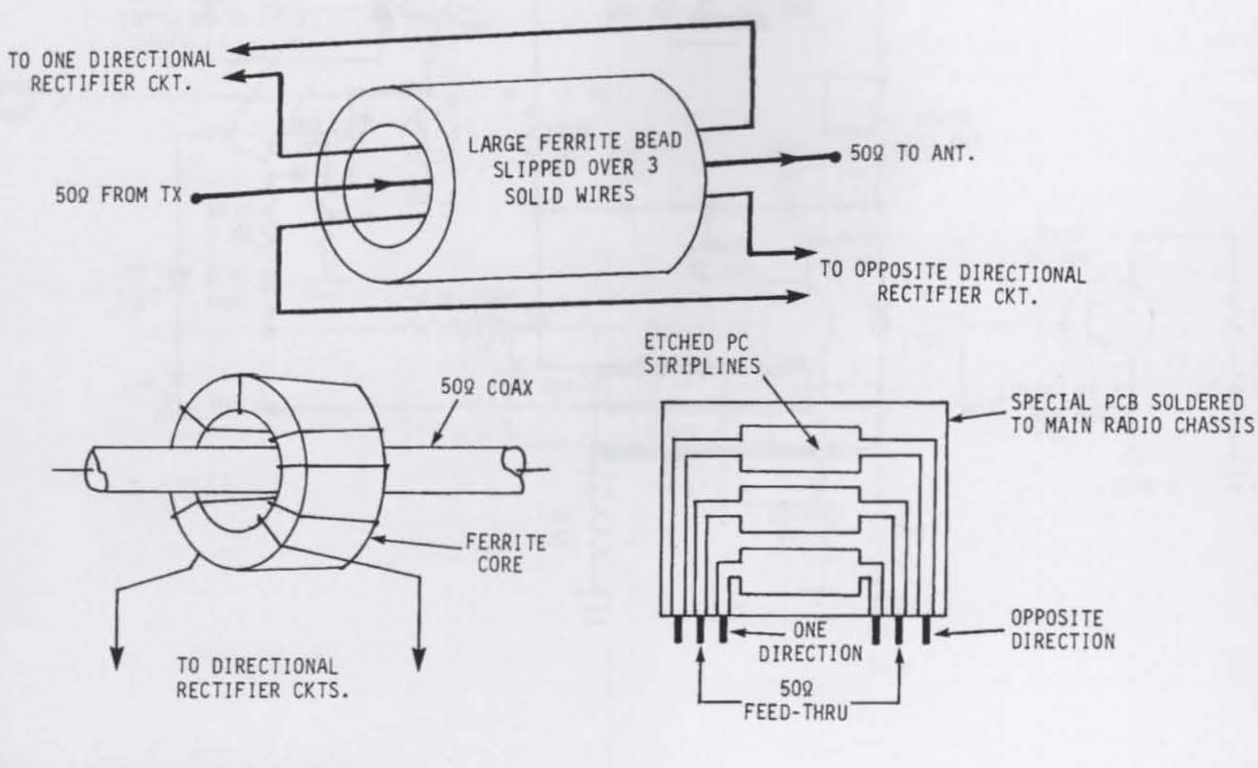


FIGURE 5-51
DIRECTIONAL RF SAMPLING METHODS

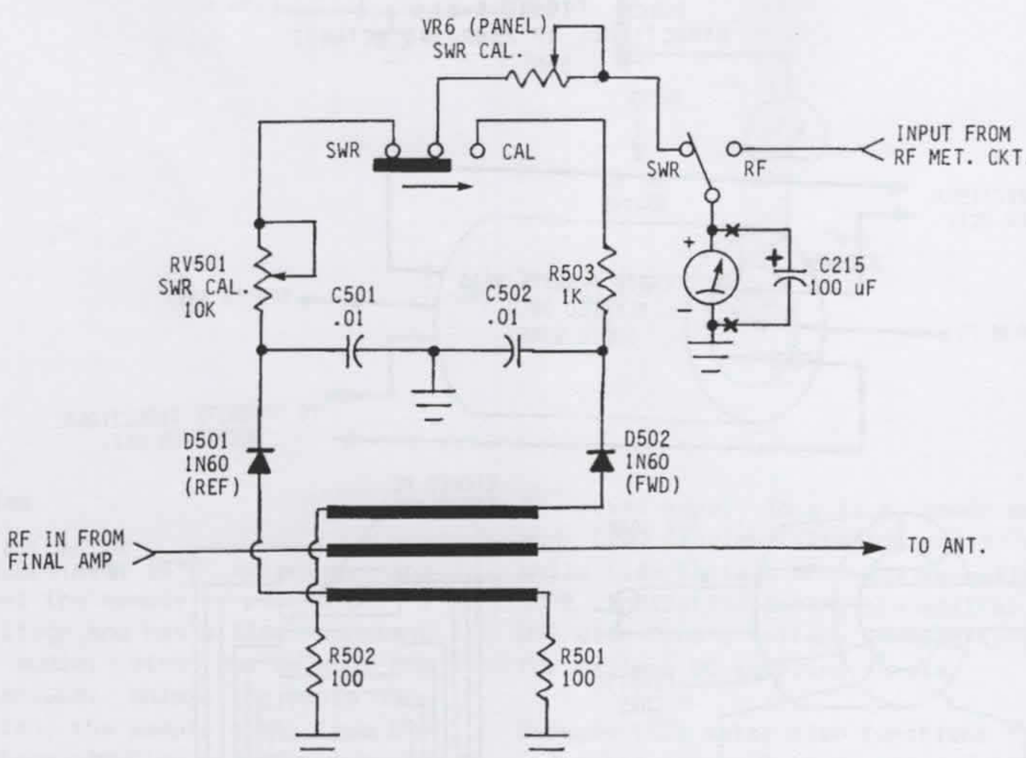


sampling loop that measures the RF input/output power balance (or imbalance) at the antenna socket. This balance is the Standing Wave Ratio or SWR. The RF power moving outward from transmitter to antenna is called the "forward" or "incident" power; that returning from the antenna is called the "reflected" 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.

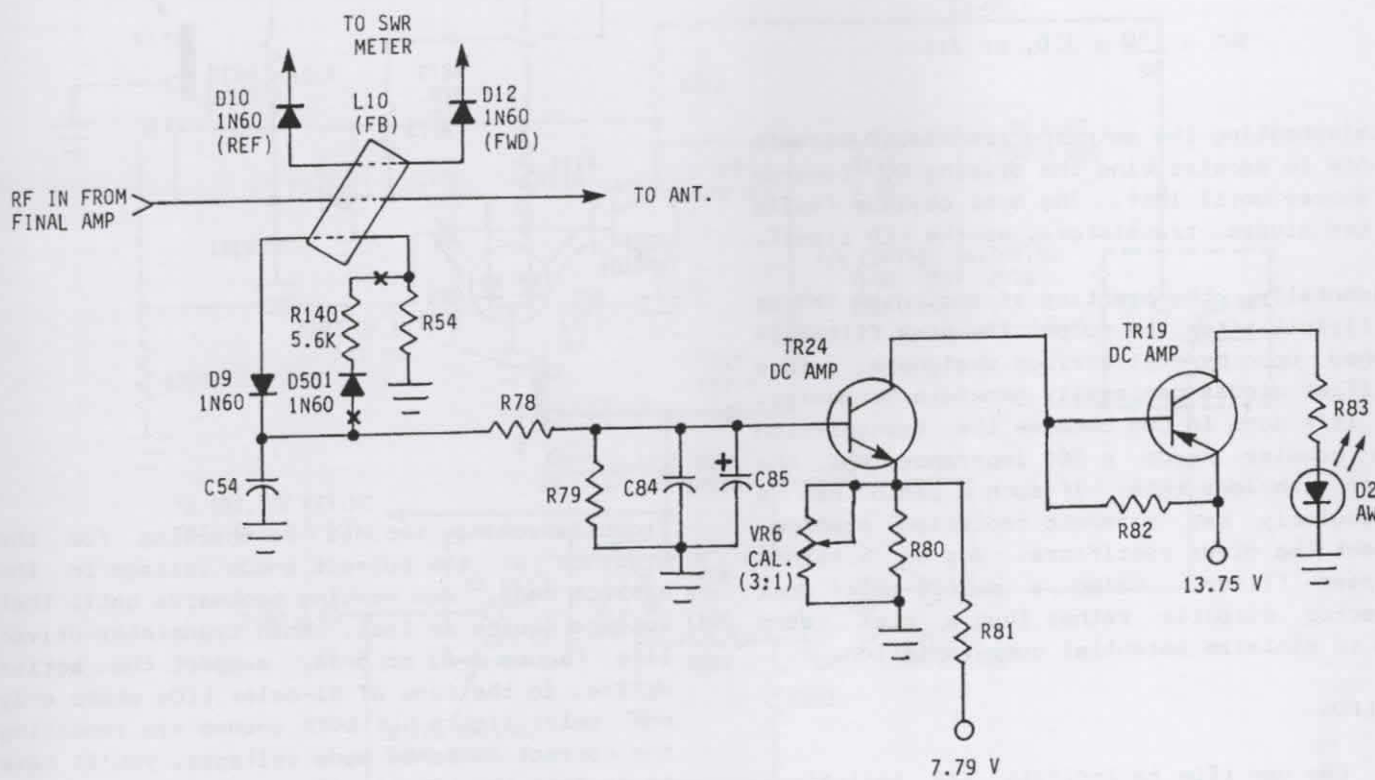
To read the proper ratio, the operator first calibrates the FORWARD voltage reading by adjusting VR6 to the "SET" or "CAL" meter mark. Then switching to the "SWR" position shows how much the bridge is unbalanced. The FORWARD voltage reading changes with reactive loads and small component variations, 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,

$$SWR = \frac{150}{50} = 3.0, \text{ or } 3:1$$

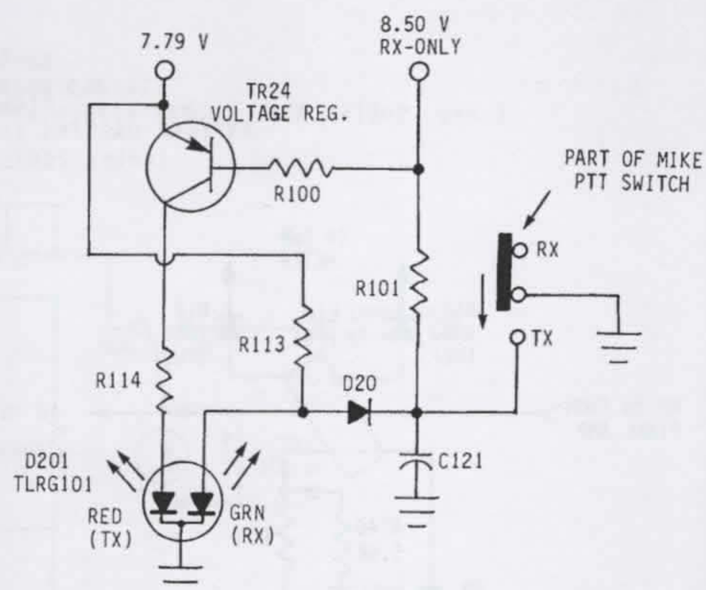
Troubleshooting the metering or AWI/LED circuit amounts to backtracking the driving DC towards its source until lost. The most obvious faults are bad diodes, transistors, or the LED itself.

Incidentally, the practice of adding an SWR or AWI circuit after 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

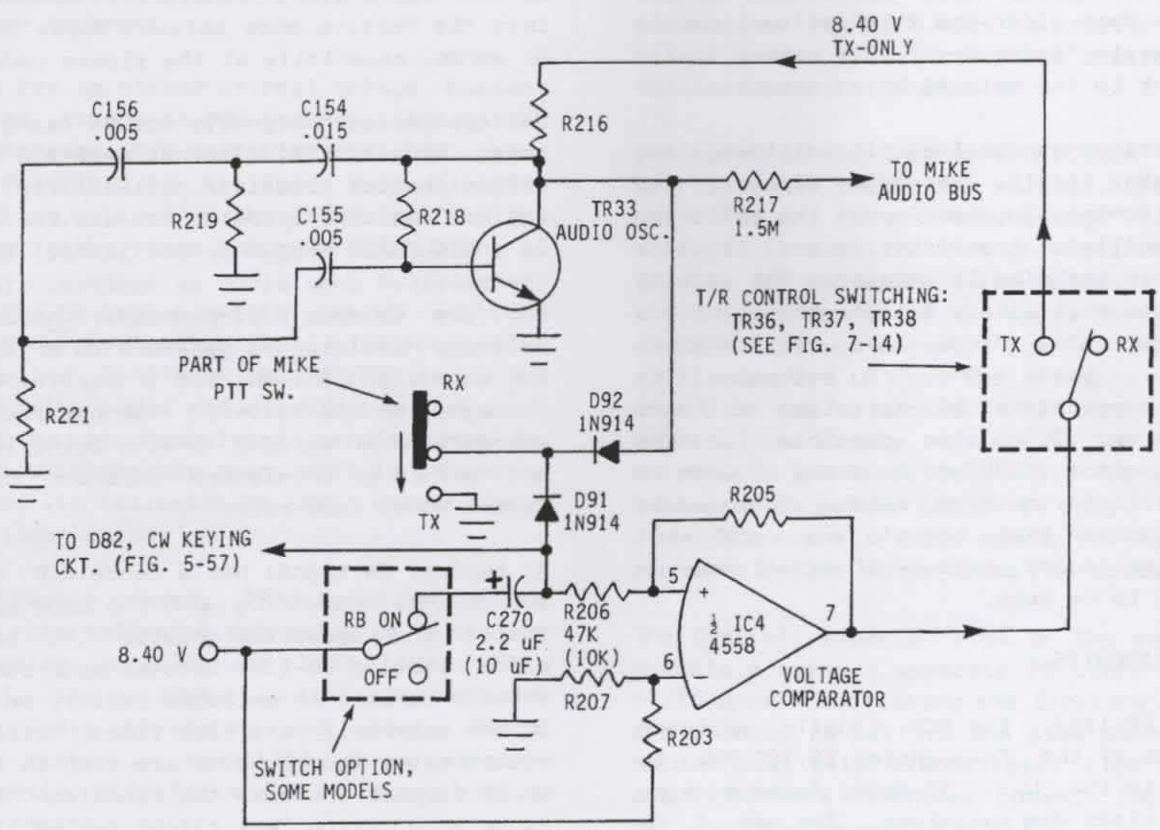
This circuit causes a short audible beep to be transmitted when the mike button is released. A listener knows the transmission is over and he can now transmit, without taking his cue from the traditional "Over" or "Go Ahead" spoken by the other station. With AM and FM this function isn't really needed, 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.

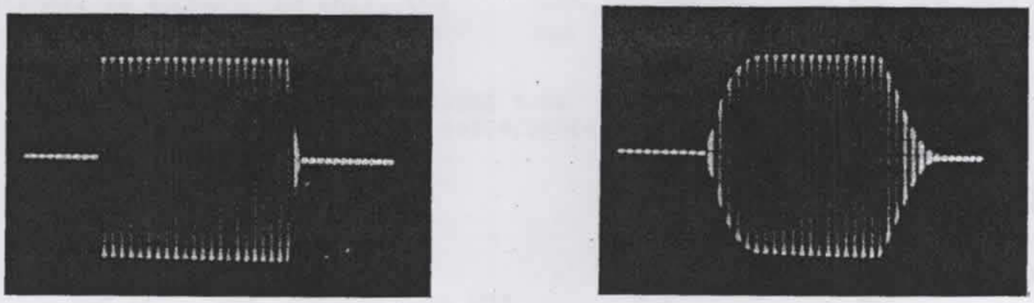
There are some unique circuit requirements for CW. A special Sidetone Oscillator is energized so the sender can monitor his Morse Code in the radio's speaker. The AM and FM modulators must be disconnected, so only the carrier is turned on and off at the Morse Code rate. The carrier frequency must be 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 <u>un</u>balance 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.

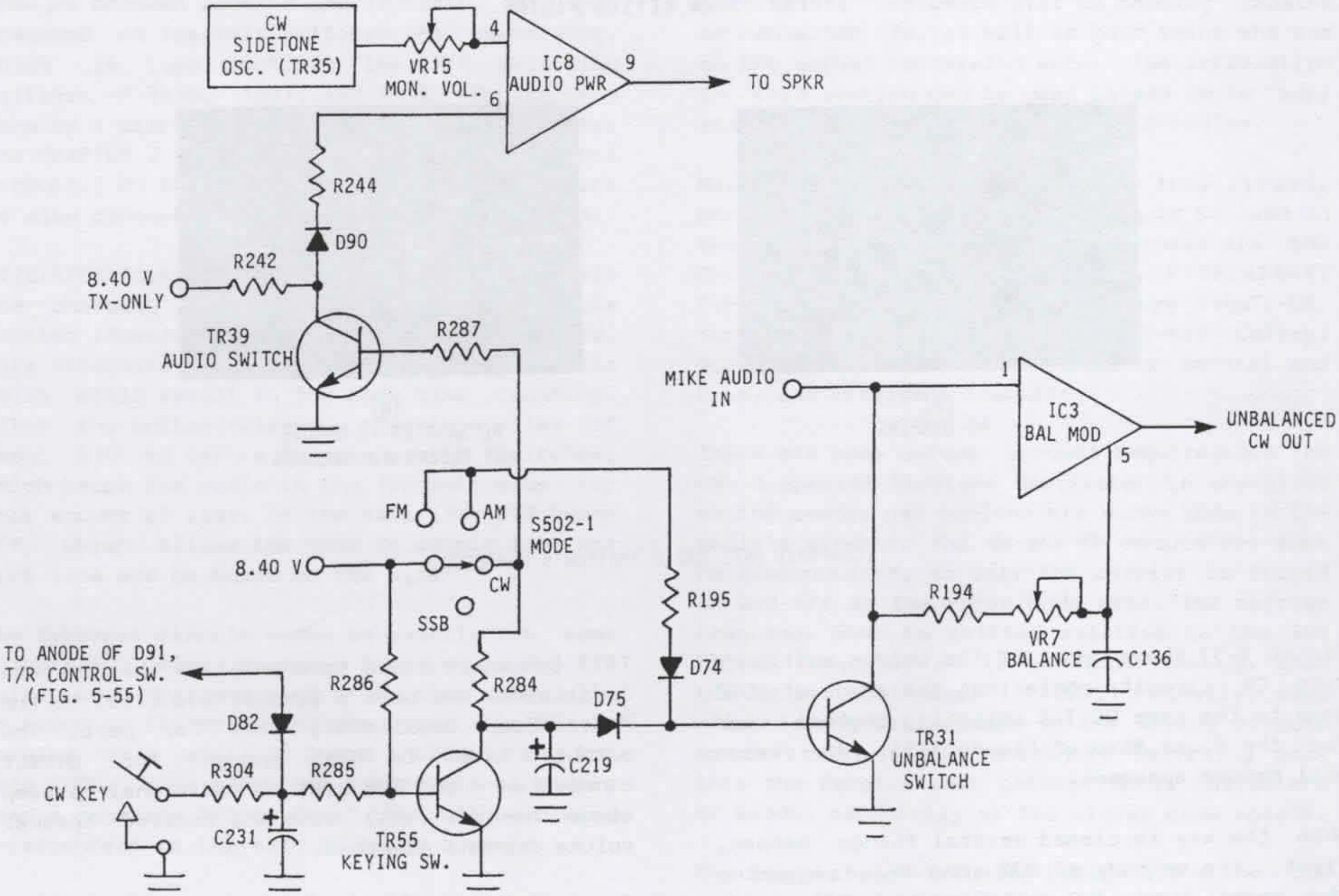
When the key is closed, TR55 loses its base bias and its collector now pulls up HIGH via R284, turning on D75 and TR31. With TR31 conducting, its collector is LOW. This shunts the mike audio to ground and upsets IC3's balancing circuit, resulting in a carrier output signal. C219 filters the voltage spikes 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)

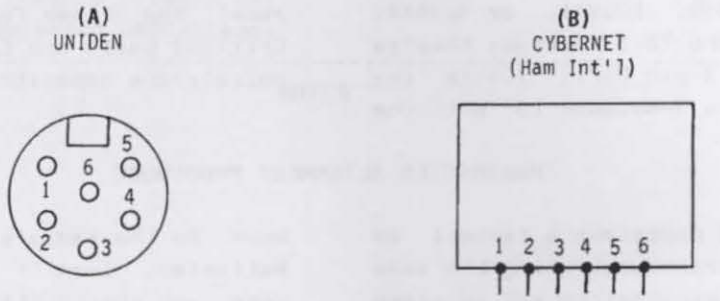
This option attempts to copy the tone-encoded squelch used in commercial VHF/UHF FM radios and Amateur 2-Meter repeaters. When the mike is keyed, a tone burst of a specific frequency and length is used to unsquelch the listener's receiver. This tone burst is generated by an audio oscillator encoder, 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

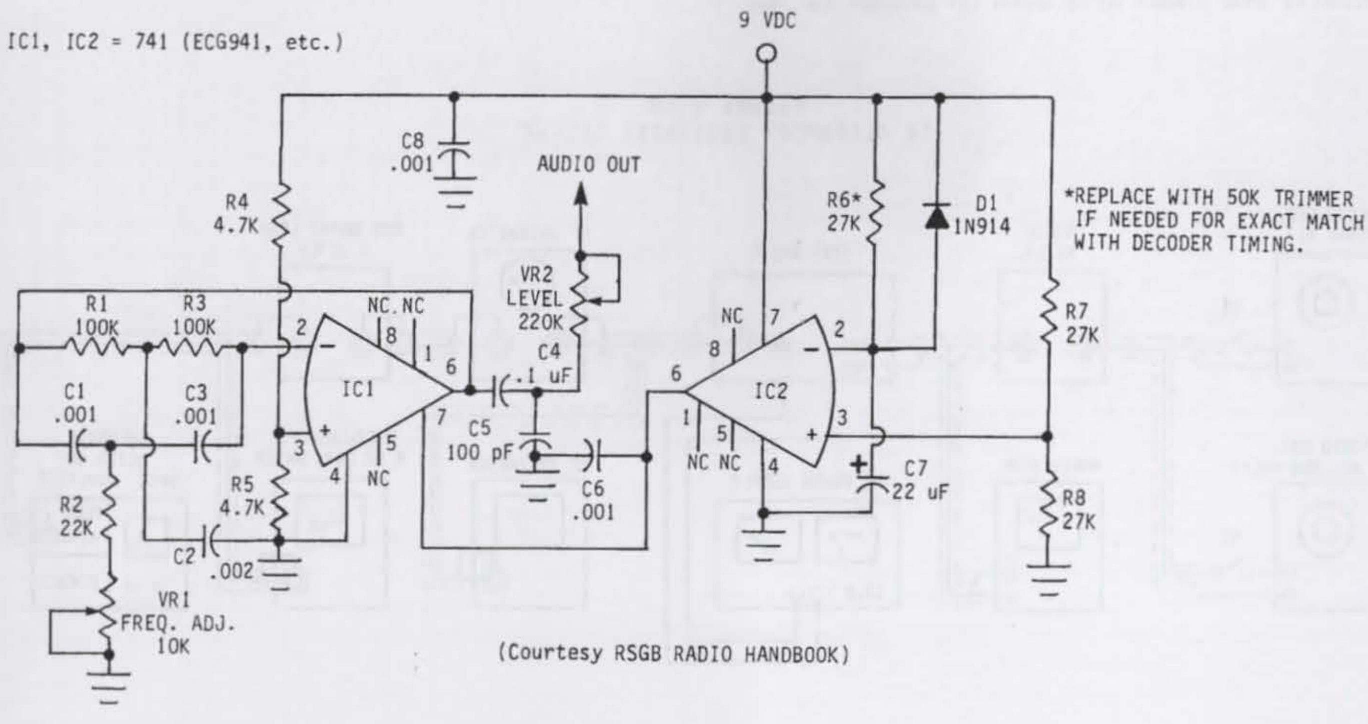
FIGURE 5-58
SEL-CALL INTERCONNECTIONS



1 = GND
2 = 8 V REG.
3 = RX AUDIO INPUT
4 = TO MIKE AUDIO BUS
5 = SQUELCH CONTROL TO 2902 SQ. IC
6 = NC

1 = 13.8 V
2 = GND
3 = TO SPKR HOT SIDE
4 = RX AUDIO INPUT
5 = TO MIKE AUDIO BUS
6 = TX SENSE: LOW-TX, HI-RX

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.

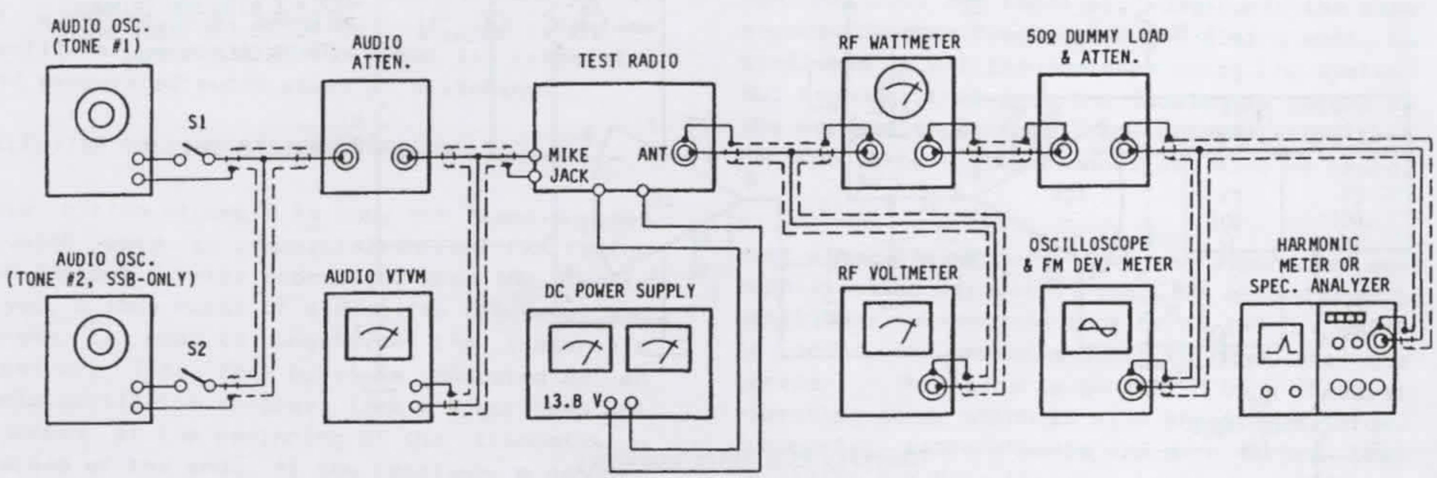
TRANSMITTER ALIGNMENT PROCEDURE

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