6 SINGLE-SIDEBAND CIRCUITS

As early as 1914 radio designers knew that if the carrier and one sideband of an AM signal were eliminated, the remaining sideband could still be used to transmit the intelligence. By 1923 a "Single Sideband" system was patented, actually for telephone use, so SSB isn't a new idea! Those early principles are still used, with the SSB CB transceiver a more refined and economical version of the original system.

SSB is the most popular and fastest-growing CB communications mode for the serious hobbyist. Its higher transmitter power and narrower bandwidth are two very practical reasons. The higher initial cost for SSB radios also tends to separate the real CB junkies from the casual users. Their owners are more likely to repair multimode CBs than to replace them. The recent 10-Meter expansion for Novice Amateurs doesn't allow AM for voice work, just SSB; this means converted CBs must be SSB types. For all these reasons, expect to see a lot more SSB radios.

There is no "official" FCC channel assignment for SSB. Over the years tradition (and common courtesy) has resulted in Ch.16 being the SSB calling channel for initial contact, with the use of Ch.35-Ch.40 reserved for SSB only; AM is definitely not welcome here! Radios having the expanded frequencies generally save the space above Ch.40 for SSB and that below Ch.1 for AM. Such operation is illegal, but both modes may still be found around the American FCC band.

Many otherwise good technicians avoid repairing SSB radios because they seem more complicated than AM or FM equipment. They're really not, if you proceed logically when repairing multimode CBs. SSB circuits are a bit more complex, but if you understand the specific differences, troubleshooting becomes very straightforward. There are two main questions when isolating problems between modes: "What is the signal path this particular mode takes?" And, "How is this path controlled electronically?" Since most transceiver circuits are shared by AM (and FM), only those unique to SSB are covered here. Mode switching circuits and methods are also included. Your repair approach is to verify all AM functions first before assuming an SSB-only fault; any problem that affects all modes equally should be treated as an AM problem.

Symptoms associated with SSB problems include:

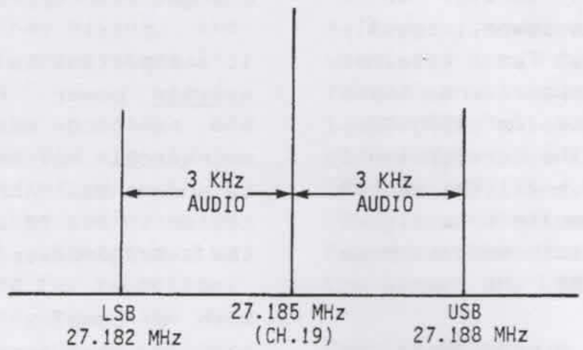
1. No Transmit on either sideband; AM (and FM) works normally.
2. No Receive on either sideband; AM (and FM) works normally.
3. No Transmit and/or Receive on only one sideband; all other functions normal.
4. Distorted or garbled reception on one or both sidebands; AM (and FM) normal.
5. No Clarifier control.
6. Distorted or garbled transmission which the receiving station is unable to clarify.
7. Low RF power output.
8. Poor sideband suppression.
9. Excessive transmitter bleedover interference to adjacent channels.

CHARACTERISTICS OF SSB

An RF carrier amplitude-modulated by a single sine wave contains three different frequencies: the carrier frequency, a frequency equal to the difference between the carrier and modulating frequency, and a frequency equal to the sum of the carrier and modulating frequency. In the case of a complex modulating waveform like a voice, the sum and difference depends upon the highest voice frequency. So these sum and difference frequencies always extend from the center carrier by an amount equal to the highest audio modulating frequency.

The sum is known as the Upper Sideband or USB, and the difference the Lower Sideband or LSB. For example, a Ch.19 carrier signal modulated by a 3 KHz audio tone would have the USB at 27.185 MHz + 0.003 MHz = 27.188 MHz, and LSB at 27.185 MHz - 0.003 MHz = 27.182 MHz. The 3 KHz audio figure is commonly used as a textbook

FIGURE 6-1
FREQUENCY DISTRIBUTION OF TYPICAL DOUBLE-SIDEBAND SIGNAL



example (including here), but the real maximum audio figure is actually closer to 2.4 KHz, or even just 2.1 KHz in some systems. Figure 6-1 shows the spectrum distribution of this signal.

Note that LSB inverts the signal: the higher the modulating frequency, the lower the RF frequency, while USB is directly proportional to the modulating frequency. In the early days of radio that made LSB more difficult to process at higher carrier frequencies. This led to a traditional use of LSB below about 10 MHz, with USB above. There's no longer any technical reason for this, but the tradition is still generally observed today; most HF operation is USB. Interestingly, the FCC certification only requires that the transmitter be capable of USB; LSB is optional for the manufacturer!

SSB Pros & Cons

A major advantage of SSB is its narrower bandwidth, only half that of a comparable AM signal. This means more stations can fit in the available spectrum space. Because of this, CB manufacturers tend to advertise radios as having many more channels than they really do. A typical American 40-channel AM/SSB radio may be advertised as a "120-Channel" radio, meaning 40 AM, 40 USB, and 40 LSB channels. Since only one mode can be used on one channel at a time, it's a very deceptive practice. Make sure your customers know the truth!

SSB also isn't affected by selective fading. This is a form of audio distortion resulting from the fact that slightly different frequencies may not arrive at the receiver at exactly the same instant. No doubt you'd heard such garbling while listening to a rapidly-fading AM shortwave station. If the USB was reflected from the ionosphere at a slightly different angle than the LSB, you'll hear the distortion. When bad enough, the sidebands may completely cancel each other out so the intelligence is lost. But with SSB, there's no definite phase relationship between the sidebands and the carrier, so this can't happen. And with no carrier, there's no annoying heterodyne to interfere with reception like on AM. Finally, the narrower SSB bandwidth greatly improves receiver IF selectivity.

The most important advantage to CB operators is the higher transmitted power. Theoretically SSB has a total advantage of 9 dB over a comparable AM signal: 6 dB resulting from more efficient transmitter use, and 3 dB resulting from the narrower receiver bandwidth with its higher S/N ratio and superior propagation characteristics. A 9 dB improvement is equal to eight times the power of comparable AM! This means greater communications range between SSB stations. A realistic average improvement is closer to 3 dB (2:1 power gain), but even this means a 25-watt SSB signal is equal to a 100-watt AM carrier. (Remember, 100% AM modulation adds 50 watts of extra power to the sidebands, of which only one 25-watt sideband would actually be used.)

Among the SSB disadvantages are its higher cost and circuit complexity. The extra circuitry must generate and detect the SSB signal, and do so with extreme frequency stability. This means much better voltage regulation, more stable oscillators, a special "clarifier" circuit to demodulate the received audio, more complicated electrical and mechanical mode switching, an expensive IF crystal filter, a physically larger chassis and cabinet, etc.

AM & SSB Power Comparison

An AM signal at 100% modulation has 2/3 of its power in the carrier, and only 1/3 of its power in the sidebands. So a 100-watt carrier would add an extra 50 watts of audio power, equally divided between both sidebands, for a total of 150 watts. Since both the upper and lower sidebands have exactly the same intelligence, one of these can be removed. The carrier isn't needed and can also be removed. All the wasted power is eliminated. This results in a signal with half the spectrum bandwidth and a more efficient use of the transmitter.

SSB power output is directly proportional to the power of the modulating audio signal. With no mike input, there's no RF output. An SSB signal is rated in terms of its "peak envelope power" or PEP. This is defined as the maximum transmitter power when the modulating voltage is at its peak. PEP has a direct effect on allowable signal distortion for any particular transmitter. For CB transmitters which allow 4 watts of unmodulated AM carrier output, the allowable SSB power is 12 watts PEP. This is based on the assumption that the typical voice has a peak-to-average audio voltage ratio that doesn't exceed about 3:1, or 4 W x 3 = 12 W PEP equivalent. (Review the photos on Page 169, which show how the peak-to-average power can be different for different voices, or be purposely changed with speech processing.)

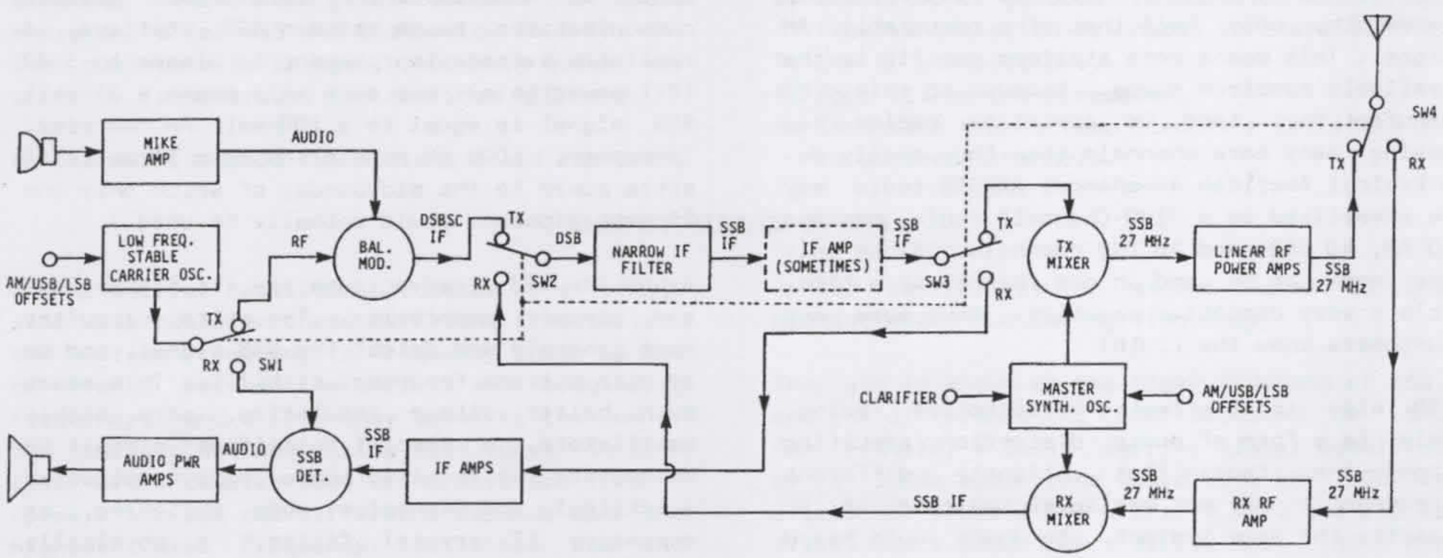
It's important to distinguish between peak and <u>average</u> power. Peaks don't occur very often, and can't be measured on a meter because the mechanical movement can't respond fast enough to show them. And even if it could, your eye couldn't see it anyway. The meter responds to the average power of several RF cycles instead.

With a complex waveform like a voice, the average measurement is the only one that counts. Wattmeters that read peak SSB power use special delay circuits to keep the meter needle in one place long enough to view. When using a single or two-tone sine wave input instead of a voice, the energy is constant and the peak power measurements then make more sense. If your customer happens to watch you tuning his rig, make sure he understands this difference; otherwise he might expect to see the wattmeter hitting the "12 W" power mark all the time when speaking into the mike. Just ain't so!

SSB SIGNAL GENERATION

Figure 6-2 shows the basic SSB CB transceiver. The dotted lines indicate the required T/R mode switching. The SSB signal is produced by first generating a relatively low-frequency, highly stable RF carrier. This signal combines with the mike audio in a special mixer called a "Balanced Modulator" which produces sum and difference frequencies. The carrier and original modulating audio are then removed, leaving only the sidebands which are at RF <u>but</u>

FIGURE 6-2
BLOCK DIAGRAM OF SSB CB TRANSCEIVER



changing at the audio rate. The double-sideband suppressed-carrier (DSBSC) RF signal is then applied to a highly selective crystal filter which removes one sideband. The result is an SSB IF signal which can then be translated up to the required 27 MHz by further mixing, and amplified by Class AB linear RF power stages.

Reception is basically just the opposite of this process, where the 27 MHz SSB signal is converted down to an IF, and mixed with a suitable carrier to demodulate the audio. In CB radios the same carrier that generates the transmitted signal is also used for reception. ("SW1.") The crystal IF filter may also be shared by Receive and Transmit, and sometimes one IF amplifier stage is too. ("SW2," "SW3.")

THE CARRIER OSCILLATOR

A 27 MHz SSB signal is too difficult to process directly and economically. Tuned circuits are critical. A received SSB signal off frequency as little as 40 Hz may be noticeably distorted, and at only 150 Hz away it may be impossible to properly demodulate and will sound like "Donald Duck" to the listener. To avoid this problem the signal is always generated at a lower or intermediate frequency, where tuned circuits aren't as touchy. This carrier frequency is purposely chosen to be near the receiver's IF, for reasons that will soon become apparent.

To further aid stability, all SSB circuits use highly regulated supply voltages. The Carrier Oscillator also functions on Receive to reinsert the missing carrier for proper SSB detection, and runs all the time on AM to provide the proper synthesizer mixing signals.

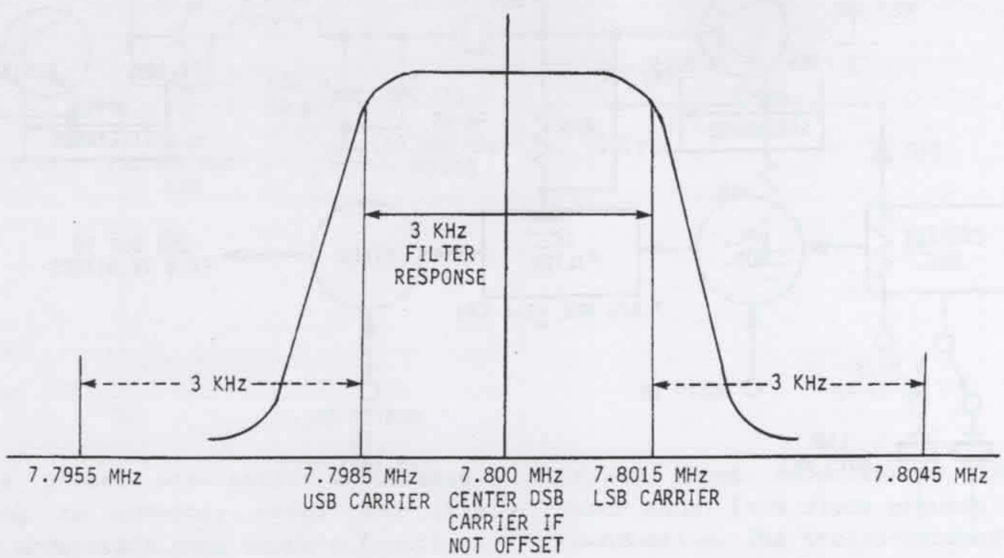
A crystal-controlled Colpitts oscillator is used for the Carrier Oscillator, and its frequency is usually 7.8 MHz, 10.695 MHz, or 11.275 MHz, which is also the 1st AM IF. (A few old radios like the Tram D201, Browning Mark II, III, IV, and the CPIs had their own unique IFs.) Special circuits shift this oscillator a few KHz around its center frequency to generate the proper AM, LSB or USB signal offsets.

Carrier Offsets

Figure 6-2 indicated a single narrow IF filter used to remove one sideband, which is the standard CB method. To do this, the carrier frequency must be placed along one side of the filter passband instead of in the exact center, which means shifting it up or down slightly. Why? Assume that the filter has a flat 3 KHz response, dropping off sharply beyond this. If the DSB RF carrier is at exactly 7.800 MHz, and the highest modulating frequency is 3 KHz, the total bandwidth will be 7.800 MHz ±0.003 MHz, or 7.797-7.803 MHz. The filter passband only has room for 3 KHz of this 6 KHz DSB signal, or 1.5 KHz from each sideband. This means signals from only 7.7985-7.8015 MHz can pass.

Figure 6-3 shows the effect of shifting the carrier frequency slightly. For example, if the

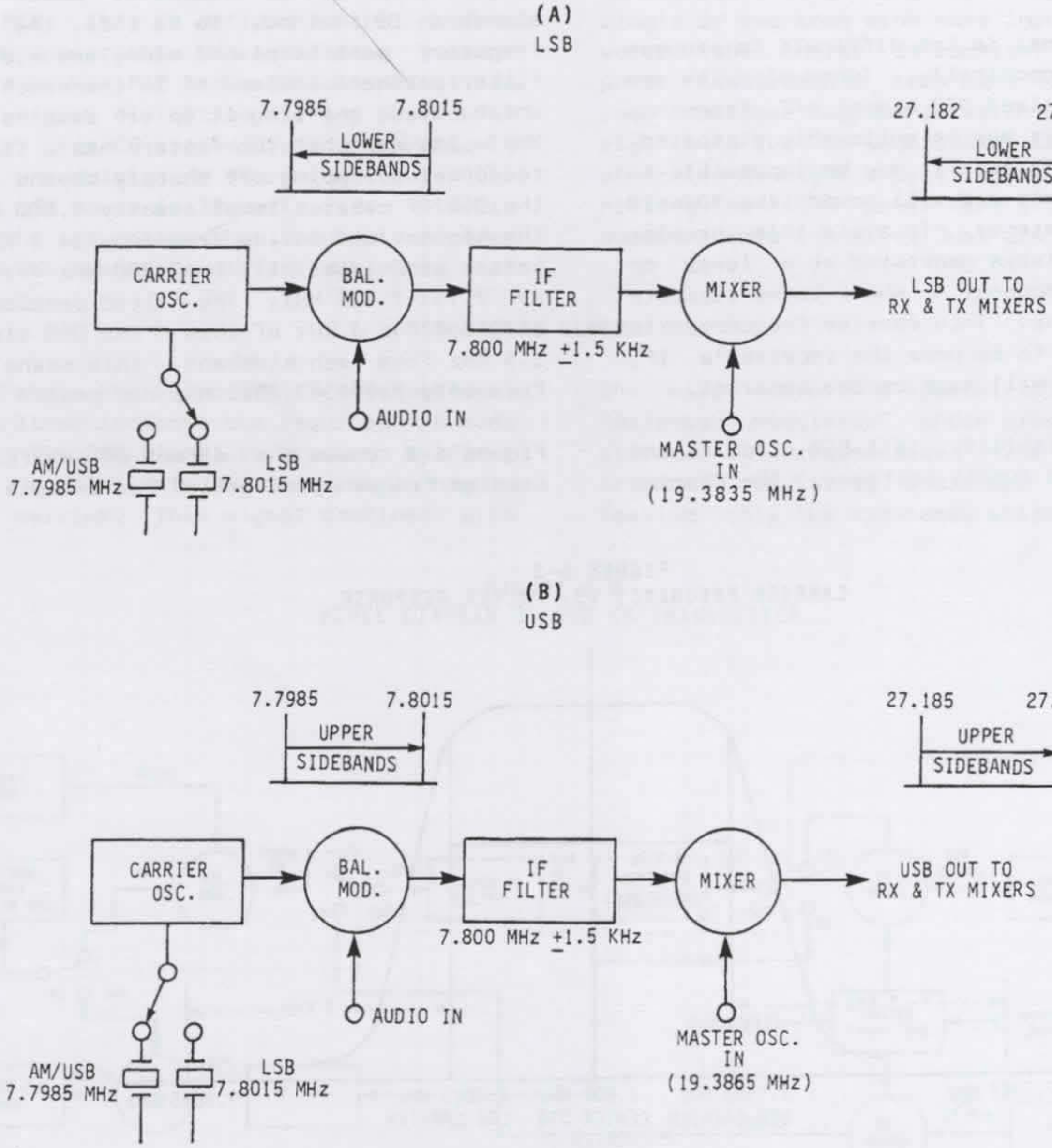
FIGURE 6-3
CARRIER FREQUENCY VS. FILTER RESPONSE



USB carrier frequency is 7.7985 MHz, the 6 KHz of audio then results in 7.7985 MHz ±3 KHz, or 7.7955-7.8015 MHz. Only the 3 KHz wide band of frequencies that's above 7.7985 MHz (the upper sideband) can pass; the lower 3 KHz will fall either on the skirt or completely outside the filter passband and be sharply attenuated. The same is true for LSB, where centering the carrier on 7.8015 MHz allows the lower 3 KHz of audio frequencies from 7.8015-7.7985 MHz to pass, but removes those from 7.8015-7.8045 MHz, which fall outside the filter passband. For correct SSB reception the process is reversed, with the carrier reinserted using the same offset characteristics as the transmission.

The choice of center frequency for the sideband filter depends upon whether or not it's needed for AM reception too. If so, the exact center IF is used and the AM receiver will be single-conversion because only one of the two sidebands is actually detected. And the AM Transmit signal never passes through the sideband filter anyway. But when AM Receive is dual-conversion, the AM and SSB signals take separate IF paths after the 1st mixer. The AM IF path has its own monolithic crystal filter or ceramic filters for selectivity. (Sometimes

FIGURE 6-4
SSB SYSTEM USING SINGLE FILTER AND OSC. OFFSETS (CH. 19)



a monolithic crystal filter is placed right after the 1st mixer, before the AM and SSB signals branch off.) This explains why many radios have sideband filters which are offset slightly (10.6935 MHz or 11.2735 MHz); they're purposely centered between the 10.692 MHz LSB/ 10.695 MHz USB or 11.272 MHz LSB/11.275 MHz USB carriers, which allows the 3 KHz of total audio sidebands to fit within the filter passband.

The use of offsets is shown in Figure 6-4. Each mode's crystal is cut slightly higher or lower than the center carrier frequency. The crystal offsets are 1.5 KHz or 2.5 KHz, depending upon the particular circuit. AM is usually (but not always) associated with USB, so that only two crystals are needed here. One early Uniden PLL type chassis (Cobra 138/139XLR and similar) used three individual crystals, an expensive method. Regardless of mixing scheme, each mode has a slightly different carrier frequency.

The preceeding method was used in most older synthesized radios and is now outdated, but there are still many popular radios using it. The current trend, even cheaper, uses a single Carrier Oscillator crystal with switchable inductance or capacitance for each mode offset. Three popular methods are described next.

Figure 6-5 shows the capacitance offset method typical of Cybernet and other manufacturers. The sideband filter is 10.6935 MHz for use on SSB only; in these models AM Receive is dual-conversion and the filter's not shared. The crystal is used in its series-resonant mode and has a series RF ground through CT5/C66 for AM/USB. The combination will pull the crystal up in frequency, to 10.695 MHz. This explains why the crystal itself is 10.692 MHz rather than exactly 10.695 MHz. Q11 is a switch which conducts on LSB, adding the capacitance of CT4/C65 and the series inductance of L14 to pull the crystal down to 10.692 MHz. C65 and C66 add stability and temperature compensation, since they divide the RF currents and prevent excess heating of the trimmers. D10/R47 cut off Q12 for AM Receive by raising its emitter to within 0.6 V of the base voltage; the carrier only needs to be reinserted for SSB reception.

FIGURE 6-5
CAPACITANCE METHOD OF CARRIER OSC. OFFSETS
(Cybernet PTBM048 chassis: JC Penney 981-6247, HyGain 2705, Lafayette Telsat SSB140, Midland 79-892, etc.)

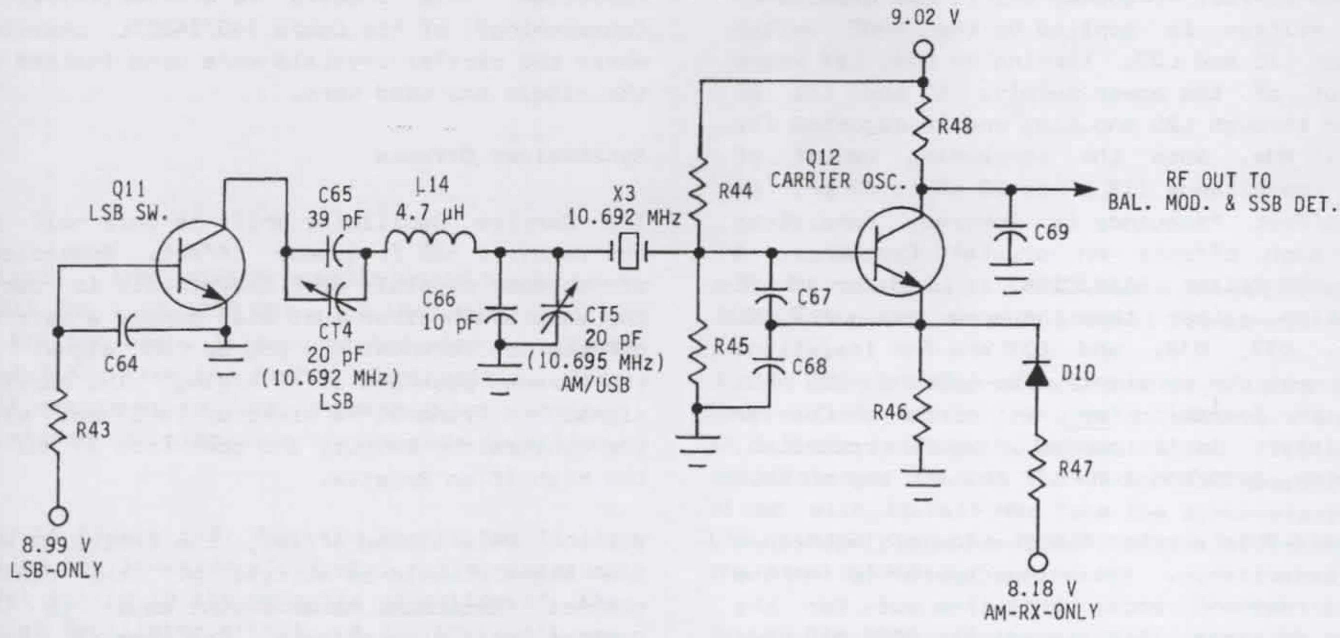
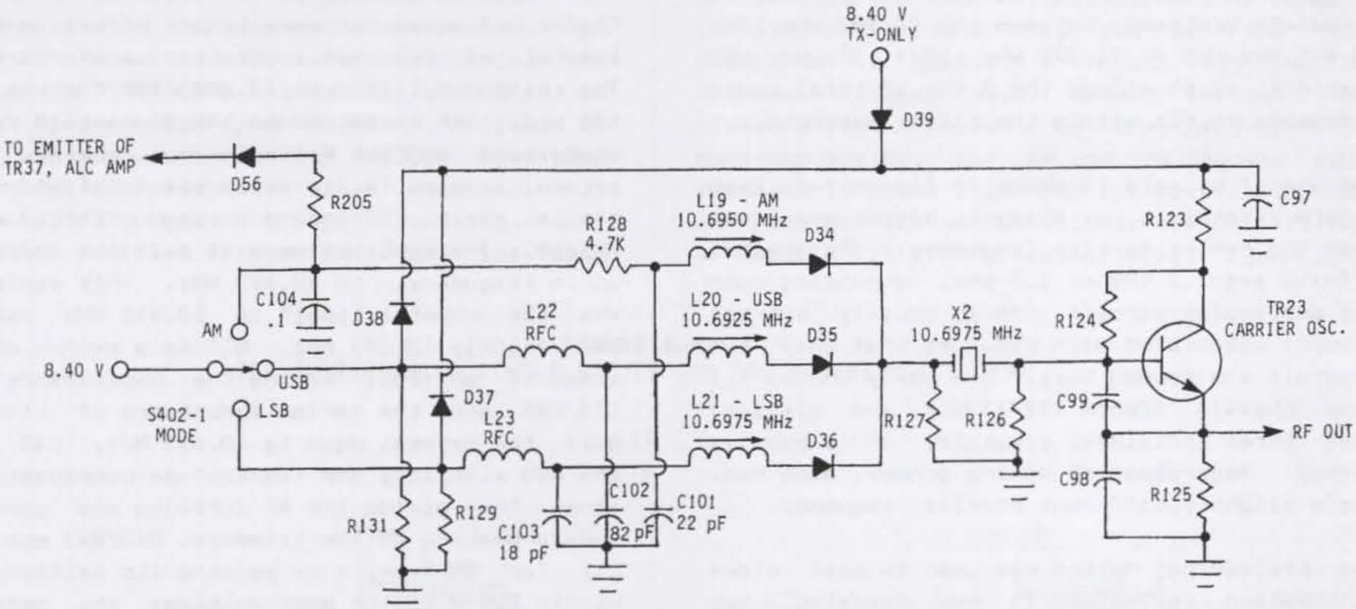


Figure 6-6 has offsets with series inductance. Diode steering is commonly used, and it's important to understand each diode's function. A combination of a tunable series inductor and fixed shunt capacitor is diode-switched for each mode. Each diode grounds through R127 when conducting. The series-resonant crystal mode is used again, which means that series inductance

FIGURE 6-6
INDUCTANCE METHOD OF CARRIER OSC. OFFSETS
(Cobra 146GTL, President AX144, Realistic TRC451, Uniden PC244, etc.)



will lower the crystal frequency. Again, this explains why the actual crystal is 10.6975 MHz rather than exactly 10.695 MHz.

The crystal is grounded for RF by each coil's associated capacitor, which is carefully chosen for the correct frequency shift. For example on USB, voltage is applied by the MODE switch through L22 and L20, turning on D35. L22 keeps RF out of the power supply. X2 has its RF ground through L20 and C102 and is adjusted for 10.6925 MHz. Note the increasing amount of shunt capacitance (18 pF to 22 pF to 82 pF) as the offset frequency is lowered, consistent with such effects on crystal frequency. A simple RC filter (R128/C104) is used for AM RF isolation rather than the more expensive RF choke. D37, D38, and D39 are for isolation; TR23 must run constantly for LSB and USB but only on Transmit for AM, since a Carrier Oscillator isn't needed for AM reception. Likewise, R205/D56 turn off the ALC amp on AM.

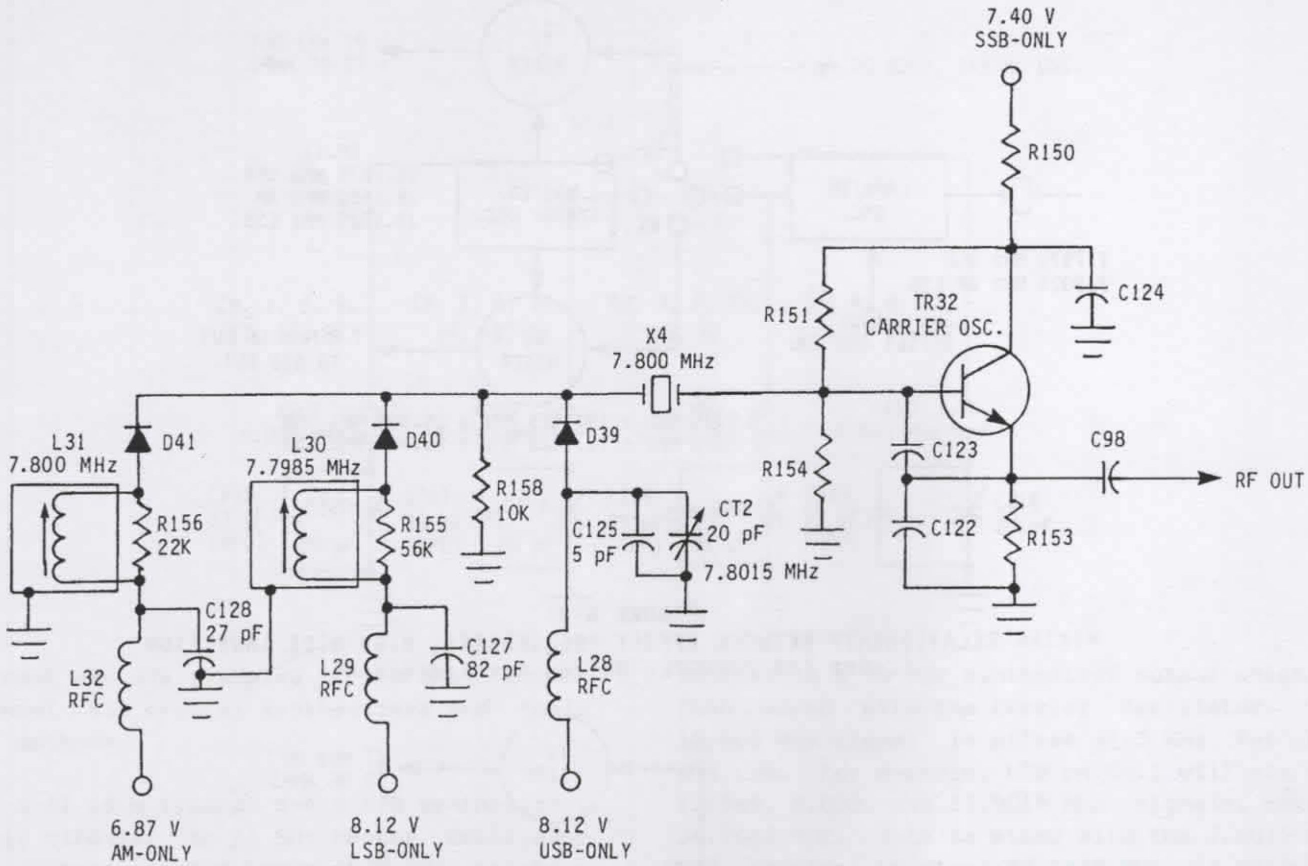
Figure 6-7 is another combination of inductance and capacitance. Again the crystal is in the series-resonant mode, this time cut for the center AM range. Steering diodes D39, D40, D41 will each ground through R158. The series capacitance of CT2/C125 pulls the crystal up to 7.8025 MHz for USB, with C125 for temperature compensation again. L30/C127 pull it down to 7.7975 MHz for LSB. AM is adjusted for exactly 7.800 MHz. R155 and R156 lower the Q of L30 and L31 respectively to broaden tuning; note how R155 is greater, lowering the Q of L30 further since LSB is more critical than AM. L28, L29, and L32 are RF chokes used for power supply isolation. This chassis is a simplification (cheapening?) of the Cobra 140/142GTL chassis, where two carrier crystals were used instead of the single one used here.

Synthesizer Offsets

The Carrier Oscillator shift is only half of the required SSB frequency offset. Regardless of whether crystal- or PLL-synthesis is used, the main synthesizer must also supply a pair of offsets to recenter the USB or LSB signal in the correct passband after mixing. The carrier signal on Transmit is mixed up to 27 MHz with the synthesizer output, and down from 27 MHz to the high IF on Receive.

Without this second offset, the entire 27 MHz SSB signal would be shifted off the center channel frequency by an amount equal to the Carrier Oscillator offsets. For example, back in Figure 6-4 the LSB carrier was offset to 7.8015 MHz and the 19 MHz LSB synthesizer was offset by -1.5 KHz, to 19.3835 MHz. If this signal had remained centered at 19.3850 MHz

FIGURE 6-7
COMBINATION INDUCTANCE/CAPACITANCE OFFSETS
(Cobra 148/2000GTL, Uniden Grant/Madison)



instead, the mixing result would have been 7.8015 MHz + 19.3850 MHz = 27.1865 MHz, exactly 1.5 KHz too high. It's corrected with an offset of -1.5 KHz from the Master Synthesizer. This shift may go up or down, depending upon whether the mixers use high-side or low-side injection.

Refer to Figure 6-8. When the Master Oscillator runs on the low side of 27 MHz, the synthesizer offset shifts in the opposite direction of the Carrier Oscillator offset. A 2.5 KHz shift was added to the AM/LSB carrier but subtracted from the 19.1650 MHz center synthesizer frequency. For Ch.1 AM/LSB, mixing the 7.8025 MHz AM/LSB carrier with the 19.1625 MHz LSB synthesizer output results in 7.8025 MHz + 19.1625 MHz = 26.965 MHz, the correct channel frequency.

In the case of high-side injection, Figure 6-9, both offsets are in the same direction; a shift of 1.5 KHz is added to or subtracted from both oscillators. Thus a 7.7985 MHz LSB carrier is mixed with 34.7635 MHz from the synthesizer on LSB, which produces 34.7635 MHz - 7.7985 MHz = the same 26.965 MHz again.

Trying to keep all these offsets straight and remembering which one goes which direction gets confusing, but it's simple if analyzed in block diagram form. The additional examples from the 23-channel era described shortly will help.

FIGURE 6-8
MIXING RELATIONSHIP BETWEEN OFFSET FREQUENCIES, LOW-SIDE INJECTION
(SBE Sidebander IV, V, Console V)

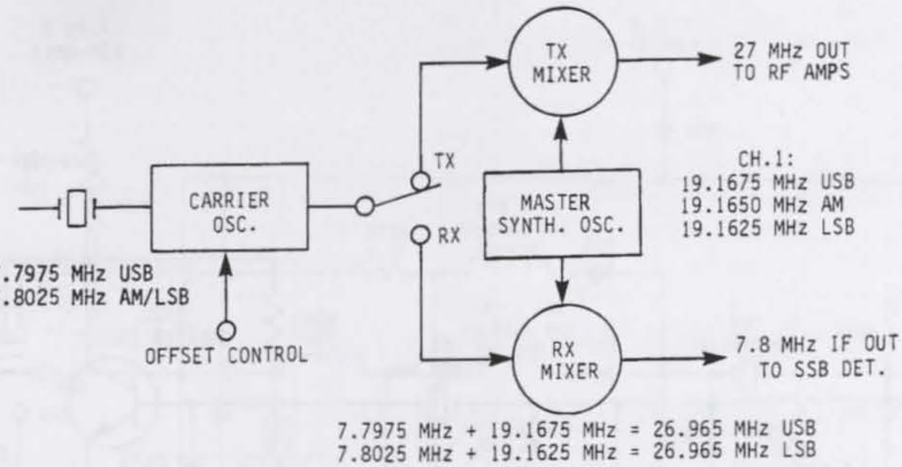
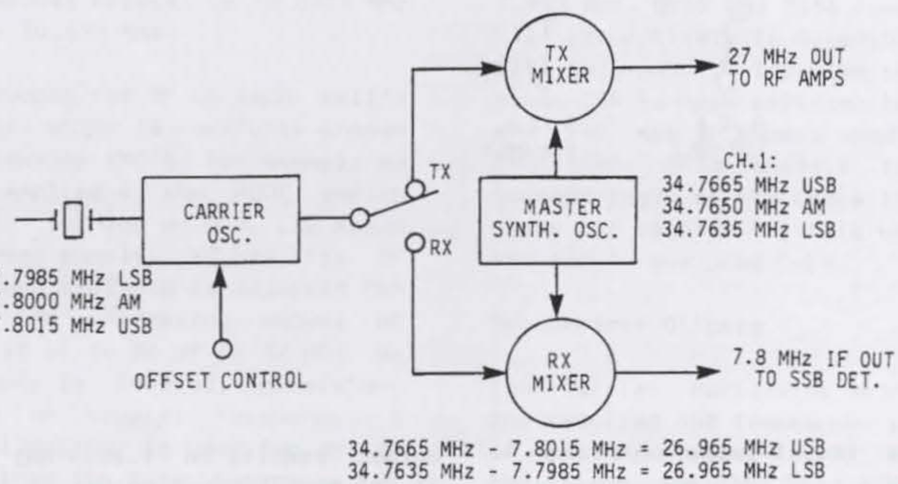


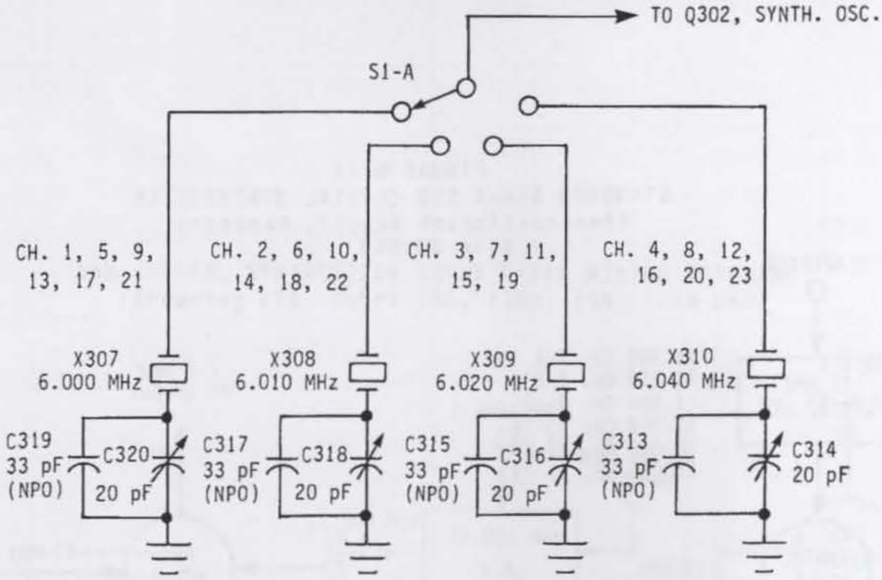
FIGURE 6-9
MIXING RELATIONSHIP BETWEEN OFFSET FREQUENCIES, HIGH-SIDE INJECTION
(Cobra 148/2000GTL, Uniden Grant/Madison)



Crystal Synthesizer Offsets

The crystal synthesizers for 23-channel SSB radios are only slightly more complex than the AM circuits described in CHAPTER 3. Unlike AM synthesizers, SSB crystal synthesizers usually include small trimmer capacitors of about 20 pF on every crystal for exact frequency netting. These trimmers are ceramic for good stability. They're shunted by small fixed ceramic disc capacitors of approximately the same value for temperature compensation, and have a "negative temperature coefficient" of 150 ppm or less. (This means the capacitance will decrease less than 150 parts-per-million per 1°C. increase in temperature.) Figure 6-10 shows the idea.

FIGURE 6-10
SHUNT STABILIZERS FOR CRYSTAL-SYNTHESIZED SSB OSCILLATORS
(Browning LTD, Cobra 132, 132A, 135, Tram D60)



Shown next are six examples of the most common 23-channel SSB crystal synthesizers and their offset methods.

Figure 6-11 is a typical 6-4-4 SSB synthesizer. In this circuit, an 11 MHz Master Oscillator mixes with one of two banks of 7 MHz crystals to produce a 19 MHz output. Two crystals are used for the Carrier Oscillator, as previously described. For example, Ch.1 AM/USB connects the 11.805 MHz and 7.3615 MHz crystals, mixing together to result in 11.805 MHz + 7.3615 MHz = 19.1665 MHz. Mixing this product with the 7.7985 MHz AM/SSB Carrier Oscillator results in 19.1665 MHz + 7.7985 MHz = 26.965 MHz. For LSB, the synthesis will be 11.805 MHz + 7.3585 MHz = 19.1635 MHz + 7.8015 MHz = 26.965 MHz again.

Note that there's no separate AM offset. LSB is offset only 1.5 KHz at the synthesizer output so it remains within the filter passband, and another 1.5 KHz in the final mixing with the Carrier Oscillator. You'll encounter many SSB synthesizers like this one; the three crystal banks may use slightly different frequencies, but will still operate on the 6-4-4 principle.

A slight variation on this circuit is shown in Figure 6-12. Here two 6 MHz and 16 MHz crystal banks mix to produce a 22 MHz signal, and then mix with a fixed 12.800 MHz oscillator. This results in a 34 MHz synthesizer output which is then mixed with the Carrier Oscillator. The 12.800 MHz signal is offset ±1.5 KHz for USB and LSB. For example, USB on Ch.1 will mix the 15.965, 6.000, and 12.8015 MHz signals, making 34.7665 MHz. This is mixed with the 7.8015 MHz USB carrier to give 34.7665 MHz - 7.8015 MHz = 26.965 MHz. This particular scheme is just as complex as the preceeding example, but uses the superior high-side mixer injection instead.

Figure 6-13 has several advantages over the preceeding circuits: a total of three rather than four oscillators are required, only one Carrier Oscillator crystal is required, and no carrier offsets are needed at all. At first glance its extra complexity seems counter-productive from a manufacturing standpoint, since it eliminates two crystals but adds a bunch of other parts instead. However we're talking literally pennies in cost differences between methods. From a marketing standpoint, every $1 in manufacturing cost increase adds roughly $5 to the final retail price!

In this circuit, 11 MHz and 8 MHz crystals mix to produce two different groups of synthesizer frequencies in the 19 MHz and 34 MHz ranges. This means that both low-side and high-side injection respectively are used, which explains why no carrier offsets are needed. This is one

FIGURE 6-11
STANDARD 6-4-4 SSB CRYSTAL SYNTHESIZER
(Pearce-Simpson Bengal, Panther)

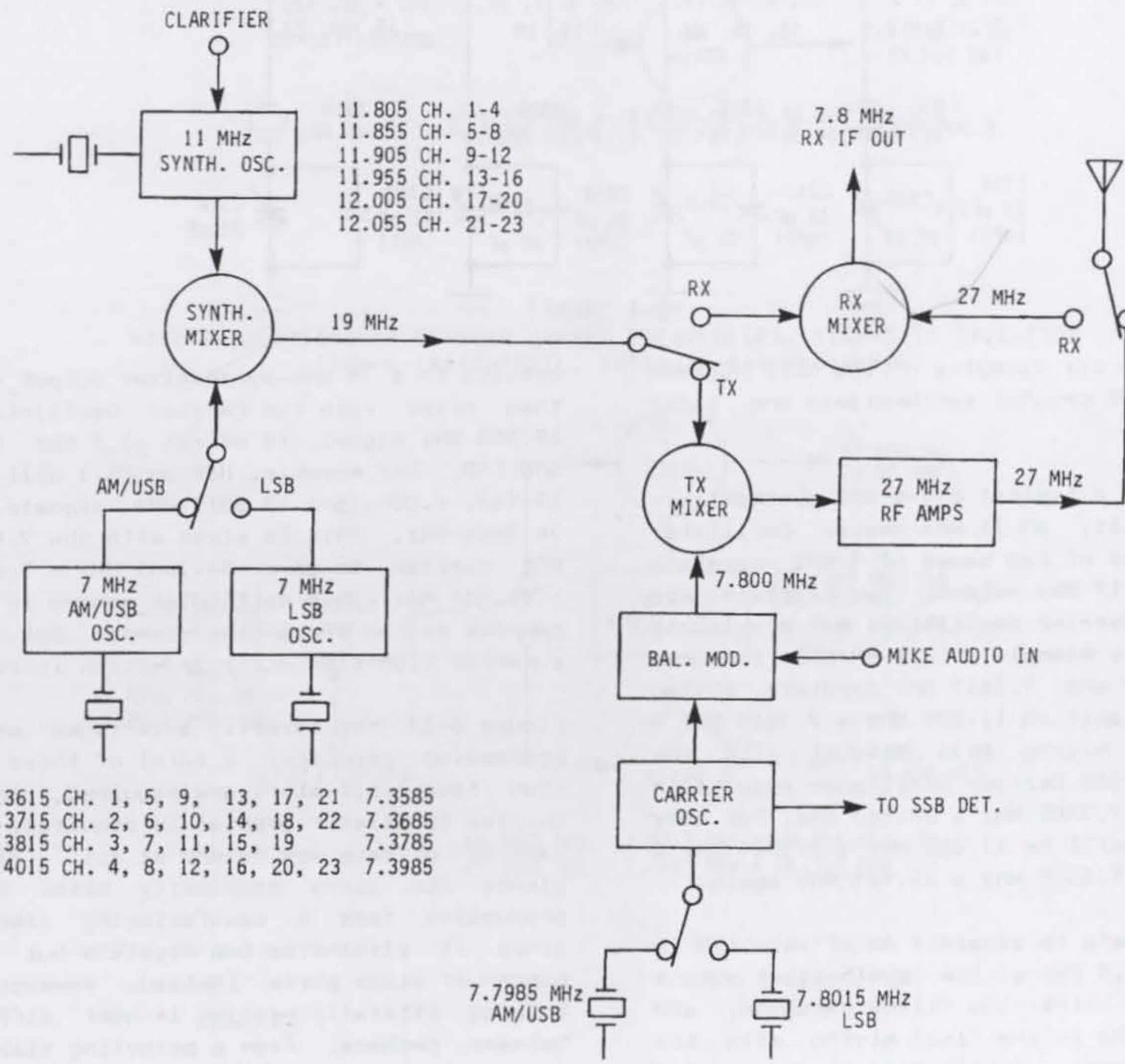


FIGURE 6-12
SSB CRYSTAL SYNTHESIZER USING FIXED MIXING FREQUENCY
(Browning LTD, Cobra 132, 132A, 135, Tram D60)

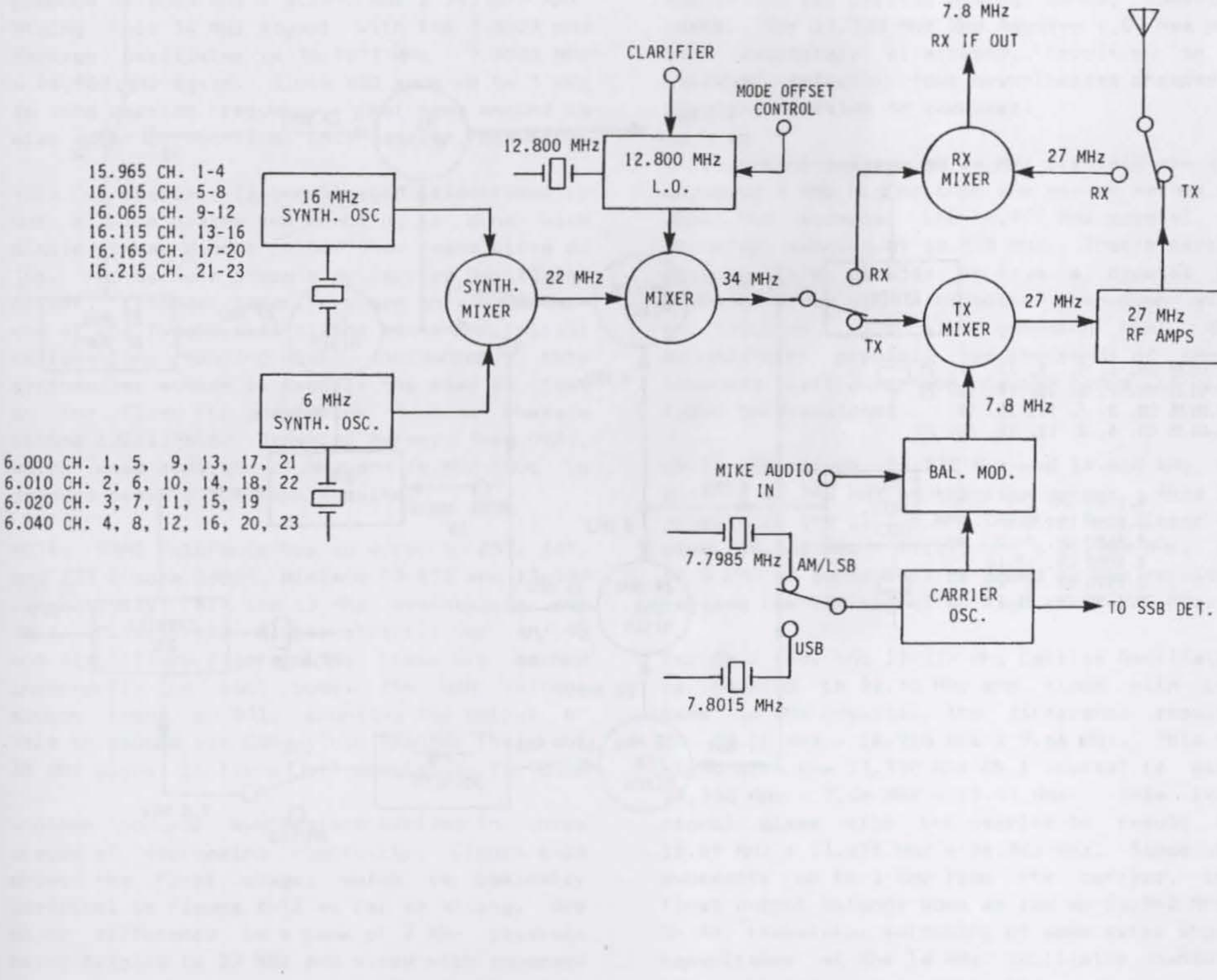
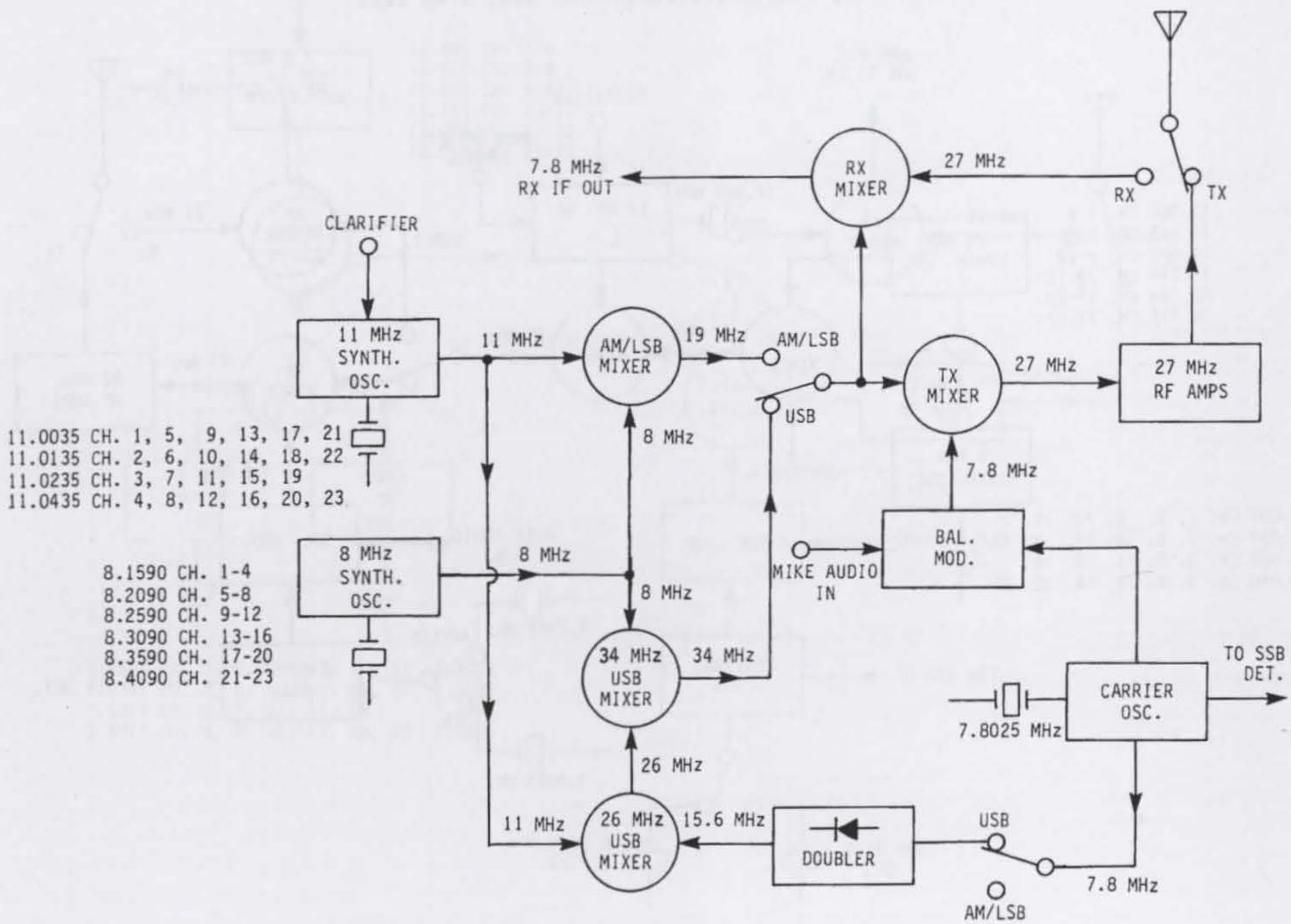


FIGURE 6-13
SSB CRYSTAL SYNTHESIZER USING BOTH HIGH-SIDE & LOW-SIDE INJECTION
(Cobra 138/A, 139/A, Johnson Viking 352, Midland 13-893, 13-895,
Pace Sidetalk 1000M, 1000B, etc.)



of those special cases where AM is associated with LSB rather than USB. For example, the Ch.1 AM/LSB mixes 11.0035 MHz and 8.1590 MHz to yield 19.1625 MHz. Mixing with the 7.8025 MHz Carrier Oscillator, the result is 19.1625 MHz + 7.8025 MHz = 26.965 MHz. Since LSB subtracts up to 3 KHz from the carrier frequency, that same amount is also being subtracted from the final Ch.1 center carrier frequency.

For USB the circuit is a bit more complicated. The 7.8025 MHz signal is first doubled to produce 15.605 MHz and then mixed only with the 11 MHz crystal. This results in 11.0035 MHz + 15.605 MHz = 26.6085 MHz. The 26 MHz composite signal is then mixed with the 8 MHz crystal to produce 26.6085 MHz + 8.1590 MHz = 34.7675 MHz. Mixing this 34 MHz signal with the 7.8025 MHz Carrier Oscillator is 34.7675 MHz - 7.8025 MHz = 26.965 MHz again. Since USB adds up to 3 KHz to the carrier frequency, that same amount is also added to the final Ch.1 carrier frequency.

This synthesizer is complicated electrically, but all the mixing and doubling is done with simple, cheap diodes rather than transistors or ICs. And because there's no Carrier Oscillator offset, trimmer capacitors are only needed on one of the two crystal mixing banks for initial calibration, reducing costs. Incidentally, this synthesizer scheme is exactly the same as that in the first PLL generation Toshiba chassis (Cobra 132/135XLR, Browning Baron, Tram D62), which used separate 19 MHz and 34 MHz VCOs to produce exactly the same results.

NOTE: SAMS Fotofacts has an error in #57, #69, and #73 (Cobra 138/A, Midland 13-893 and 13-895 respectively) at the 19 MHz synthesizer amp TR14. Circuitrace #10 is strictly for AM/LSB and Circuitrace #11 for USB; these are marked incorrectly in each book. The USB voltage source turns on D31, shunting the output of TR14 to ground via C90. This insures that the 19 MHz signal is turned off completely for USB.

Another popular synthesizer evolved in three stages of decreasing complexity. Figure 6-14 shows the first stage, which is basically identical to Figure 6-11 as far as mixing. One major difference is a bank of 7 MHz crystals being tripled to 23 MHz and mixed with separate 14 MHz crystal banks for AM/USB and LSB. This produces a 38 MHz synthesizer signal and high-side injection. The IF is now 11.275 MHz, the second main difference. A separate 11.730 MHz receiver L.O. mixes that down to 455 KHz.

In Figure 6-15, the 7 MHz tripler stage itself has been eliminated, allowing a 23 MHz bank of crystals to be used directly. Otherwise it's exactly the same as Figure 6-14. The 11.730 MHz 2nd L.O./2nd Mixer stages for dual-conversion AM Receive is only used in the better versions.

Figure 6-16 shows the final circuit revision. Note it's virtually identical to Figure 6-13, where separate AM/USB and LSB synthesizer outputs are also used and where no Carrier Oscillator offsets are needed. The synthesizers are now 38 MHz and 16 MHz respectively. This greatly reduces crystal requirements, to just eleven crystals for the entire radio. Trimmer and stabilizing capacitors are only used for one of the two crystal mixing banks, lowering costs. The 11.730 MHz 2nd Receive L.O. has now been completely eliminated, resulting in a somewhat inferior (but nevertheless cheaper!) single-conversion AM receiver.

In this synthesizer the 14 MHz crystals are all adjusted 3 KHz higher than the marked values on USB. For example, the 14.907 MHz crystal is actually running at 14.910 MHz. That's partly because it's cheaper to trim a crystal by pulling it up with a capacitor than down with an inductor. I'm also guessing that the manufacturer probably had thousands of these crystals left over from the LSB banks of the first two versions!

Ch.1 USB mixes 23.330 MHz and 14.910 MHz to give a 38.240 MHz synthesizer output. This is mixed with the 11.275 MHz Carrier Oscillator to give 38.240 MHz - 11.275 MHz = 26.965 MHz. Up to 3 KHz of audio will be added to the carrier, raising the USB signal as high as 26.968 MHz.

For Ch.1 LSB, the 11.275 MHz Carrier Oscillator is doubled to 22.55 MHz and mixed with the same 14 MHz crystal. The difference results in 22.55 MHz - 14.910 MHz = 7.64 MHz. This is mixed with the 23.330 MHz Ch.1 crystal to give 23.330 MHz - 7.64 MHz = 15.69 MHz. This last signal mixes with the carrier to result in 15.69 MHz + 11.275 MHz = 26.965 MHz. Since LSB subtracts up to 3 KHz from the carrier, the final output extends down as low as 26.962 MHz. On AM, transistor switching of some extra shunt capacitance at the 14 MHz oscillator centers its carrier frequency correctly.

Almost every 23-channel AM/SSB radio uses a variation of one of these six synthesizers. Specific crystal frequencies are usually the

FIGURE 6-14

SSB CRYSTAL SYNTHESIZER WITH HIGH-SIDE INJECTION IN ALL MODES

(Midland 13-896, 13-898B, Royce 1-640, etc.)

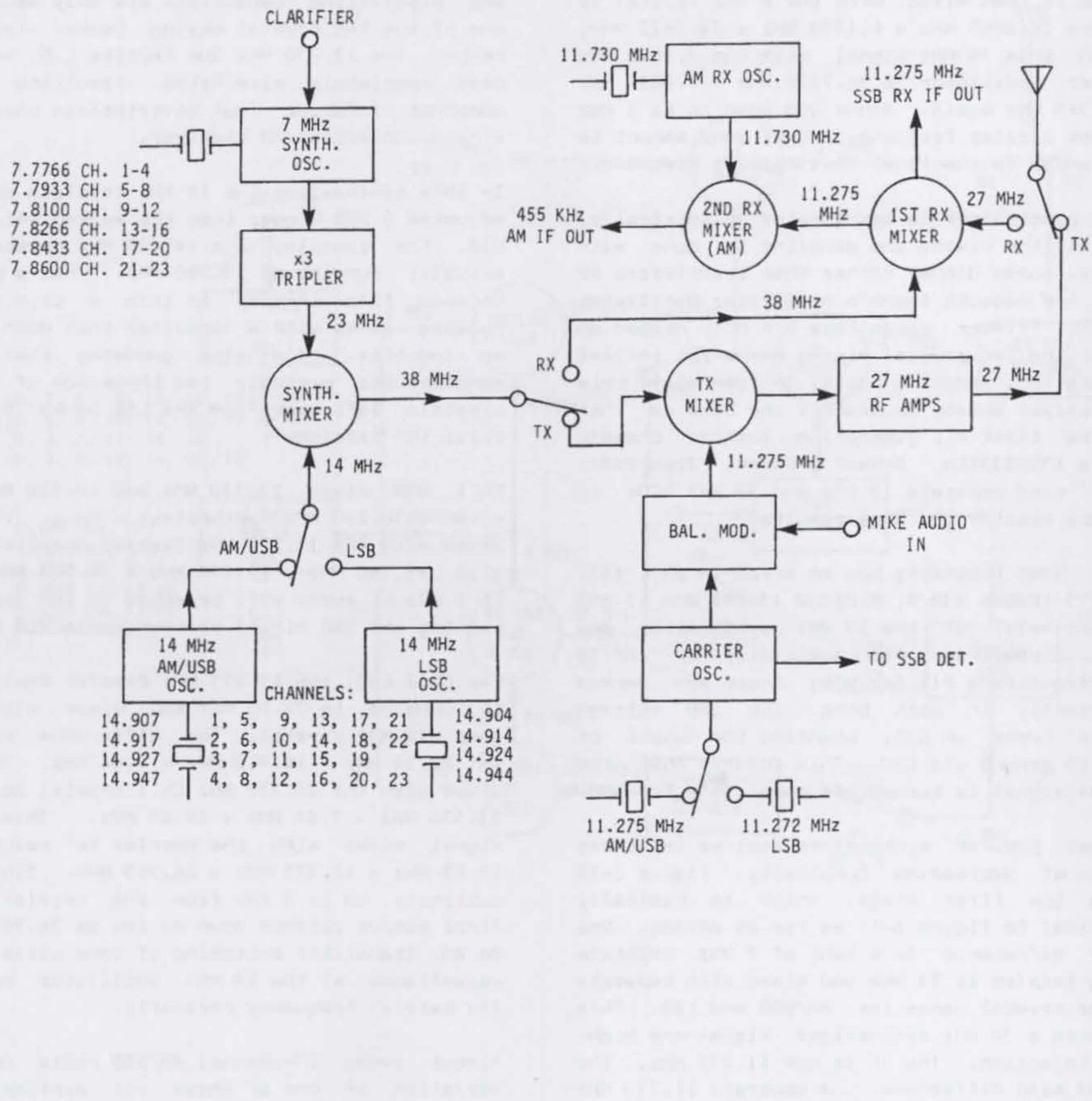


FIGURE 6-15
SIMPLIFIED SSB CRYSTAL SYNTHESIZER OF FIG. 6-14
(Lafayette Telsat SSB100, Realistic TRC47, TRC48, etc.)

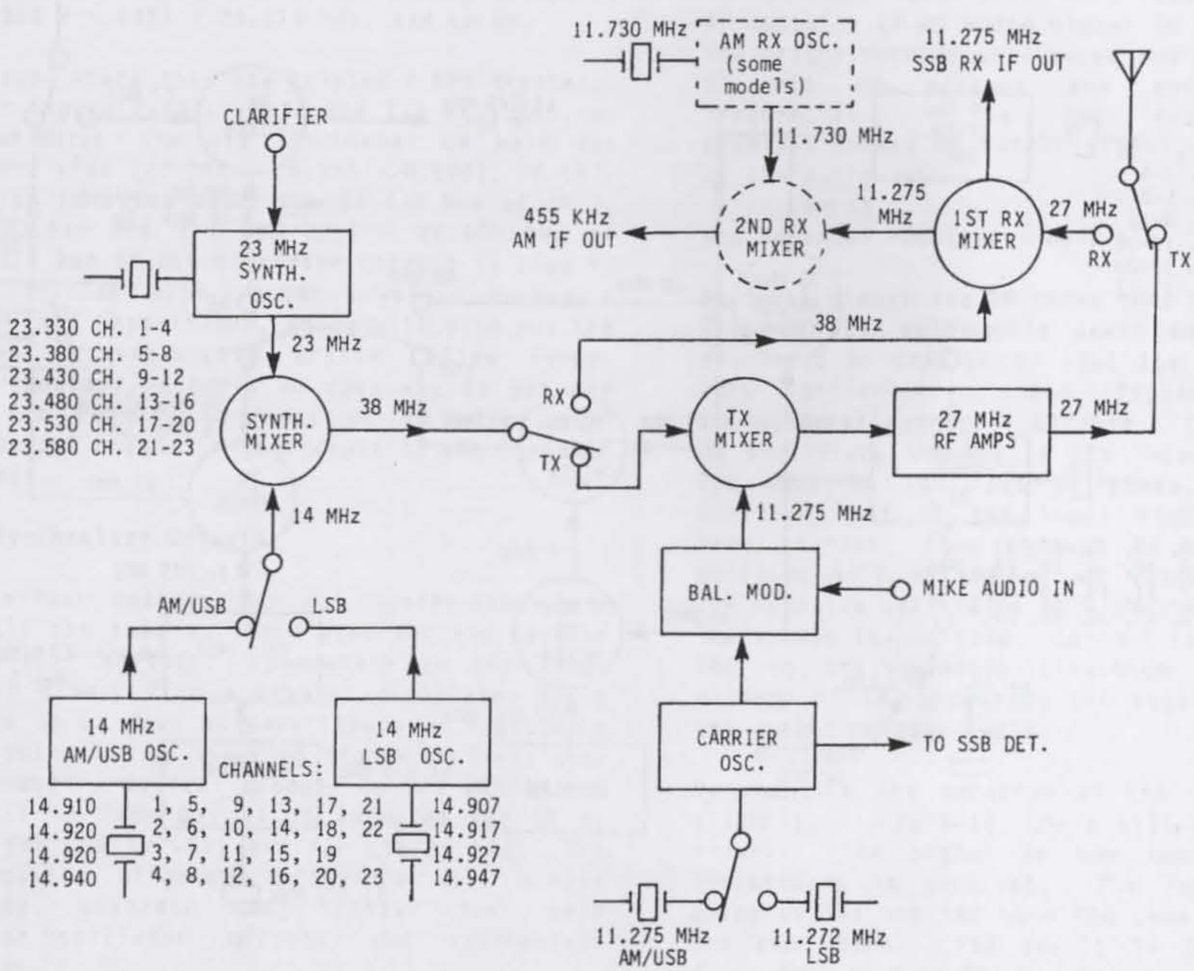
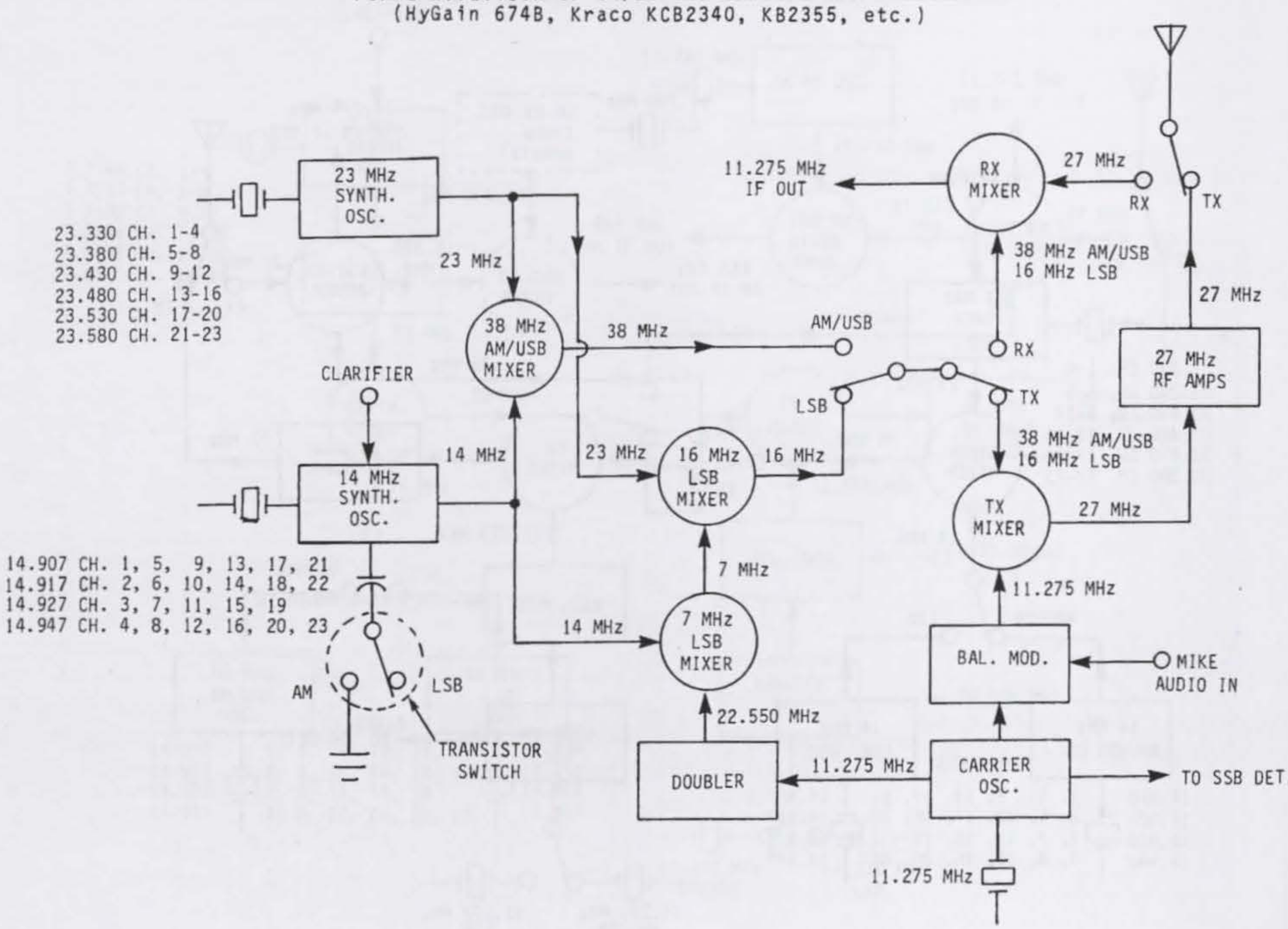


FIGURE 6-16
FINAL EVOLUTION OF 14/23 SSB CRYSTAL SYNTHESIZER
(HyGain 674B, Kraco KCB2340, KB2355, etc.)



only difference. Exceptions include some of the older tube-type rigs, and some of the old classic, premium rigs like the Tram D201 or Browning Mark II or Mark III. Close study of their schematics will reveal the specific mixing schemes. Crystal mixing charts for the most common SSB radios are found at the end of this chapter.

For conversion to the new 10-Meter Ham bands, add a total of 1.245 MHz to each of the six master mixing crystals from the preceding examples, and realign the radio. How did I figure this? If 28.500 MHz is the highest legal Novice SSB frequency, just subtract the former CB Ch.23, which is 27.255 MHz. This is a difference of [28.500 - 27.255] = 1.245 MHz. For example in Figure 6-16, add this amount to each of the six 23 MHz master mixing crystals; [23.330 + 1.245] = 24.575 MHz, and so on.

In cases where they use tripled 7 MHz crystals, (like Figure 6-14), you'd add 1/3 of 1.245, or 0.415 MHz. The old 23-channel CB band was 290 KHz wide (27.255 - 26.965 = 0.290), so this results in a new band from 28.210 MHz at Ch.1, to [28.210 MHz + 0.290 MHz] = 28.500 MHz at Ch.23. And if the Clarifier circuit is tied to this crystal bank, order crystals having a 10 pF Load Capacitance, which will give you the largest possible VXO crystal slide range. Unfortunately, there's no easy way to get the 100 KHz repeater offsets on 10 Meters with 23-channel crystal rigs because of the fixed IF filters.

PLL Synthesizer Offsets

The offset methods for PLL synthesizers are exactly the same as those used for the Carrier Oscillator offsets. Somewhere in the loop, you'll always find a crystal oscillator being pulled up or down by capacitance or inductance and controlled by steering diodes or transistor switches. A typical example is the MB8719 PLL circuit on Page 83; X4 is adjusted for AM by L23, for USB by L59, and for LSB by L22. The synthesizer alignment procedure will always include separate adjustments for both Carrier Oscillator offsets and synthesizer offsets.

THE SPEECH AMPLIFIER

This consists of one or two stages which will amplify the mike output up to a usable level. The only real difference from AM or FM is the destination of the mike audio. The AM path goes to a high-level audio amplifier and the FM path to a reactance modulator. SSB requires only a small fraction of the AM audio power, going instead to a special circuit called a "Balanced Modulator." Each audio path may be directly hard-wired, or use transistor/diode steering. Sometimes separate speech amps are used for each mode, as well as separate trimmers for AM and SSB mike levels. The AMC feedback loop is usually shared with SSB too. See CHAPTER 5 for circuit details.

THE BALANCED MODULATOR

The key to generating the SSB signal is in the Balanced Modulator, a special type of bridge circuit. The BM bridge consists of non-linear elements like diodes, or transistors biased to non-linearity. The Carrier Oscillator signal is applied and currents flowing within the bridge cancel each other out, resulting in zero RF output. If an audio signal is then applied, the bridge becomes unbalanced and the audio and RF mix to produce sum and difference frequencies. The net result is a double-sideband RF output signal, but changing at the audio rate.

How Balanced Modulators Work

At first glance the BM looks very much like the Class B push-pull audio power amp previously discussed in CHAPTER 4. But its operation is very different. See Figure 6-17, a conventional push-pull circuit. To operate as an amplifier, signals at the bases of TR1 and TR2 must be 180° out of phase. With the positive half of the input signal at TR1's base, current flow through T2 produces the positive half of the output voltage. During the negative half TR1's base goes negative, but TR2's base is positive. Current now flows from TR2 in the opposite direction through the primary of T2, producing the negative half of the output voltage cycle.

By changing the location of the input signal slightly, Figure 6-18, there will be no output signal. The signal is now applied to the transistors in parallel. The inputs at the bases of TR1 and TR2 have the same polarity at the same time. The result is that current flows down T2 from TR1 at the same time current is flowing up T2 from TR2, and vice-versa. Current flow through both transistors is equal but opposite; the magnetic fields cancel each other so there's no output signal. The circuit as it's shown here doesn't appear to be doing any useful work. But if the input signal happens to be a CB Carrier Oscillator, the result is a carrier which is balanced out or suppressed.

FIGURE 6-17
STANDARD PUSH-PULL AMPLIFIER CIRCUIT
(Courtesy Prentice-Hall Inc.)

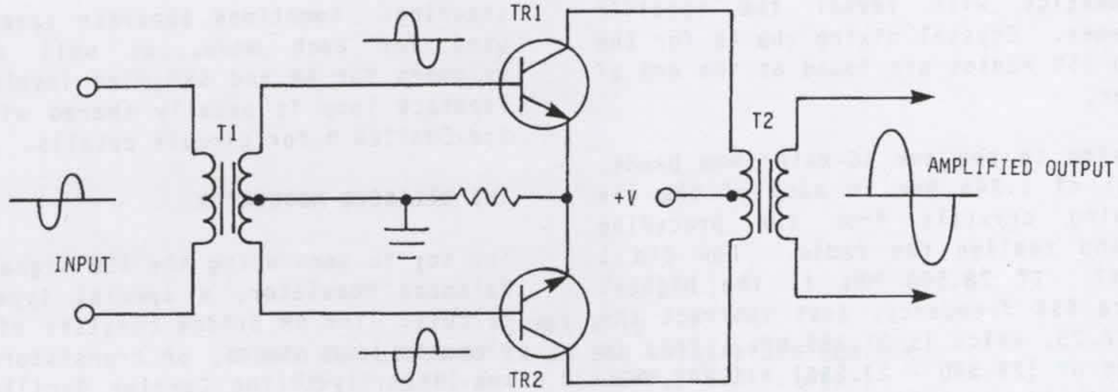


FIGURE 6-18
PUSH-PULL CIRCUIT WITH SIGNAL APPLIED IN PHASE
(Courtesy Prentice-Hall Inc.)

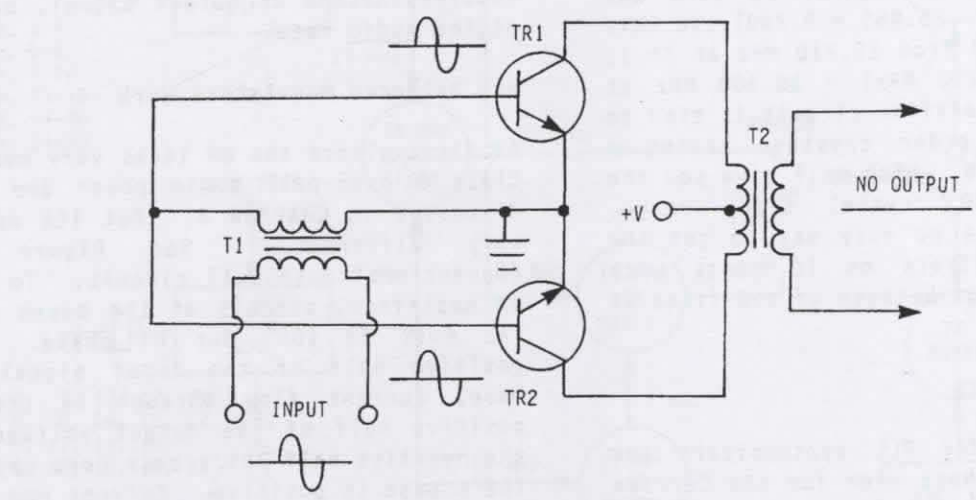
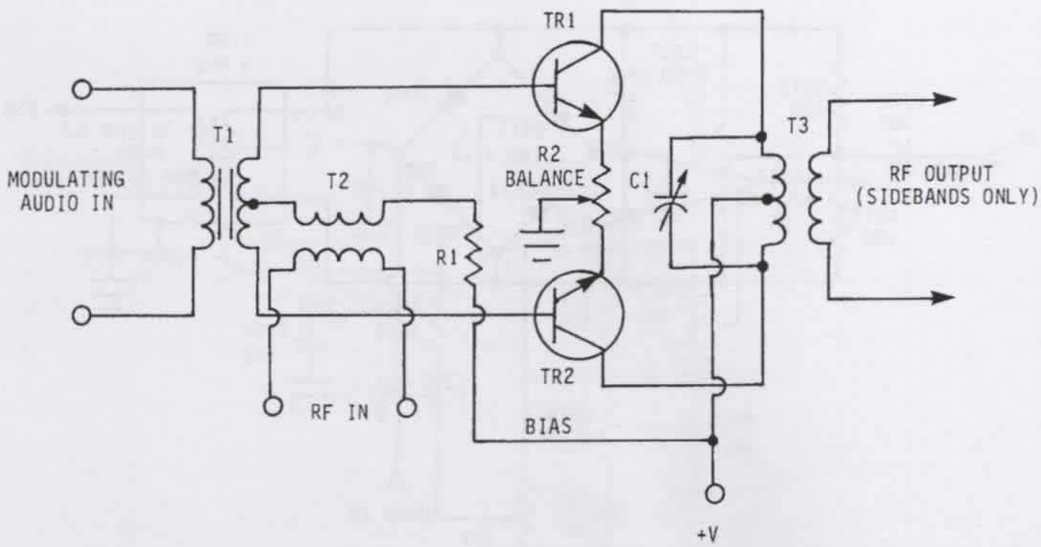


Figure 6-19 shows the final modification. Look familiar? It's a simplified combination of the previous two circuits. The RF carrier is applied in the signal-cancelling manner of Figure 6-18 (in parallel), and the audio in the conventional push-pull manner of Figure 6-17. The carrier will not appear in the output.

But the effect of the audio is different: on the positive swing of the audio voltage, the base of one transistor goes negative while the other is positive, and vice-versa for the negative audio swing. Current can now flow on both halves of the audio through alternating transistors, inducing an RF output current in the tank circuit of C1/T3. The audio input upsets the cancelled RF carrier at the audio rate, producing only the RF sidebands. The tank circuit has such high impedance to audio frequencies that they don't appear in the output either. R1 supplies the proper bias, and R2 balances the transistors for equal currents.

When both RF and audio are simultaneously applied to a non-linear balanced bridge like this, RF currents of the carrier frequency, audio frequency, and the sum and difference frequencies flow within it. The audio input in effect controls the bias on the transistor bases to produce a modulated RF output. But the carrier frequency currents cancel out, and the modulating audio voltage doesn't appear in the

FIGURE 6-19
SIMPLIFIED BALANCED MODULATOR
(Courtesy Prentice-Hall Inc.)



output either because its injection level is purposely made low relative to the RF level. The modulated RF that does appear contains only the sum and difference frequencies; i.e., the USB and LSB. A double-sideband, suppressed-carrier signal has been created.

The Diode Ring Balanced Modulator

In CB circuits, discrete transistors and most transformers aren't used due to the high cost. Instead diodes are used in the older models and ICs in all newer radios. Since diodes are non-linear devices, the two inputs mix to produce sum and difference sidebands. Figure 6-20 is a typical diode ring BM. The expensive center-tapped transformers of the earlier examples are eliminated by substituting balanced RC circuits instead. R214 and C207 are adjusted for maximum carrier null on the wattmeter. The four diodes form a ring-shaped balanced bridge circuit.

Assume that during the positive half of the RF input cycle, the top of T200 is positive and the bottom negative, and there's no audio input. In this condition D212 and D214 will conduct, so current flows up the primary of T200. On the negative half of the RF cycle these conditions are reversed. D213 and D211 conduct and current flows down the primary of T200. Since these currents are exactly equal and opposite, they cancel each other and there's no RF output at the secondary of T200.

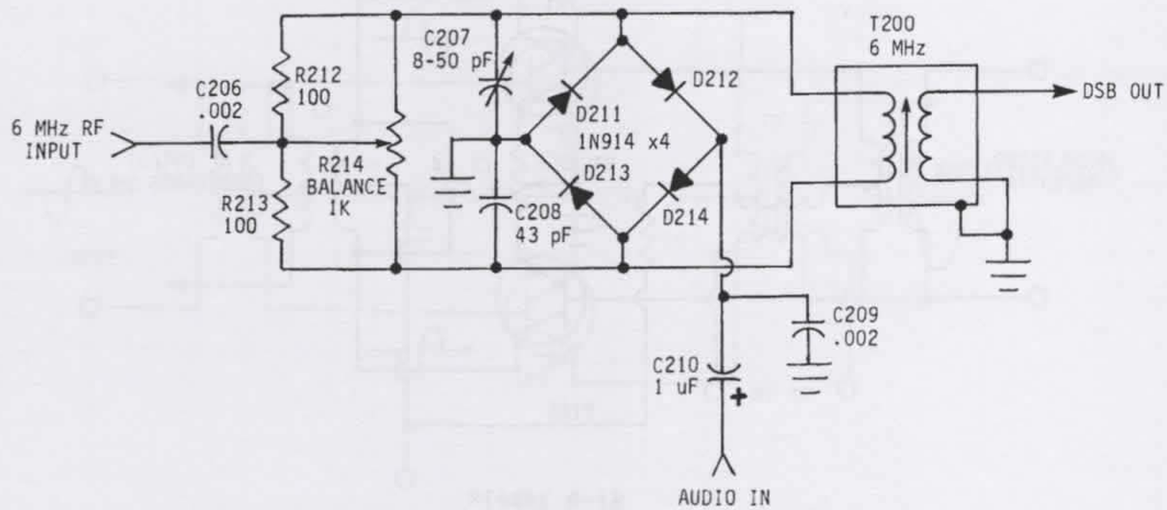
When audio is added to the RF, the diodes mix both signals to produce sum and difference frequencies. The RF injection voltage is purposely made larger than the audio voltage so diode conduction will be determined by the RF portion, typically about 1.0 V of RF and 0.5 V or less of audio. When audio is simultaneously applied with RF, the currents flow in the same directions as before except they're unequal; the bridge is unbalanced. The impedances of T200 and C209 are such that significant audio voltage won't develop at T200's secondary, but RF voltage will. This RF voltage is only that of the sum and difference frequencies, since the carrier frequency has been balanced out.

NOTE: D211 was mistakenly drawn backwards in SAMS Fotofacts #88 for the Tram D201, but is correct as shown here.

In the ring type BM, good balance is essential for proper operation. The individual ring diodes must be carefully matched for equal forward and back resistances to maintain balance. But since they can't ever be perfectly matched, adjustments like C207 and R214 are always included in such circuits.

This circuit, using ordinary 1N914 type silicon switching diodes, is capable of up to -60 dB carrier suppression, an excellent figure. Typical spec for a good CB is -55 dB. For the interested experimenter this may sometimes be

FIGURE 6-20
DIODE RING BALANCED MODULATOR
(Tram D201/D201A)



further improved by replacing the diodes with "hot carrier" types. These diodes are specially constructed to have extremely fast switching times, lower forward conduction voltage and reverse current, less noise, and higher breakdown voltage than ordinary silicon diodes.

The IC Balanced Modulator

The current CB method for the BM uses ICs. One advantage besides saving space is that since the silicon junctions are all formed on a single common substrate, they are extremely well-matched and share a common temperature environment. They also have built-in amplifiers to provide useful x2 or x3 voltage gain, which reduces the drive requirements from the Carrier Oscillator. The harmonic output is lower too.

Since diodes are low-impedance devices when conducting, a buffer stage must be included between the Carrier Oscillator and the input of diode-ring BMs. ICs often include buffering, which further reduces the number of parts. ICs used include the SL640/1640, MC1496, and AN612. The AN612 is by far the most common in CBs.

Figure 6-21 shows a typical circuit. Balance control VR4 is all that's needed. Note the small value of oscillator input coupling via capacitive divider C98/C207. The level of carrier injection affects the degree of suppression. The optimum input level is about 50-100 mV, which is what's found in most CBs. The loose coupling also prevents loading and frequency pulling of the Carrier Oscillator, so a buffer stage generally isn't needed.

UNBALANCING FOR AM OR FM TRANSMISSION

The BM must be unbalanced in the AM or FM modes so the Carrier Oscillator (which runs on AM and FM too) can mix with the synthesizer output to produce the 27 MHz carrier signal. There are several methods used to accomplish this.

With diode rings, the schematic usually reveals that the ring is unbalanced by the injection of an AM-only voltage, is bypassed completely, or a separate path is formed between the Carrier Oscillator and Transmit Mixer. In Figure 6-22, extra voltage is added to the ring on AM via CR206 and an AM-only Transmit voltage source. For USB/LSB, only mike audio flows along this path. Heavy filtering by C614, L602, and R612/C615 keeps RF out of the power supply and mike circuits.

Figure 6-23 shows how a special AM-only path is made when CD5 and CD6 turn on. This connects the Carrier Oscillator directly to the Transmit Mixer stage. A second diode switch, CD7, conducts only on SSB and shunts C11 across the Carrier Oscillator path, effectively killing any RF and forcing the Carrier Oscillator to take the path to the BM instead. CD13 is for isolation from other mode switching voltages.

In Figure 6-24, the MODE switch itself simply hard-wires the AM path completely around the

FIGURE 6-21
IC BALANCED MODULATOR
(Cobra 148/2000GTL, Uniden Grant/Madison)

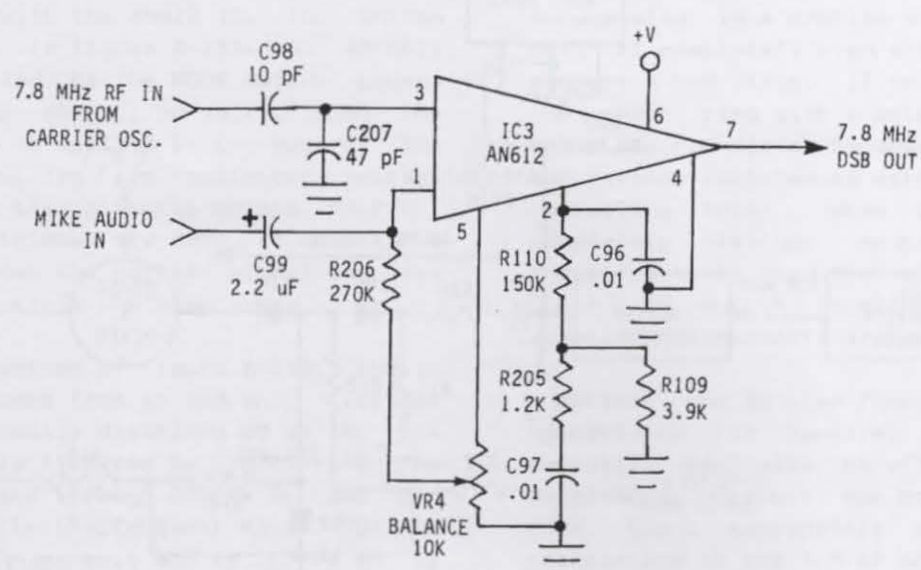


FIGURE 6-22
UNBALANCING VIA AM-ONLY RING VOLTAGE
(Johnson Messenger 4730, Viking 4740)

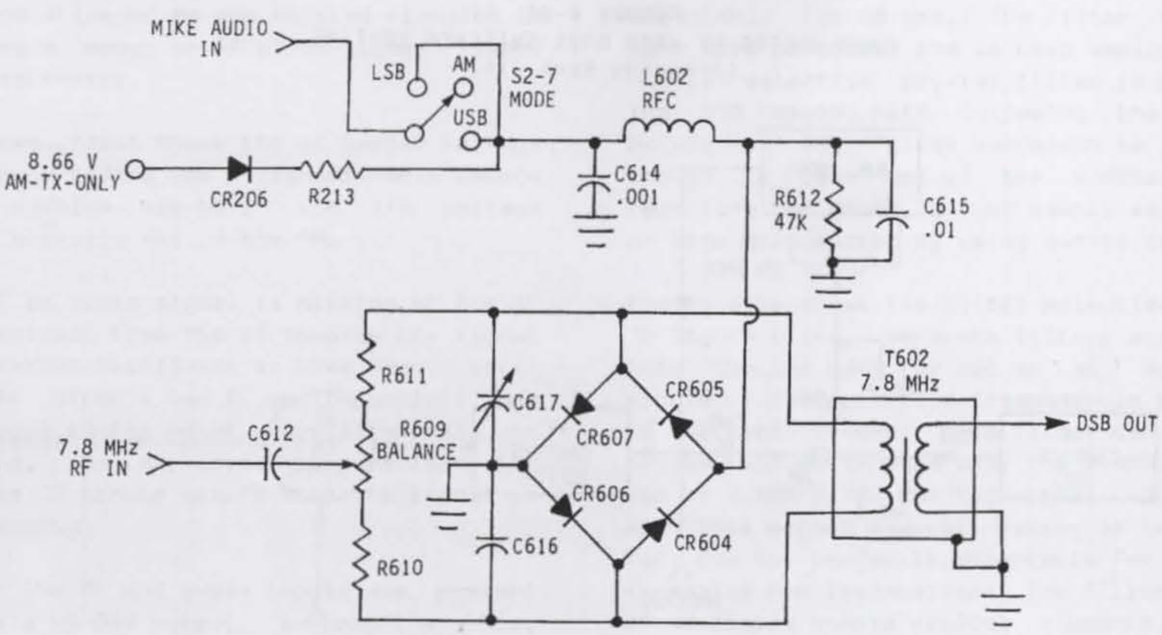


FIGURE 6-23
UNBALANCING BY SPECIAL AM-ONLY PATH
(Browning LTD, Cobra 132/135, 132A, Tram D60)

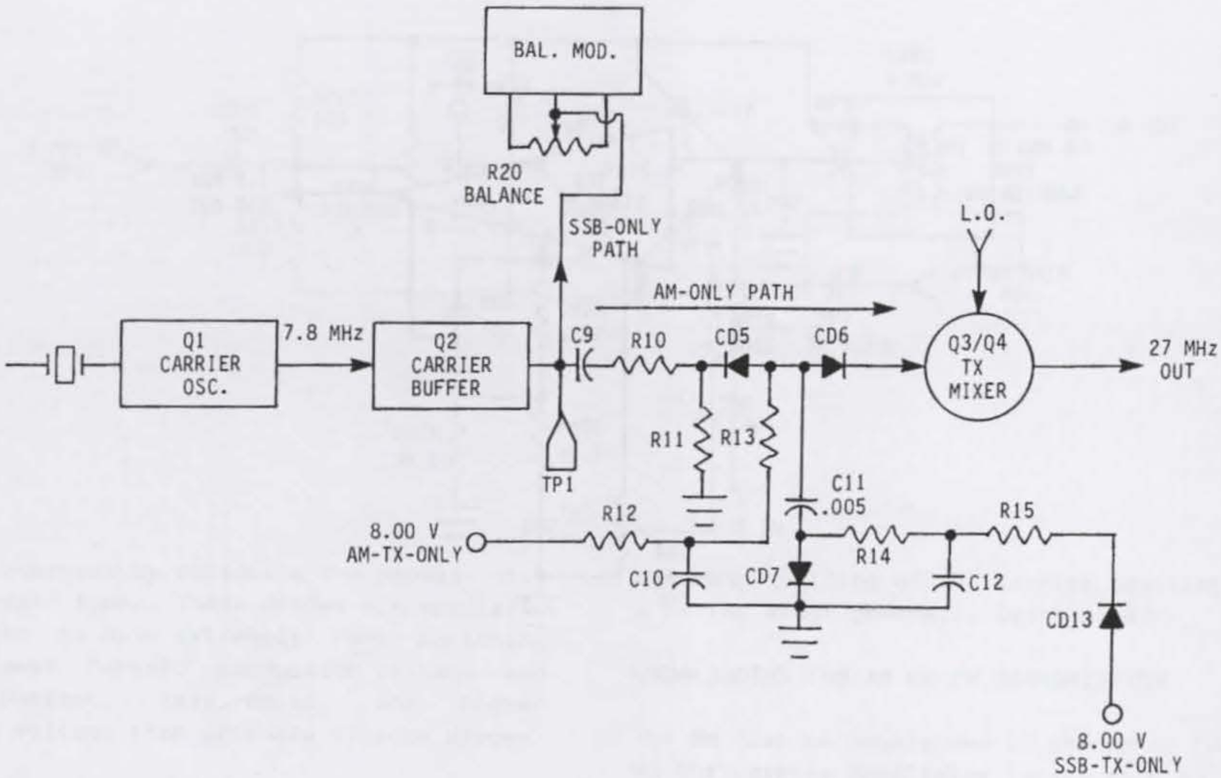
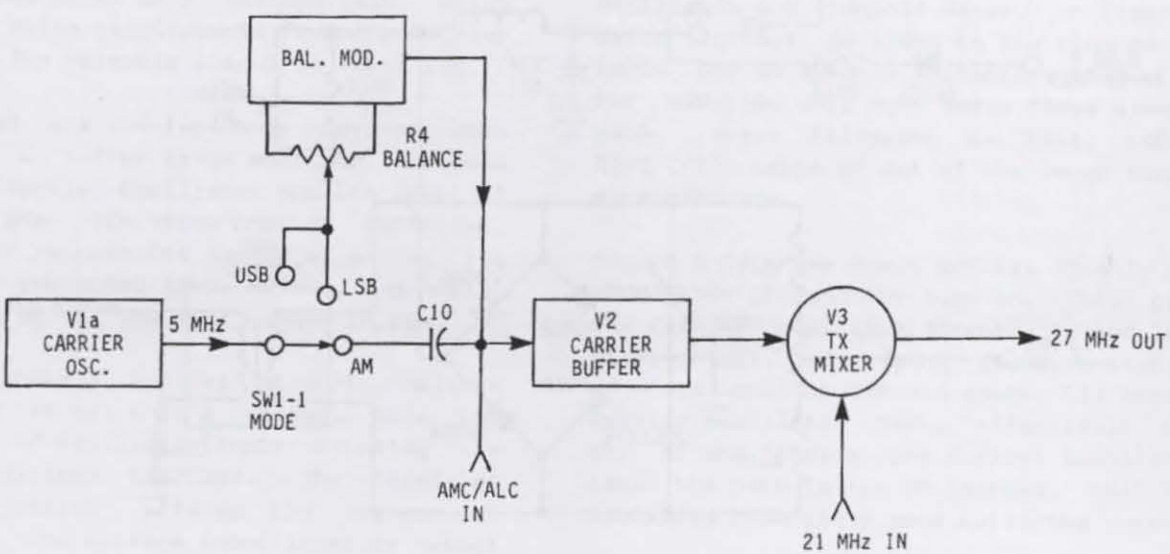


FIGURE 6-24
UNBALANCING BY HARD MODE-SWITCHED ROUTING
(Browning Mark III)



BM, passing instead directly through C10 to the Transmit Mixer.

With ICs, the switching is simpler. Since they have a BALANCE trimmer, a slight voltage change on AM will unbalance it. Figure 6-25 shows two ways it's done with the AN612 IC. The Uniden method is shown in Figure 6-25A. An AM-only voltage controlled by the MODE switch causes IC3 Pin 1 to drop about 1.50 volts. When the AM-only voltage is applied to the base of TR21 it conducts, pulling its collector voltage down. Since it's tied directly across IC3 Pin 1 and the BALANCE trimmer via R206, it upsets the balance and allows the carrier signal to pass through. It also kills the mike audio.

In the Cybernet method of Figure 6-25B, the IC power itself comes from an SSB-only voltage source, automatically disabling it on AM. The voltage is heavily filtered by L16/C77/C78. The carrier is coupled through C74 to RF amp Q15 instead and then to the Transmit Mixer. Q15 is only used for AM-Transmit and is turned on by R67/D14/R65. On SSB, the carrier signal to Q15 is shunted out by C85 because diode Q45 is now conducting, forcing the SSB signal to take a separate RX IF path. (Not shown.) Q15 is labelled schematically as a "carrier insertion" stage when used for AM Transmit, since it injects one of the required mixing signals.

BM TROUBLESHOOTING

Problem isolation of BM and related circuits is done using a 'scope or RF probe/signal tracer and a DC voltmeter.

For IC types, first check the IC supply voltage itself; many radios use a Transmit-only source and the problem may be in the T/R voltage switching circuit, not in the BM.

If the RF or audio signal is missing at the IC input, backtrack from the IC towards the signal source (Carrier Oscillator or mike amps) until it's lost. Since a bad IC could possibly load down an input to the point where it appears to be missing, you may need to unsolder the appropriate IC pin to verify that the signal is in fact missing.

When both the RF and audio inputs are present but there's no DSB output, suspect the chip, especially if indicated DC pin voltages are way off. If the circuit includes a tuned output transformer to couple the DSB signal to the next stage, check this for shorts or opens. Same for coupling capacitors. The sideband IF filter is another possible suspect; if shorted or leaky it could load down the DSB output.

For diode ring type modulators, if carrier suppression is a problem and you're unable to null it completely even with the adjustments, suspect a bad diode. If you find one, replace the whole ring with a matched set. You can match the new diodes by measuring their forward and reverse resistances with an ohmmeter before installing them. When the DSB output is completely missing, 'scope the RF and audio input paths to find the missing signal. The input or output coupling transformers and associated components are other possibilities.

Sometimes the BM also functions as a Balanced Demodulator for Receive; in such cases SSB reception may also be affected. Or the AM unbalancing circuit may be working all the time. Check appropriate switching diodes or transistors in the T/R or AM/SSB circuits.

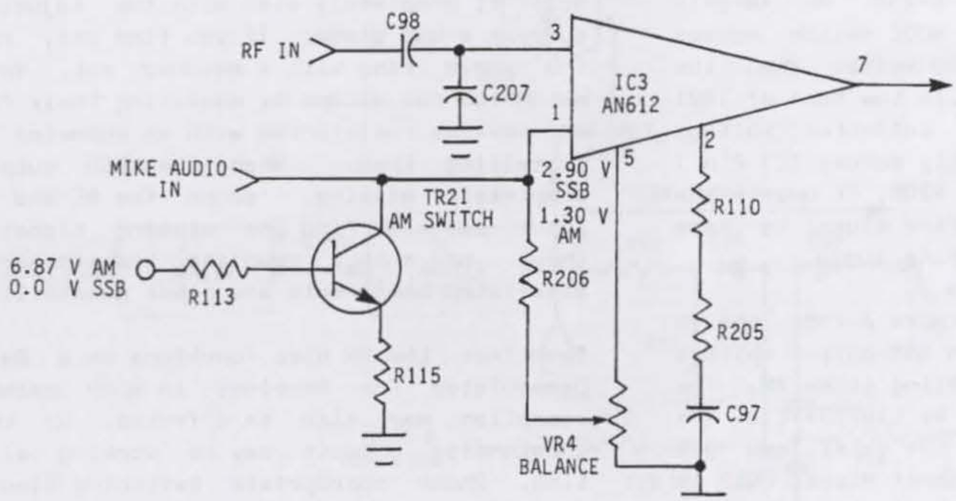
SIDEBAND SELECTION METHODS

After the DSB suppressed-carrier signal is generated, the unwanted sideband must be removed. There are two ways to do this: by taking advantage of the phase relationship between USB and LSB, or by sharp filtering. The phasing method is very complicated and tricky at high IF frequencies, making it unsuitable for CB use. The filter method is much more practical and is used exclusively. A highly selective crystal filter is placed in the DSB signal path following the Balanced Modulator. The filter bandwidth is just wide enough to pass one of the sidebands while rejecting the other, a task easily accomplished at high frequencies by using quartz crystals.

Figure 6-26 shows two filter selection methods. In Figure 6-26A, separate filters are switched into the DSB path for USB or LSB. Note that a single 7.8 MHz carrier frequency is used with no offsets needed; each filter can be made narrow enough to pass only the 7.800-7.803 MHz USB or 7.800-7.797 MHz LSB signal. The problem with this method is cost, making it impractical for CBs but perfectly acceptable for the more expensive Ham transceivers. The filters consist of multiple quartz crystal elements, usually six or eight of them in a sealed unit. It's an expensive part, and using two of them would be unthinkable in a mass-produced CB radio.

FIGURE 6-25
UNBALANCING IN IC-TYPE BALANCED MODULATORS

(A)
UNIDEN METHOD
(Cobra 148/2000GTL, Uniden Grant/Madison)



(B)
CYBERNET METHOD
(PTBM048 chassis: HyGain 2705, JC Penney 981-6247,
Lafayette Telsat SSB140, Midland 79-892, etc.)

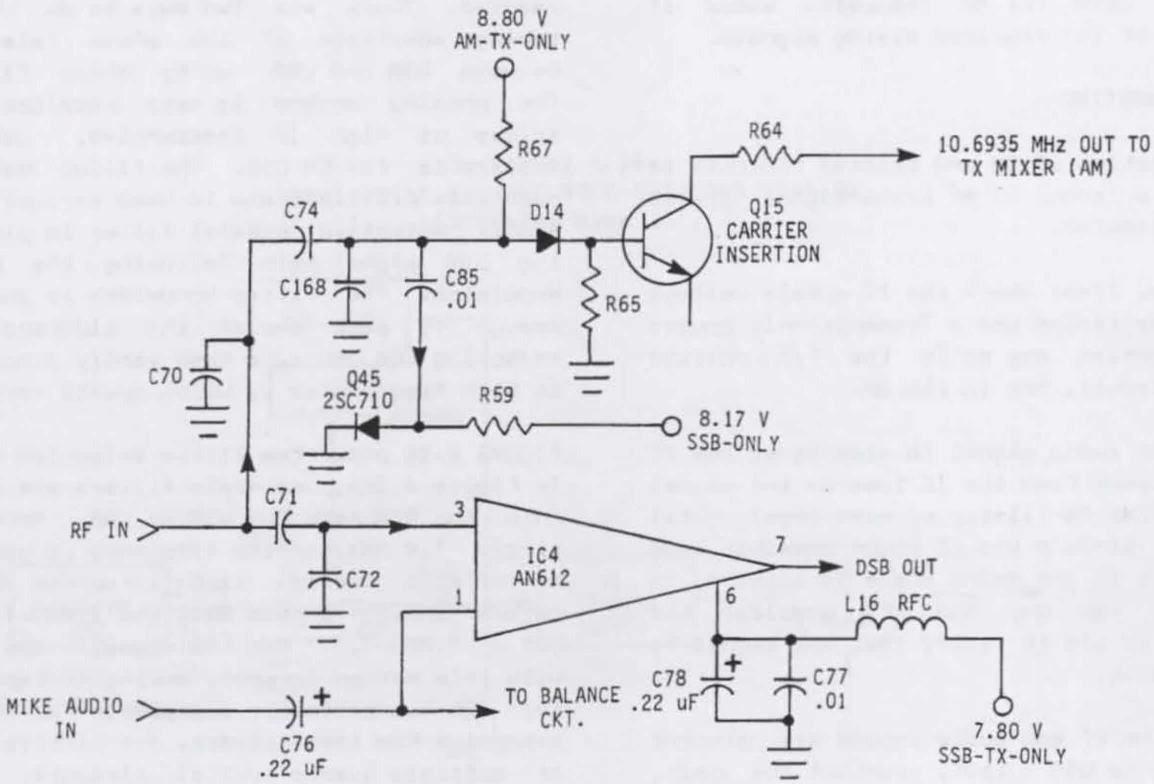
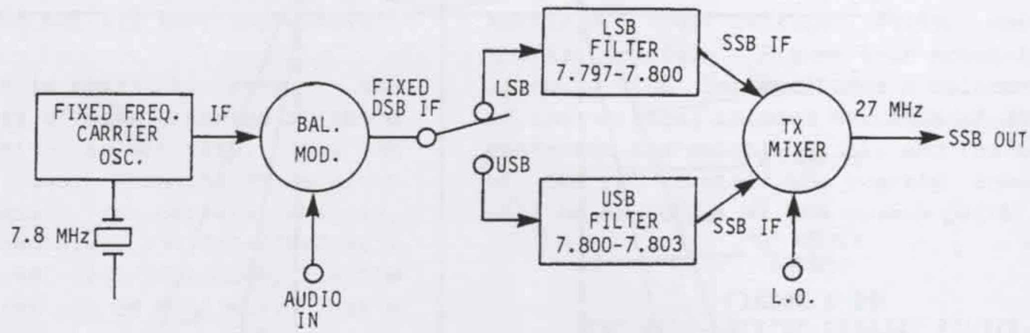
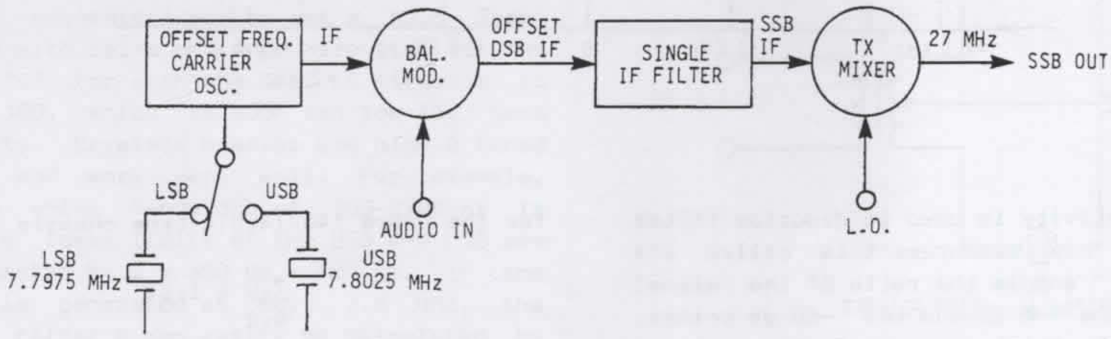


FIGURE 6-26
SIDEBAND SELECTION METHODS

(A)
SINGLE CARRIER FREQUENCY/DUAL FILTER METHOD



(B)
DUAL CARRIER FREQUENCY/SINGLE FILTER METHOD



By contrast, an ordinary Colpitts crystal oscillator is relatively cheap, so two crystals can be switched using diodes or transistors. Or a single Carrier Oscillator crystal can be pulled up or down slightly using capacitors and inductors. This is seen in Figure 6-26B. The reasons and methods for producing such offsets were discussed earlier. The DSB signal is thus shifted up or down slightly around the center IF frequency, allowing the chosen sideband to pass through a single multipole crystal filter. Summing up, the first method uses a constant IF with two individual sideband filters, while the second (CB) method uses a constant filter frequency with two separate IFs instead.

Characteristics of Crystal Filters

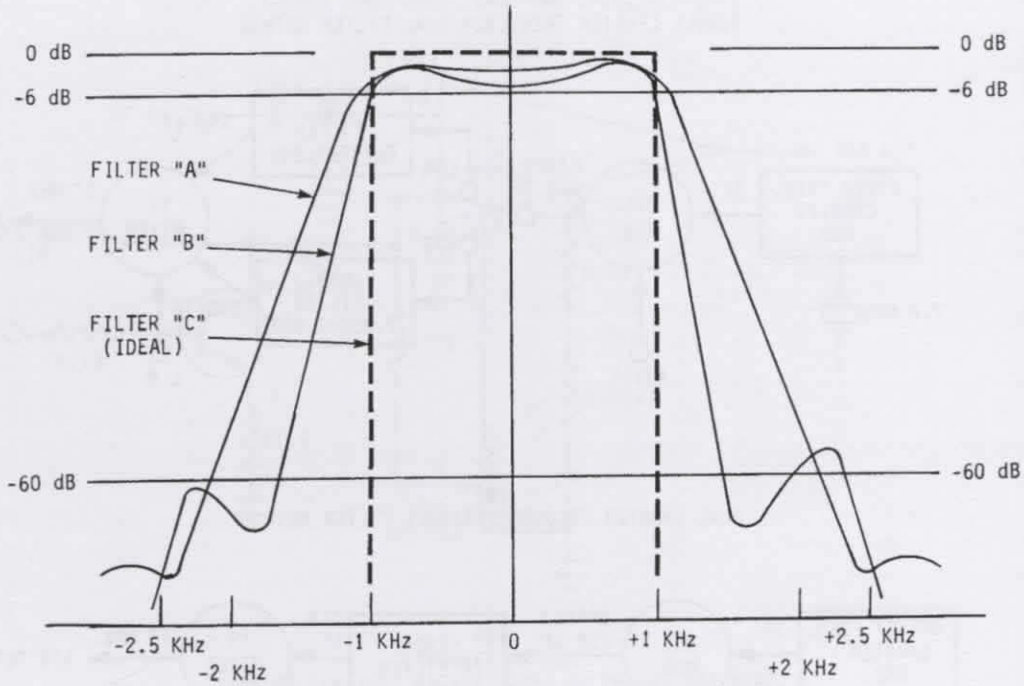
The ideal crystal filter has a "bandpass" characteristic, which means its response is perfectly flat (no ripple) across the desired frequency band, rapidly attenuating frequencies outside this range. The degree of attenuation is called the "skirt selectivity" because the response curve of frequency vs. attenuation is shaped like a woman's skirt. (See Page 105.)

Since a band of audio frequencies from about 300-2500 Hz is used, this implies the bandwidth of the filter must be about 2500 Hz - 300 Hz = 2200 Hz wide, dropping off rapidly outside this limit. Figure 6-27 shows response curves for an ideal filter and two typical real filters. Notice the skirts of Filter "A" aren't as sharp as those of Filter "B," which uses additional crystal networks to increase selectivity.

Filter Shape Factor

A real crystal filter can't drop straight down (completely vertical skirts, as in Filter "C") outside its passband, so a standardized measure

FIGURE 6-27
COMPARISON OF SSB FILTER RESPONSE CHARACTERISTICS



of skirt selectivity is used to describe filter performance. This measurement is called its "Shape Factor," and is the ratio of the signal bandwidth at the -6 dB and the -60 dB points. Obviously if the skirts were perfectly vertical like the ideal filter, the bandwidth at both points would be exactly the same, and the Shape Factor would therefore be 1:1, or simply "1."

The Shape Factor indicates the degree to which the real filter differs from the ideal; the closer to 1.0, the better. For good unwanted sideband suppression, a Shape Factor of 2.0 or less is desirable. This means the bandwidth's no more than twice as wide at -60 dB as it is at -6 dB. The following shows SSB selectivity specs for two popular Uniden chassis, from which we'll compute their Shape Factor:

MODEL	-6 dB	-60 dB
Cobra 140/142GTL type:	4.2 KHz	7.0 KHz
Cobra 148GTL-DX type:	2.1 KHz	3.3 KHz

The Shape Factor is simply the bigger number divided by the smaller number. The Shape Factor for the Cobra 140/142GTL type chassis is

$$\frac{7.0}{4.2} = 1.67$$

Similarly, the Cobra 148GTL-DX type chassis has a Shape Factor of

$$\frac{3.3}{2.1} = 1.57$$

Both chassis therefore have excellent filter characteristics. However there's one big difference: the 140/142GTL filter begins with a much wider bandwidth of 4.2 KHz. Why? Because it uses a single-conversion receiver for AM as well as SSB. The 148GTL-DX is dual-conversion on AM/FM, which means only the SSB signal goes through the filter; AM and FM take a different IF path. The 140/142GTL circuit must pass SSB and AM through its filter, which must be wider to accomodate a wider AM bandwidth. Its filter is a compromise, being too wide for SSB and too narrow for a typical 6 KHz AM signal. The AM audio response is thus limited to 2.1 KHz, just like on SSB. (Half of 4.2 KHz = 2.1 KHz, since only one AM sideband will ever be detected.)

Incidentally, many manufacturers don't list their selectivity specs at both standard points on the curve, often specifying just the -6 dB bandwidth. This is deceptive, because there's no way to know how sharp the skirts are without the second figure. I have a feeling they don't want to advertise this particular spec, probably because it's not all that impressive!

When the SSB filter is shared by Transmit and Receive, its quality affects unwanted sideband suppression and receiver selectivity. (And AM receiver selectivity too, when the AM receiver is single-conversion.) In certain chassis, such as the Sears Roadtalker 934.3826/3827/3831 and the J.C. Penney 981-6241/6246/6248, the SSB selectivity specifies -60 dB @ ±5 KHz. That's wide enough to pass the complete DSB signal, and it shows up in poorer receiver selectivity and adjacent-channel rejection.

Filter Q

The most economical way to get a good Shape Factor is with pairs of tuned circuits. But the maximum "Q" for even the best LC circuits is perhaps 300, which is much too low for good selectivity. Crystals however are high-Q tuned circuits and work very well. For example, assume a voice bandwidth of 300-2500 Hz is used; the lower limits of the USB and LSB are thus separated by 2 x 300 Hz = 600 Hz. If the carrier is generated at say, 7.8 MHz, the required filter Q can easily be calculated by starting with the basic formula,

$$BW = f_R \div Q,$$

where BW = bandwidth at the half-power (i.e., -3 dB) points,
f_R = resonant frequency,
Q = selectivity factor.

Rearranging this and solving instead for Q,

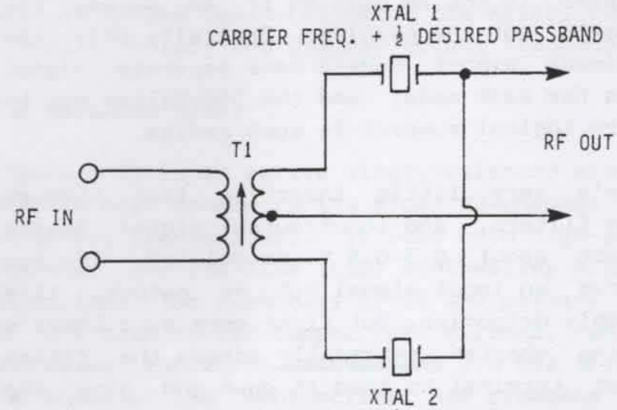
$$Q = f_R \div BW, \text{ or } \frac{7.8 \text{ MHz}}{600 \text{ Hz}} = 13{,}000$$

Such extremely high selectivity factors can only be achieved by using crystal or mechanical filters. Crystals are available with Qs from about 10,000 to over 100,000. It's precisely that selectivity which makes single-conversion SSB receivers possible in the first place. Good selectivity and image rejection are obtained at a relatively high IF, without the need for double-conversion as in AM. Provided there's no stray circuit capacitance to leak the signals around them, inexpensive crystal filters can be made for frequencies as high as 50 MHz.

The Half-Lattice Crystal Filter

Good CB sideband selectivity is achieved using multiple "half-lattice" filter networks of quartz crystals. Figure 6-28 shows the basic circuit. The lattice forms a balanced bridge; if the voltages between the ends of T1 and its centertap are exactly equal, and the impedances of the two crystals are exactly equal, there will be no output at the common point.

FIGURE 6-28
THE HALF-LATTICE CRYSTAL FILTER



The two crystals must differ in frequency by an amount equal to slightly less than the desired passband. For example, a filter with a 2.4 KHz passband centered at 7.8 MHz might use crystals of roughly 7.8 MHz ±1 KHz, or 7.799 MHz and 7.801 MHz. In CHAPTER 3 we discussed crystal oscillators operating in the series-resonant or parallel-resonant modes. The technical names for these modes are the "zero of impedance" and the "pole of impedance" respectively. The parallel crystal mode is slightly higher in frequency than the series mode.

It turns out that the filter bandwidth is determined by the spacings of these poles and zeros, so the exact crystal frequencies depend upon actual operating modes, and crystal calculations will be more complex than the preceeding example would indicate. The passband response is kept flat by careful adjustment of the terminating impedances, and by making the series-resonant frequency of one crystal equal to the parallel-resonant frequency of the other crystal. This maintains the bridge balance.

The Multiple-Lattice Crystal Filter

The simple half-lattice filter is only capable of about -30 dB sideband suppression, which isn't good enough. (The FCC minimum is -40 dB, with -55 dB more typical.) To increase this, two more filter sections are added in series. This results in much sharper skirts while maintaining the desired bandwidth. Typically six quartz crystals are used to cascade three half-lattice filter sections.

A six-pole crystal filter like this is usually constructed in a sealed metal can having only input, output and ground terminals, and isn't serviceable. But filter failure is very rare and easy to diagnose. In many radios the filter is also in the AM path so if AM works, the filter's not the problem. Generally only the multimode export models have separate signal paths for each mode, and the SSB filter may be a more logical suspect in such radios.

There's very little insertion loss through these filters, and input/output signal levels measure about 0.3-0.5 V unmodulated. If you observe an input signal but no output, it's probably defective. But first make sure there's nothing shorted externally across the filter output terminal to load it down and give the appearance of a bad filter.

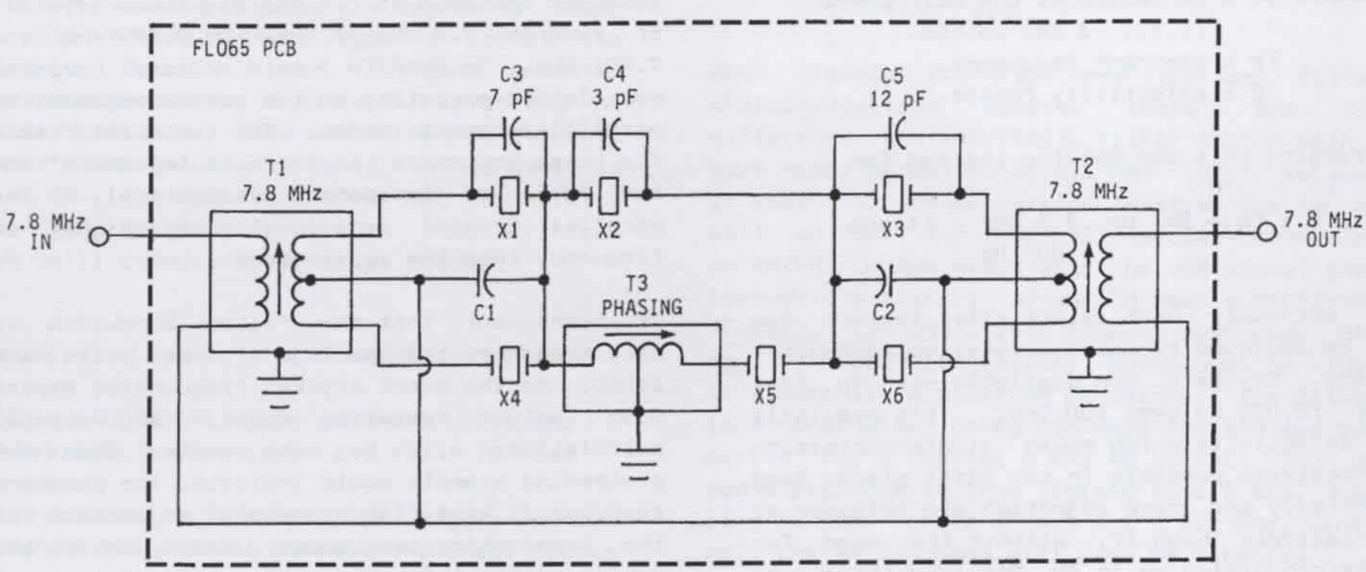
A notable exception to the sealed filter is the discrete Uniden filter found in the popular Cobra 140/142GTL, Cobra 148/2000GTL, and their equivalent chassis. Apparently they decided it was cheaper to make their own than buy them from somebody else, so they simply built them on a small PC board which fits into the main PC board. Figure 6-29 shows the FL065 SSB filter circuit. Yes, I actually dissected one and traced out the schematic for you!

T1 and T2 peak the input and output for maximum at the 7.8 MHz design frequency, and also provide impedance transformation. The higher the impedance, the higher the Q and therefore the selectivity. C3, C4, and C5 trim X1, X2 and X3 respectively, which are the higher frequency crystals. Without trimmers, the filter skirts would tend to broaden out towards the bottom. These filters are individually tested after construction, and the fixed trimmer values may vary slightly from those shown here.

Unfortunately, trimmers also add undesirable reactances which allow nearby frequencies to pass through. Even the metal plates of the crystal holders can add stray capacitance. To eliminate these effects, phasing coil T3 is included. This adds an equal but opposite-phase reactance to cancel the capacitive reactance.

There are other leakage reactances in series with the crystals which would lower their resonant frequencies if not controlled. These

FIGURE 6-29
INSIDE THE DISCRETE UNIDEN FL065 SSB CRYSTAL FILTER



are eliminated by C1 and C2, which resonate with the leakage inductances of T1 and T2 to cancel them out. This makes it possible to use cheap, non-critical coupling transformers.

It's unlikely these discrete filters can be repaired, although you might try it. First determine if a signal is passing through the filter. Then if there's no question of a bad crystal, confirmed by signal tracing and a crystal checker, try replacing it with one at 7.8 MHz. (Obviously there's no way to know the original's exact specs.) For you experimenters, replace the crystal, inject the 7.8 MHz from your signal generator at the input terminal, and peak all coils for maximum RF at the output terminal. Replace it in the main board and check the unwanted sideband suppression. If it works you've learned something new, reduced the repair cost, and impressed the customer.

While this section has been very theoretical, a good technician should understand what's going on inside the "black box" even though he can't do much about it. Crystal filter design is very complicated and I've just touched on the basics here. If you're really interested, check the RADIO AMATEUR'S HANDBOOK or similar references.

THE TRANSMITTER MIXER

Compared to FM, AM, or CW (which is simply unmodulated AM), an SSB signal is a complex waveform which can't be mixed up to a higher frequency because the RF stages must be linear; mixers are non-linear circuits by definition. Instead the SSB signal must first be generated at a lower frequency by the Carrier Oscillator. Once the SSB signal is generated, it can then be raised to 27 MHz for power amplification.

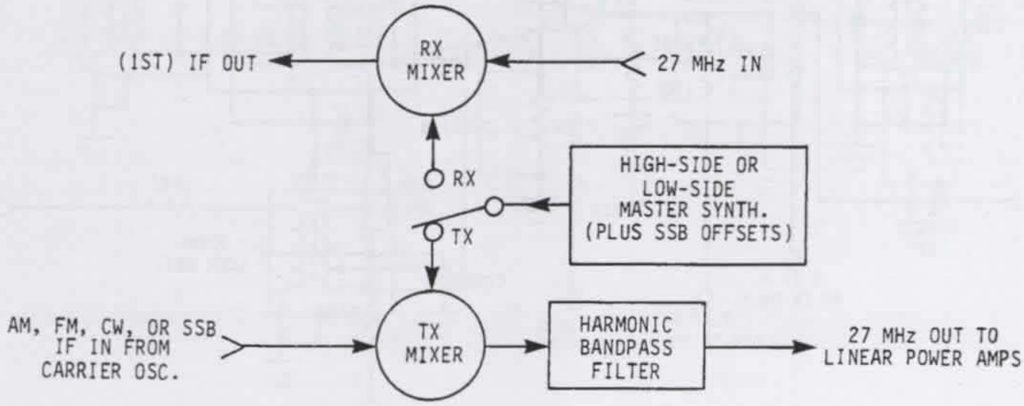
This up-conversion process is a form of mixing called "conversion," "translation," "mixing," or "heterodyning." It's just like the process of mixing in receivers, but reversed: instead of mixing an incoming 27 MHz signal with the output of the synthesizer to produce the IF, the synthesizer mixes with the IF (the Carrier Oscillator) to produce the 27 MHz transmitter signal. This signal is then amplified only by linear stages, or extreme distortion (splatter) will result. Figure 6-30 shows both processes.

The Transmit Mixer works in all modes, since the BM is unbalanced for AM/CW (and FM) and is like the mixers described in CHAPTER 5. Both high-side and low-side injection are used, with the mixer always being an active device because gain is needed too. Following the Mixer, tuned circuits select the desired output frequency.

The Balanced Mixer

Figure 6-31 is an active singly-balanced mixer. This is most common to the older 23-channel and early PLL transceivers. It uses both high-side (AM/USB) and low-side (LSB) synthesizer signal injection. The secondary of T8 and primary of T9 are both center-tapped for balance, which increases isolation between the 7.8 MHz IF and the input of the synthesizer. R69 broadens the response of T8. A small forward bias is provided by R77 and voltage divider R75/R76, but like all mixers it's still a Class C stage. C60 and C61 decouple RF. The optional R175 (dotted lines) broadens the response of T9 if

FIGURE 6-30
T/R MIXER PRINCIPLES



needed. T9, T10, and T11 form a bandpass filter to remove all mixing products except 27 MHz. The low values of C62 and C63 result in loose coupling (high Q) for maximum selectivity.

The MOSFET Mixer

A dual-gate MOSFET mixer, Figure 6-32, offers superior signal-handling ability with reduced

FIGURE 6-31
SINGLE-BALANCED ACTIVE TX MIXER
(Browning Baron, Cobra 132/135XLR)

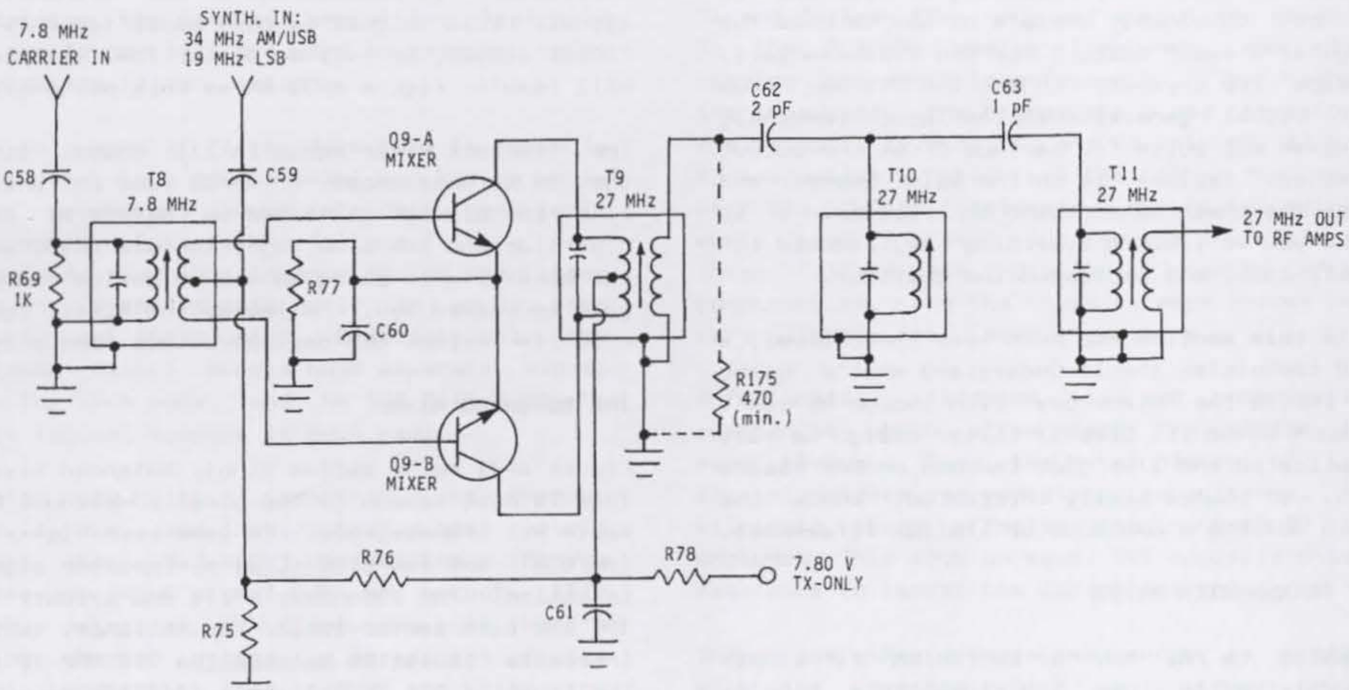
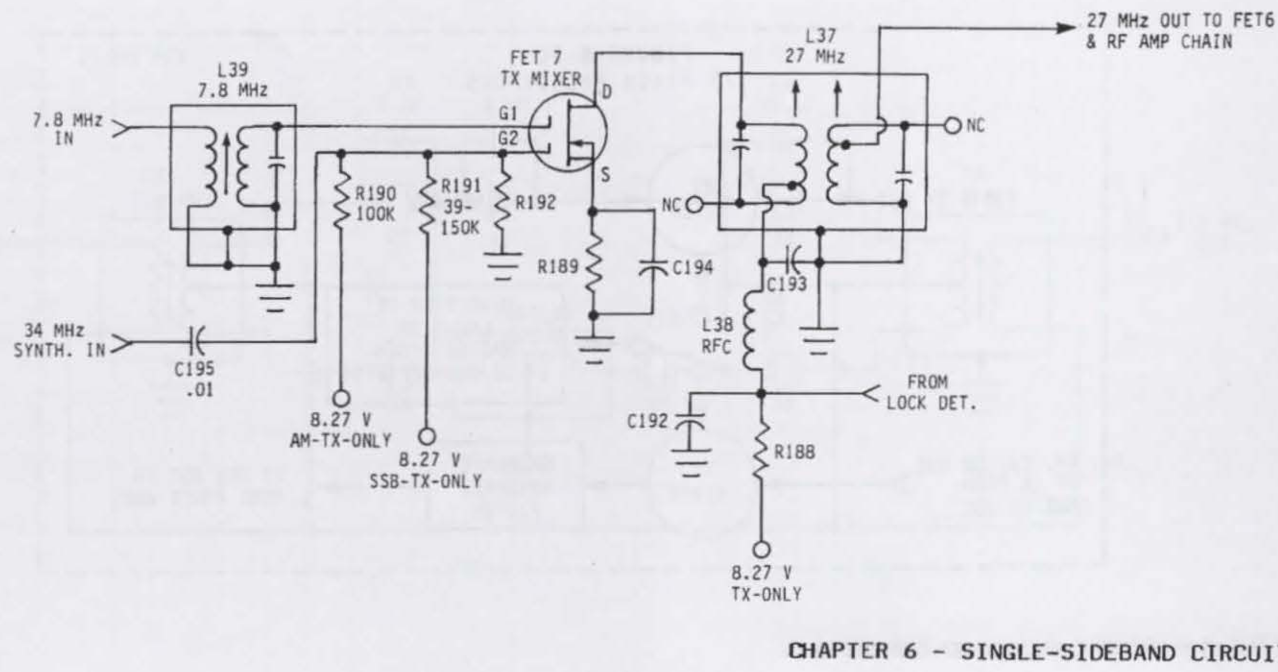


FIGURE 6-32
DUAL-GATE MOSFET TX MIXER
(Cobra 138/139XLR, President Adams, Realistic TRC458, etc.)



harmonic and IMD distortion. The 7.8 MHz IF carrier signal is coupled to gate 1 by L39, and the 34 MHz VCO synthesizer signal coupled to gate 2 by C195. Note the value of C195, typical of high-impedance FET or tube circuits. MOSFETs need positive gate voltage to amplify, supplied by R191 on SSB and R190 for AM. The separate AM and SSB gate voltages are used to optimize mixer performance in each mode. C192, C193, and L38 decouple RF from the power supply.

The primary of L37 has been tapped down at a relatively low-impedance point to preserve the IMD and cross-modulation characteristics of FET7. Otherwise excessive drain voltage would develop on signal peaks, which can overload the drain tank circuit and increase harmonics and distortion. This can be a problem at the kind of low drain voltages (6-8 VDC) that are used in CB mixers, since the driving signals may be relatively large. The secondary is tapped at a high-impedance point to maintain a high Q for harmonic rejection, and to help match the high input impedance of FET6 which follows it.

Also connected to the drain supply at R188 is the PLL Lock Detector circuit. If the loop becomes unlocked, this point is pulled LOW and turns off FET7 so the radio can't transmit on the wrong frequency. Connection to the Transmit Mixer is the most common control point for PLL Lock Detector/Transmit Inhibit circuits.

The IC Mixer

All modern SSB CB models use IC mixers for simplicity and high gain. The ICs contain double-balanced mixer circuits which offer maximum suppression of IMD and other distortion products, and maximum isolation between the input and output ports. Figure 6-33 shows the Uniden circuit with the S042P mixer chip. The 7.8 MHz carrier is coupled to one input by L48, and the 34 MHz VCO to the other input by L47. The 27 MHz output is across pins 2 and 3, which are the collectors of the IC's balanced output transistors. L46 and L45 are part of a 27 MHz bandpass filter and are lightly coupled by C163 to maintain its high Q. R190 is a balancing resistor chosen for best mixer performance at the particular frequencies used, which is why it's external to the chip. In some models R190 may be replaced by a jumper wire, with only the internal IC resistors needed.

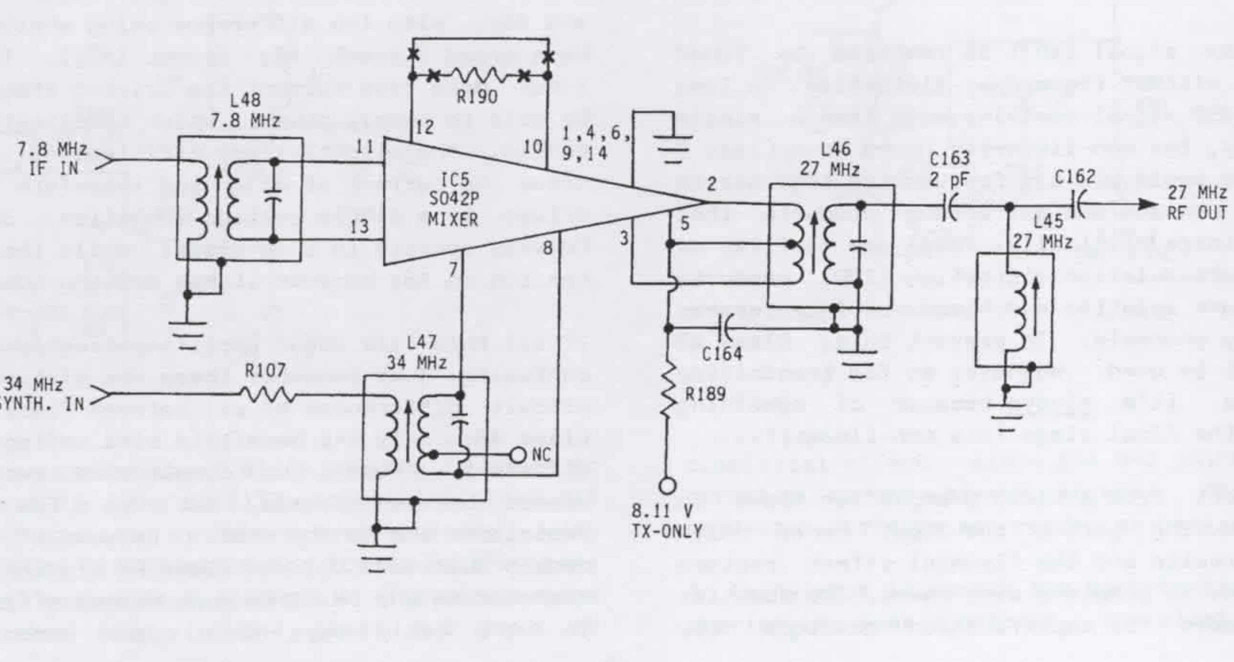
MIXER TROUBLESHOOTING

Symptoms of a bad Transmit Mixer include:

1. No Transmit, any mode.
2. Low RF power output.

The circuit is checked exactly the same way as a receiver mixer. Since the mixer operates in all Transmit modes, these symptoms will show up

FIGURE 6-33
UNIDEN IC-TYPE TX MIXER
(Cobra 148/2000GTL, Uniden Grant/Madison)



in all modes, not just SSB. First determine if both inputs are present using a 'scope and frequency counter. In transistorized radios the synthesizer input will typically measure about 1.0-1.5 V P-P, while the carrier signal will be about 200-500 mV at the filter output. These mixers generally have a small amount of voltage gain, depending upon whether there are three or four RF amps following it. Output levels in the preceeding examples are all about 0.6 V P-P.

If an input is missing, backtrack towards its source until you find the open circuit. Radios with electronic T/R switching use steering diodes to route the carrier signal, and a bad diode will stop the transmitter cold. If both inputs are present, 'scope the output and interpret device voltages. The active device is the most likely failure. Passive components to check are the transformers (including their alignment!) and coupling or bypass capacitors.

LINEAR RF POWER AMPLIFIERS

The signal is amplified to the 12 W PEP level by "linear" RF power stages. This is a form of amplification in which the output is an exact copy of the input, only bigger. Compare this to the Class C RF power amp used for AM or FM; it generates many distortion products, but they're not important because tuned circuits restore the original sine wave via the flywheel effect. But SSB isn't a sine wave; it's a complex waveform composed of an infinite number of frequencies, from the unmodulated carrier to the carrier $\pm$ the highest modulating frequency. (Except when using a single audio tone input.)

A complex signal can't be restored by tuned circuits without tremendous distortion. As long as the SSB signal contains more than a single frequency, the non-linearity found in a Class C amplifier would mix all frequencies together to produce new sum and difference products that weren't there originally. These are familiar as the intermodulation distortion (IMD) products that cause splatter and bleedover interference to nearby channels. To prevent this, Class AB bias must be used. Whenever an SSB transmitter splatters, it's always because of something driving the Final stage into non-linearity.

The output from a Class C amplifier flows in pulses during part of the input cycle only. Tuned circuits and the flywheel effect restore the pulses to complete sine waves. The positive bias needed for amplification develops only when the input signal is large enough to overcome the reverse bias, and this happens only a fraction of the time. Such bias is possible with a sine wave input because it has a known and constant amplitude for which bias values can be calculated.

An SSB signal has no such predictability, and its amplitude is continuously changing with speech. If Class C biasing was used, only the highest signal peaks would be amplified; most of the input signal would be ignored. So the amplified signal wouldn't be a faithful copy of the input signal. This implies that the gain of an SSB RF power amplifier must be constant regardless of the input signal level, and this can only be achieved with a linear amplifier.

Class AB Biasing

An amplifier biased so collector current flows more than 50% but less than 100% of the input signal time is known as a "Class AB" amplifier. This condition is a compromise between the Class A and Class B type amplifiers discussed earlier. Compare this to the Class C amplifier, which has output from about 25% to 40% of the input drive time. Because the Class AB linear amplifier operates on the majority of the input signal time (typically about 78%), the missing portion can be reproduced by the flywheel effect with minimum distortion. The output is a linear or more exact copy of the input.

Class AB biasing isn't as efficient as Class C, but does have higher gain and smaller drive requirements. Class AB is subdivided into AB_1 and AB_2, with the difference being whether the base draws current (AB_2) or not (AB_1). If the input does draw current the driving stage must be able to supply power, which complicates its design. The slightly less efficient AB_1 stage draws no current at all, and therefore can be driven by a simple voltage amplifier. SSB CB Drivers operate in this class, while the Final can run in AB_2 because it has driving power.

If all this talk about amplifier classes seems confusing, just remember there are virtually no circuit differences at all between Class C and Class AB; only the base/grid bias voltages are different. There's no complicated switching needed between classes, but even a few extra resistors add to the cost. Because of this, modern multimode CBs run Class AB all the time, even for AM and FM. It's just not as efficient. In the early days when costs weren't so critical, manufacturers sometimes did switch the bias between AM and SSB in solid-state transmitters. (Tube-type transmitters always do.) Because linear amps have more gain than Class C RF amps, problems of instability and transistor heating are more serious and require more careful design and attention.

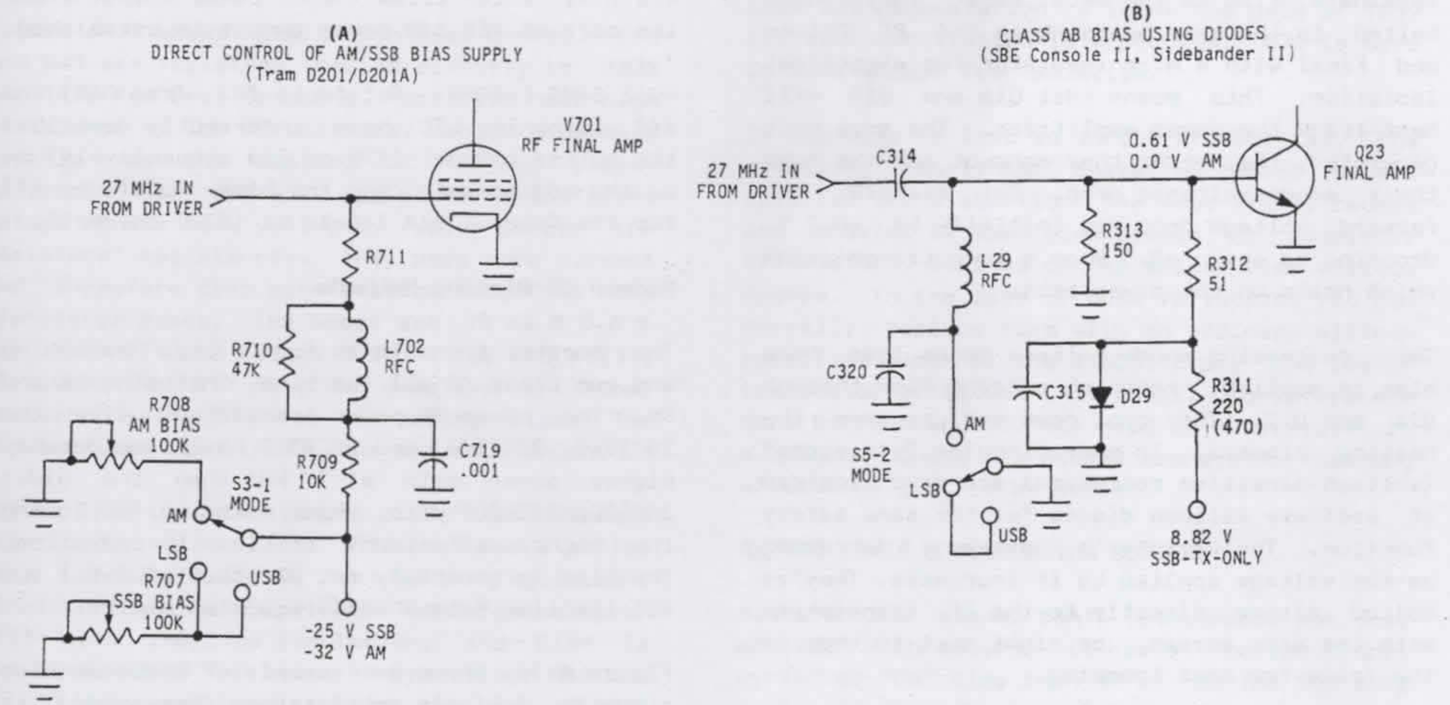
Switchable Biasing Methods

The following examples are in chronological order of CB evolution, and demonstrate what to expect when servicing the equipment you're likely to see on the bench. In most cases only the Final stage is drawn for simplicity, but the Driver will have a similar bias circuit.

Figure 6-34 shows switchable Class AB/C bias. In Figure 6-34A, the control grid of V701 has its bias applied through a voltage divider consisting of R708/R709 for AM, or R707/R709 for SSB. Voltage dividers are common biasing techniques because they help stabilize the voltage. A stiff bias supply is necessary for good linearity and IMD characteristics in all linear amps. C719 and L702 decouple RF from the bias supply. R710 swamps out L702, lowering its Q to aid stability. The specified bias voltages of -25 VDC SSB and -32 VDC AM seem reasonable because Class C by definition implies a higher negative grid bias, forcing the tube further into the cutoff region.

In Figure 6-34B, the forward SSB bias of about 0.6 V is established using D29. R311 limits current to a safe level and with R312 forms a voltage divider for stability. The voltage supply to R311 is only present on SSB. The use of a diode for biasing is a very common method, although not always giving the best IMD value for a particular transistor. Note the use of L29, an RF choke for AM only. This raises the base impedance of Q23 and along with the simultaneous removal of the base bias switches the transistor to the Class C condition. R313 lowers the Q of L29 for better stability.

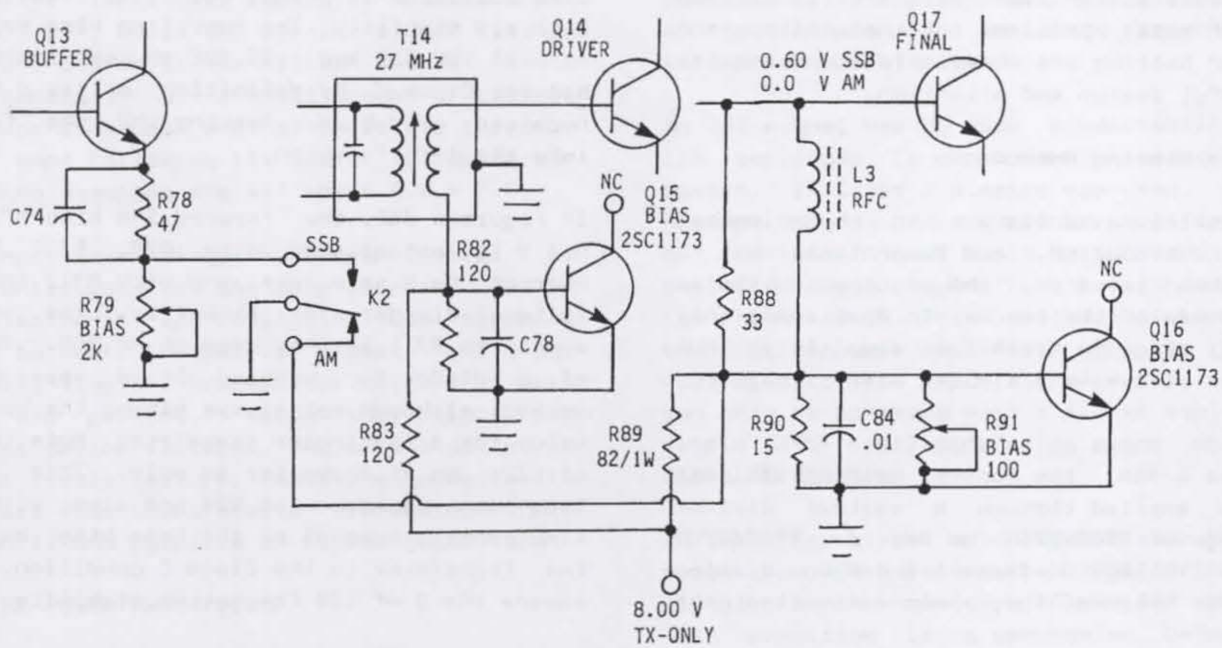
FIGURE 6-34
AM/SSB BIAS SWITCHING METHODS



A clever variation of diode biasing is shown in Figure 6-35. The 2SC1173 power transistors Q15 and Q16 are used as heat-tracking diodes, with the diode terminals being formed by the base (anode) and emitter (cathode). The collectors are also tied to the bases but have no electrical effect, since the b-c junctions are normally reverse-biased anyway. The metal collector surfaces are needed as heat sensors.

A transistor is merely two back-to-back diodes sharing the same substrate. The plastic TO-220

FIGURE 6-35
USE OF POWER TRANSISTORS FOR BIAS DIODES
(Browning LTD, Cobra 132A/135A, Tram D60)



power devices have their collectors (center terminals) tied to the metal tabs. They can be bolted to the same heatsink as the RF Driver and Final with a mica insulator for electrical isolation. This means that Q15 and Q16 will heat-track the power amplifiers. The more heat generated, the harder they conduct and the more their anode voltages drop. For example, the forward voltage drop may initially be +0.7 V, dropping to say, +0.5 V on a long transmission which heats up the power amps.

This decreasing anode voltage means less base bias is applied, reducing current flow through Q14 and Q17. They cool down and reverse the heating process. In many circuits "varistors" (voltage-sensitive resistors) are used instead of ordinary silicon diodes for the same safety function. The varistor's resistance decreases as the voltage applied to it increases. They're bolted either directly to the RF transistors with the same screws, or right next to them on the frame for heat tracking.

The 8.0 V Transmit-only source is effectively grounded through R89 and the relay on AM, pulling it down and disconnecting it from the base of Q17. Instead L3 and R88/R90 establish the b-e impedance to develop Class C bias. For SSB, voltage is applied to divider R88/R89/R90 and trimmer R91 to set the 0.6 V base bias on Q17. The bias on buffer Q13 is adjustable on AM via R79, which trims the RF power output after the correct PEP SSB power output is establshed.

NOTE SAMS ERRORS: Fotofacts #62 (Tram D60) and #66 (Browning LTD) have incorrectly described the buffer trimpot (R98 or R85 respectively) as an AMC adjustment, not the bias. Fotofacts #73 for the Cobra 132/A labels it (R79) correctly.

Modern CB Biasing Methods

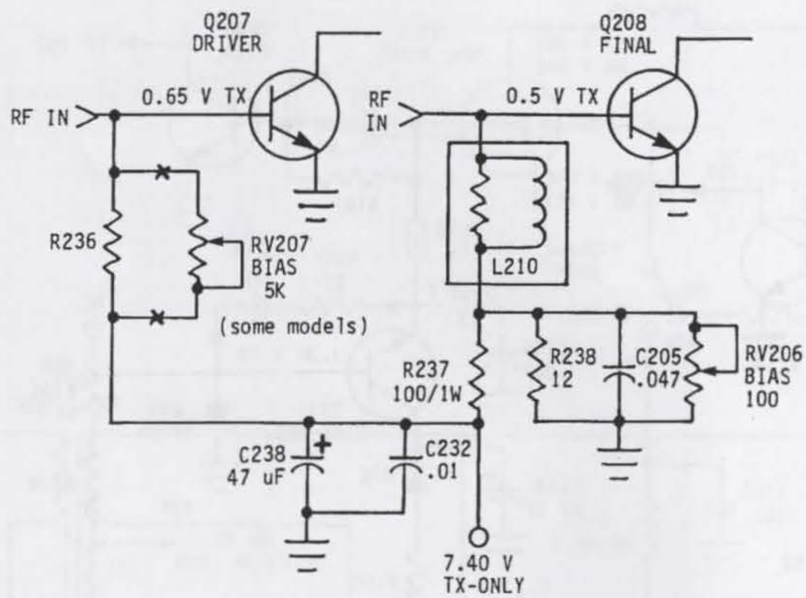
The current trend is to ignore bias switching and run Class AB all the time, including AM and FM. The newer RF power transistors like the 2SC1969, 2SC2166, and 2SC2312 have considerably higher power gain at 27 MHz than the older 2SC1306/2SC1307 pair, which makes up for losing the higher efficiency of Class C operation. The bias is generally set at about +0.5-0.7 VDC all the time from a well-regulated source.

Figure 6-36 shows an example of a common bias circuit. A highly regulated voltage source is applied to the Final by a voltage divider consisting of RV206, R238 and R237. L210 is an RF choke to maintain the base impedance of Q208, and the parallel resistor lowers its Q. R237 has a 1-watt rating due to the high current being drawn in the Final stage. In some similar Cybernet models, the Driver bias isn't

FIGURE 6-36

TYPICAL MODERN AM/SSB BIAS SUPPLY

(GE 3-5825B, 5875A, Midland 78-574, 78-891, 78-999, SBE LCBS-4)



adjustable and comes from the same voltage source using fixed resistors only.

Figure 6-37 shows the Uniden bias method. D50 and D49 are varistors bolted directly to TR38 and TR36 for heat tracking. Varistors have high resistance at low DC voltages, which decreases rapidly as the applied DC voltage rises. Increasing the drive to the power transistors raises their base voltages, which lowers the varistors' resistances. They pass more current and therefore drop more voltage away from the transistor bases. The specs are 20 ma @ 0.6 V for the MV1Y and 100 ma @ 1.3 V for the MV13Y, although the MV1Y is often used even in Final circuits having 30-40 ma of resting bias. The correct lead identifications are also shown.

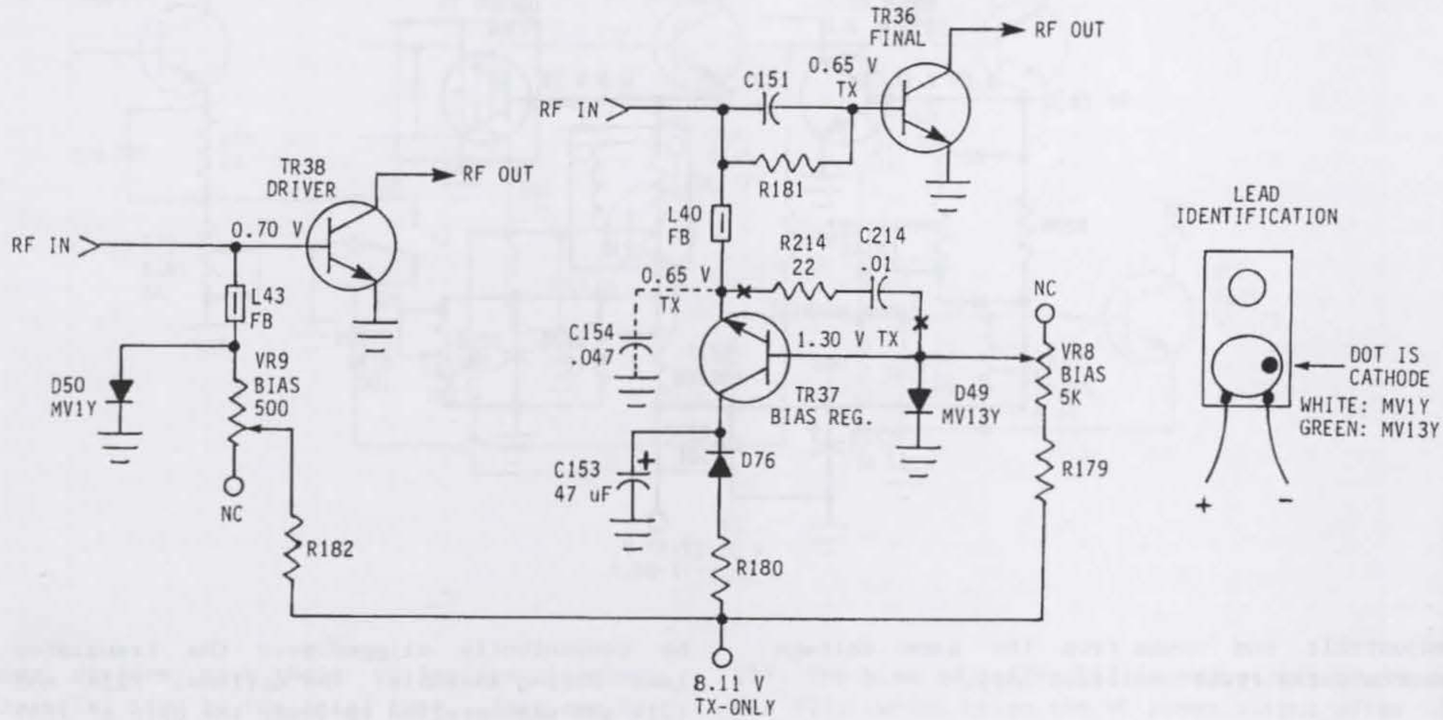
Driver TR38 uses the simple diode bias already described, while Final TR36 includes a series pass transistor (TR37) for better regulation, since it draws more current. The large value of C153 also improves regulation, and C154 is sometimes added for extra RF bypassing. D49 has a 1.30 V forward drop, setting the base of TR37 at this voltage. The additional 0.65 V b-e drop results in the desired bias of about 1.30 V - 0.65 V = +0.65 V at the emitter of TR37 and the base of TR36. L43 and L40 are ferrite beads which act as RF chokes to maintain high RF base impedance, but are cheaper than coils and can be conveniently slipped over the transistor lead during assembly. The optional R214 and C214 add degeneration to lower the gain of TR37 if self-oscillation is a problem. D76 is used in some models for isolation.

If the bias is lost in an SSB transmitter, the resulting non-linear operation causes severe splatter and distortion. The most likely causes are shorted or open bias diodes or regulator transistors, or loss of the actual bias voltage source. In the case of open varistors, you can normally replace them with an ordinary silicon rectifier diode of the 1N4001 type, and the RF transistor still won't overheat. Varistors are hard to find and you may need to substitute in a pinch. Check for excess transistor heating afterwards just to be sure!

AM/SSB POWER & MODULATION CONTROL

Since an SSB signal isn't continuous but only present with speech, it has a shorter "duty cycle" or "ON" time than AM or FM. The SSB duty cycle is only about half that of the constant-carrier modes, which is one reason the legal SSB power limit is approximately double that of AM. In other words, the 12-watt PEP peaks when averaged over time produce about the same amount of tube or transistor heating as that of a 4-watt AM or FM carrier.

FIGURE 6-37
BIAS USING VARISTORS & TRANSISTOR REGULATOR
(Cobra 148/2000GTL, Uniden Grant/Madison)



To account for this power difference, the gain of the RF amps must be changed between modes. Even if it were legal, a 12-watt AM/FM carrier would quickly burn out the power tubes or transistors, since they're not rated high enough to dissipate this much continuous power. Manufacturers never overbuild these circuits when a cheaper device will do.

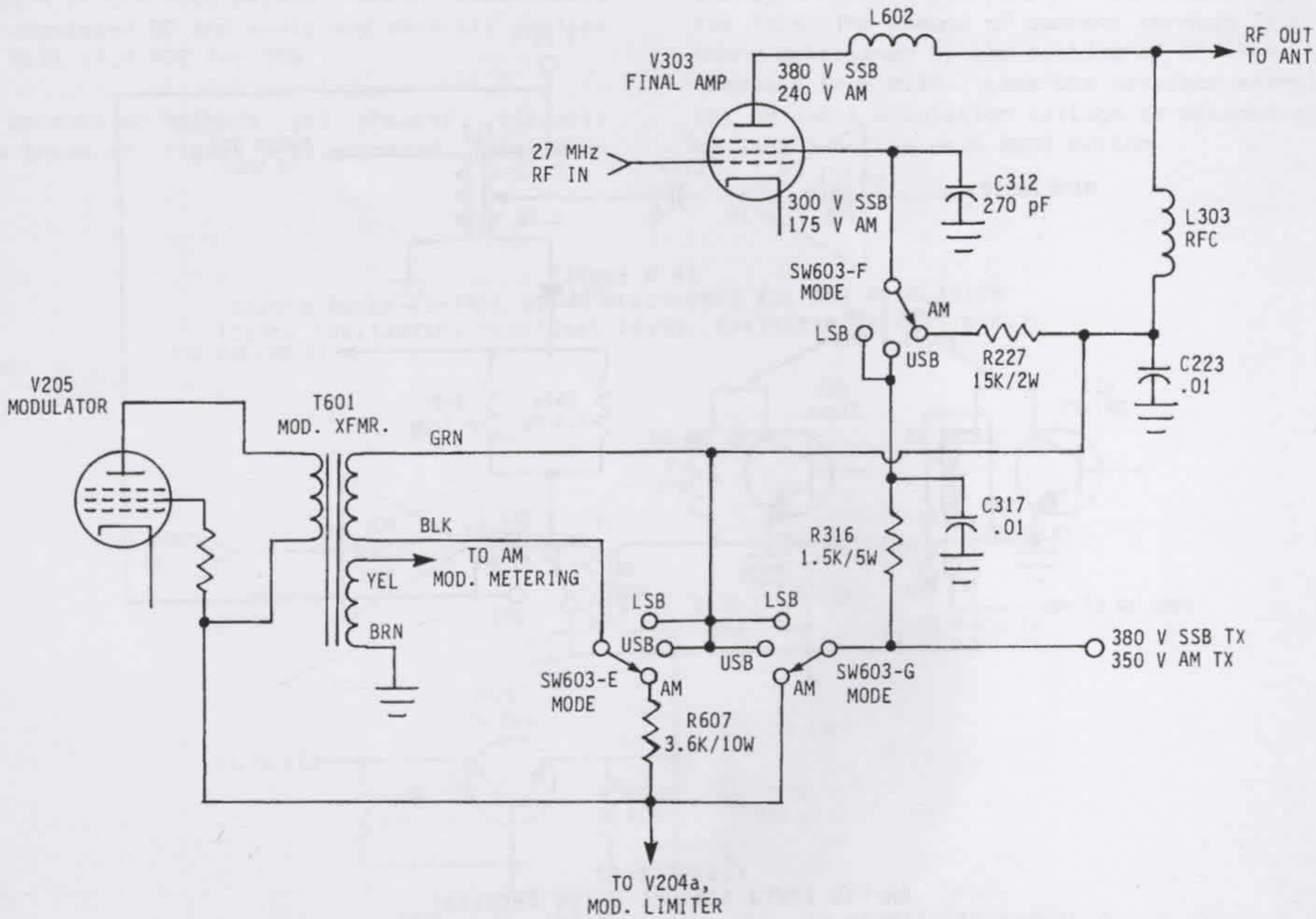
Safe control of the amplifier duty cycle is done by reducing the Driver and Final DC collector voltages in solid-state AM/FM radios, or by reducing the Final plate and screen voltages in tube radios. As this voltage is lowered, less current flows so the RF power output is lowered. In tube circuits the AM Final plate and screen voltages are lowered by series dropping resistors. For solid-state transmitters, the transistors receive the full 13.8 VDC collector supply on SSB. (Minus any voltage drop through the series resistance of the hash suppression choke or other wiring.) This produces a 12 W PEP output, while on AM or FM the supply is lowered to about 5.0-7.5 VDC to produce the 4 W constant carrier output.

The AM/FM collector supply voltage comes from a separate adjustable regulator circuit, called "AM POWER," "AM CARRIER," or "AM REG." In older equipment, fixed series dropping resistors were often used. Since all voltage control is ultimately tied to the MODE switch, a dirty or broken switch contact could easily cause the "No Transmit" symptom in a particular mode.

A second mode switching function associated with this voltage change involves the modulated audio path. In the case of high-level AM, the audio modulating voltage is added to the plate or collector voltage to produce amplitude variations. (For SSB, low-level AM, and FM, the modulation was already produced at an earlier transmitter stage.) Therefore any high-level AM modulating voltage must be disconnected for SSB (and FM), and this control is generally made using another section of the same MODE switch that controls the DC supply voltages.

Figure 6-38 is an example of power control in a tube-type radio. Large power resistors are placed in series with the high-voltage supply.

FIGURE 6-38
TUBE TYPE AM/SSB TX POWER CONTROL
(Browning Mark 4, Mark 4A)



On AM, the +350 VDC supply is directed via R607 to the plate of Final amp V303, and to its screen through R227 and SW603-F. R607 and the GREEN/BLACK secondary winding of modulation transformer T601 are in series with the DC supply and V303, so both DC and audio are applied to it. On SSB, the main DC supply increases to +380 VDC and completely bypasses R607, T601, and R227. A second, smaller screen dropping resistor (R316) is now used to raise the SSB screen voltage. The plate and screen supply to Modulator V205 are also disconnected, killing the audio voltage. The large difference in plate and screen voltages of V303 between modes accounts for the RF power difference.

Series dropping resistors were also found in many older solid-state circuits like that of Figure 6-39. The MODE switch again controls the DC and audio paths. On SSB, the full supply voltage of 13.75 VDC is applied directly to the RF amps while simultaneously disconnecting the modulated audio. On AM, the DC supply passes through the primary of T13, CD34, R92A/R92B, and S4. The resistors are factory chosen as required to produce the 4-watt output. Two or three low power (1-3 W) types are paralleled, being cheaper than one large 5-watt or 10-watt power resistor. Multiple resistors also help split the current to reduce individual resistor heating. Even the small winding resistance of T13 (0.6Ω) is enough to drop some voltage too, considering there's typically about 1.0 A of collector current flowing. CD34 adds another 0.6 V drop, leaving 9.0 VDC for the collectors.

In Figure 6-40 the AM DC voltage is adjusted by wirewound rheostat VR4, a very crude method. Because of the high current flowing, this pot is physically large, bulky, and expensive. It's found in the earlier Cybernet models like the Colt Black Shadow, HyGain 2705 (V)/3108 (VIII),

FIGURE 6-39
AM/SSB POWER CONTROL USING FIXED SERIES RESISTANCE
(Browning Baron, Cobra 132/135XLR, Tram D62)

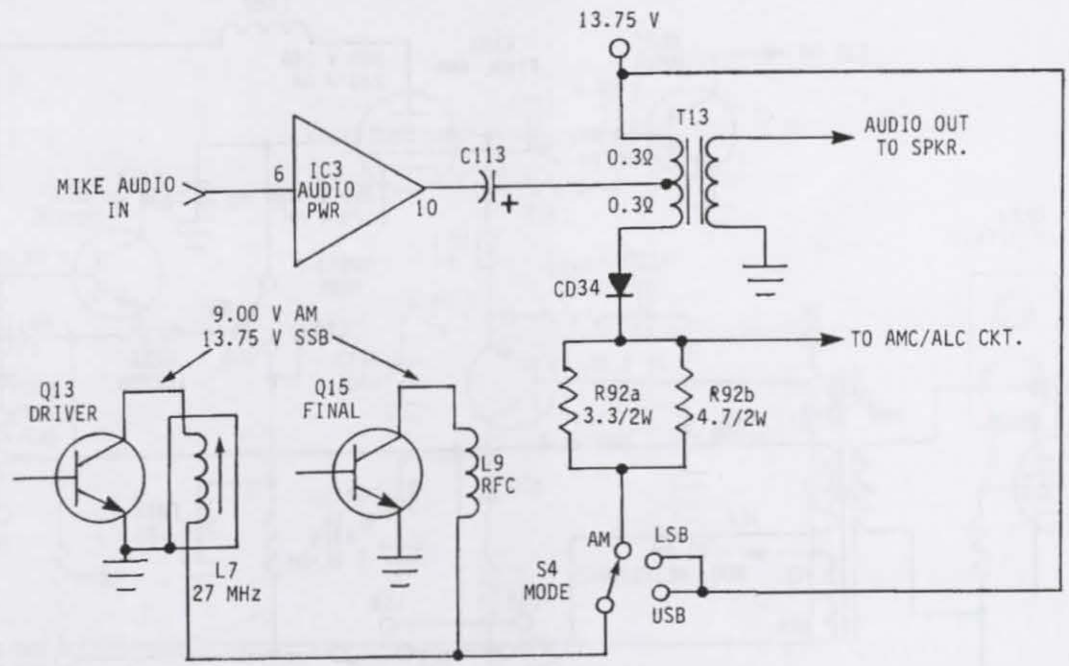
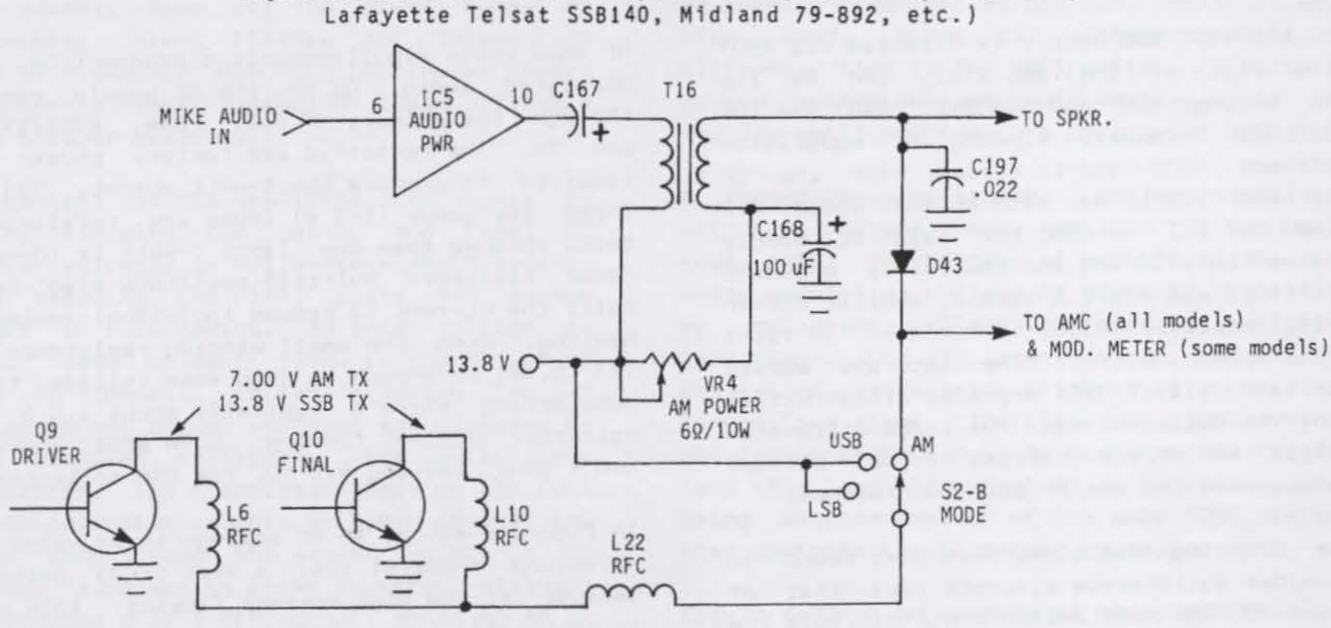


FIGURE 6-40
AM/SSB POWER CONTROL USING RHEOSTAT
(Cybernet PTBM048 chassis: HyGain 2705, JC Penney 981-6247,
Lafayette Telsat SSB140, Midland 79-892, etc.)



J.C. Penney 981-6247, Lafayette Telsat SSB140, Midland 78-574, 79-892, RCA 14T302, and the G.E. 3-5875A "Superbase." The modulated audio path is controlled further downstream by a section of the MODE switch, which disconnects the regulated DC and audio and directly applies the full 13.8 VDC for SSB.

As production methods got cheaper, circuits like those of Figure 6-41 appeared. This is an ordinary series-pass voltage regulator. TR25 is the regulator, and TR26 its controller. The harder TR25 conducts, the more current it will pass, and therefore the higher the supplied voltage. Zener D26 sets the conduction point for TR26. The amount of current through TR26 is then determined by the setting of VR8 and the feedback from R110. Like the previous example, the AM audio modulation voltage is disconnected by S402-3 on the main MODE switch.

FIGURE 6-41
AM/SSB POWER CONTROL USING ELECTRONIC VOLTAGE REGULATION
(Cobra 138/139XLR, President Adams, Realistic TRC458, etc.)

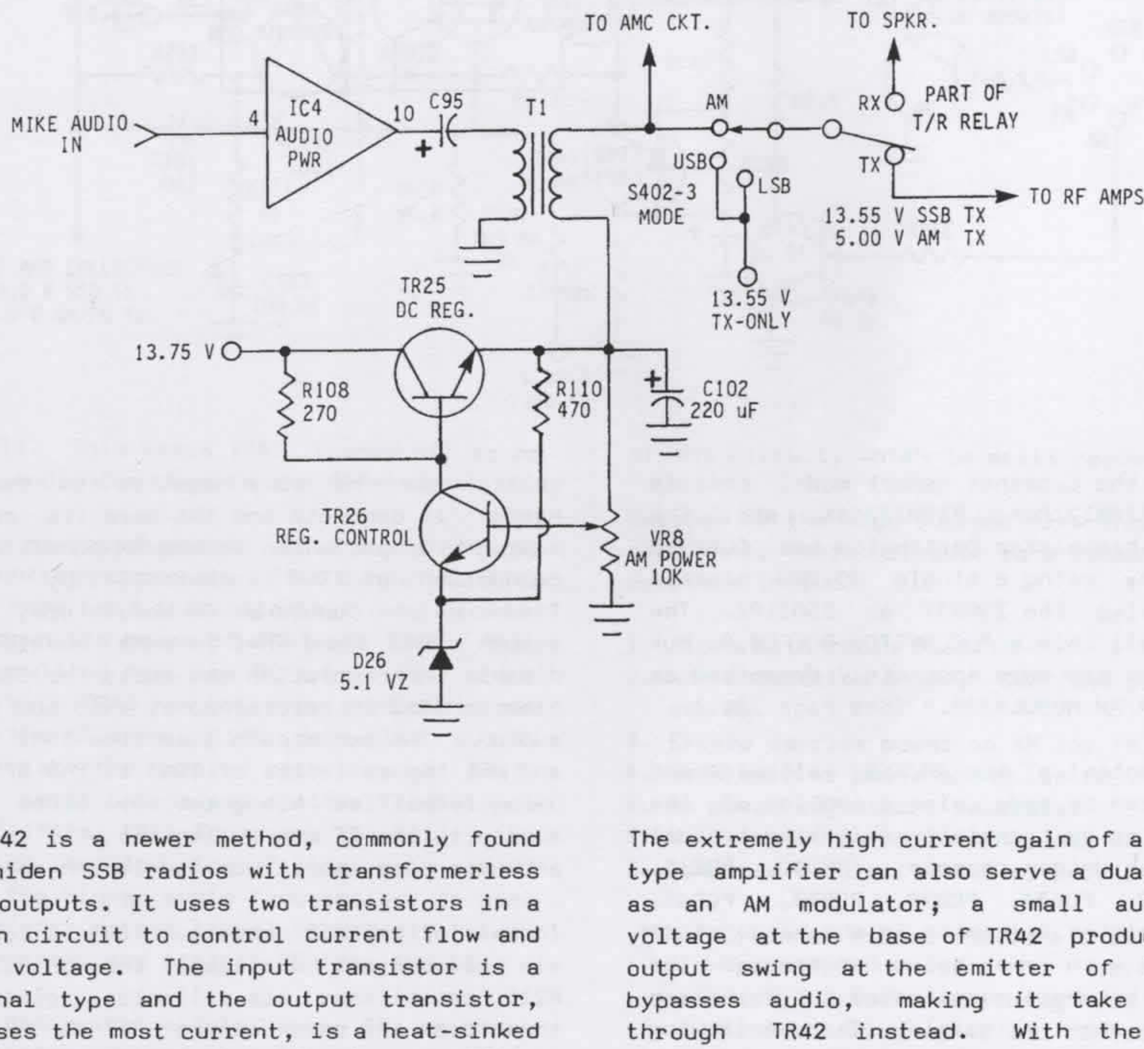
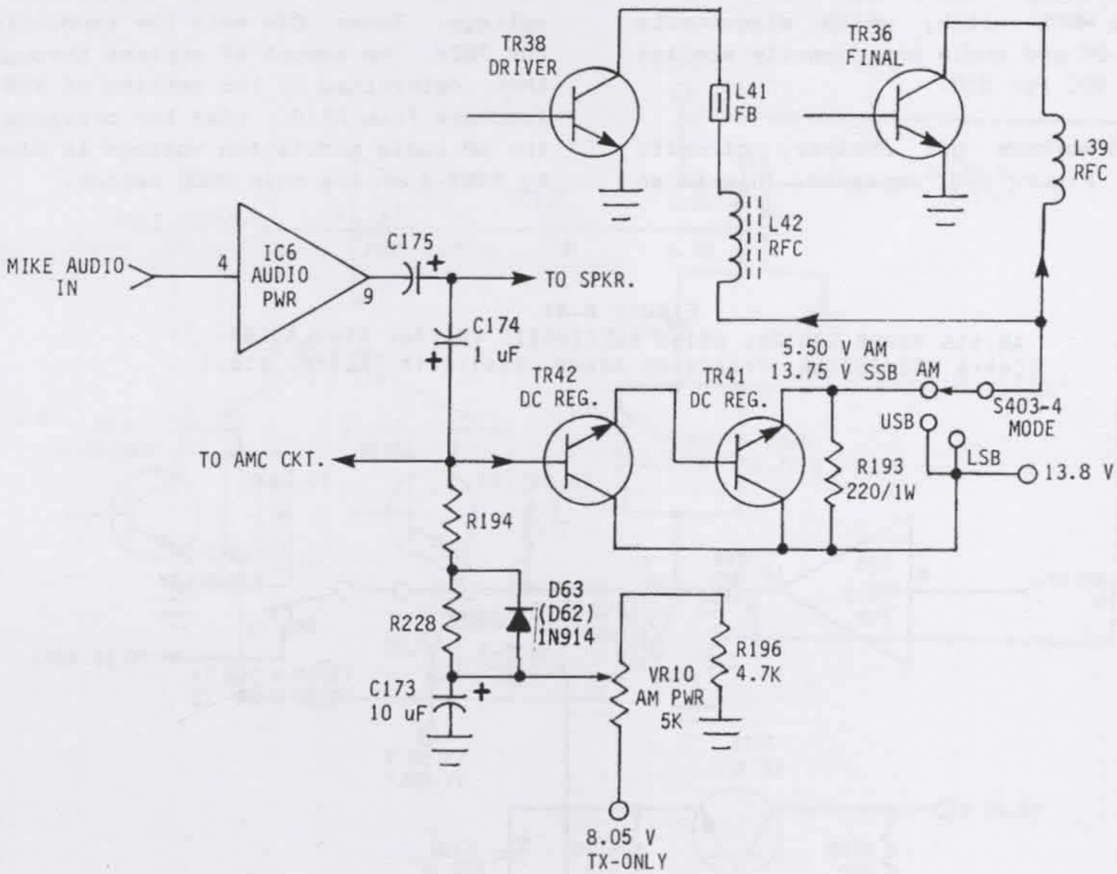


Figure 6-42 is a newer method, commonly found in the Uniden SSB radios with transformerless IC audio outputs. It uses two transistors in a Darlington circuit to control current flow and therefore voltage. The input transistor is a small-signal type and the output transistor, which passes the most current, is a heat-sinked TO-220 type. VR10 sets the base bias for TR42. The harder TR42 turns on, the more current passes through its emitter to turn on TR41. And the harder TR41 conducts, the more current it passes to the RF Driver and Final. D63 isolates RF and clamps excessive modulation peaks.

The extremely high current gain of a Darlington type amplifier can also serve a dual function as an AM modulator; a small audio input voltage at the base of TR42 produces a large output swing at the emitter of TR41. C173 bypasses audio, making it take the path through TR42 instead. With the TR38/TR36 collector voltages swinging at an audio rate, amplitude modulation results. A section of the MODE switch directs the audio path again. On AM the circuit passes both regulated DC (4.5-7 V) <u>and</u> audio to the Driver and Final, while on SSB it passes only the main 13.8 VDC supply.

FIGURE 6-42
AM/SSB POWER CONTROL USING DARLINGTON REGULATOR
(Cobra 148/2000GTL, Uniden Grant/Madison)



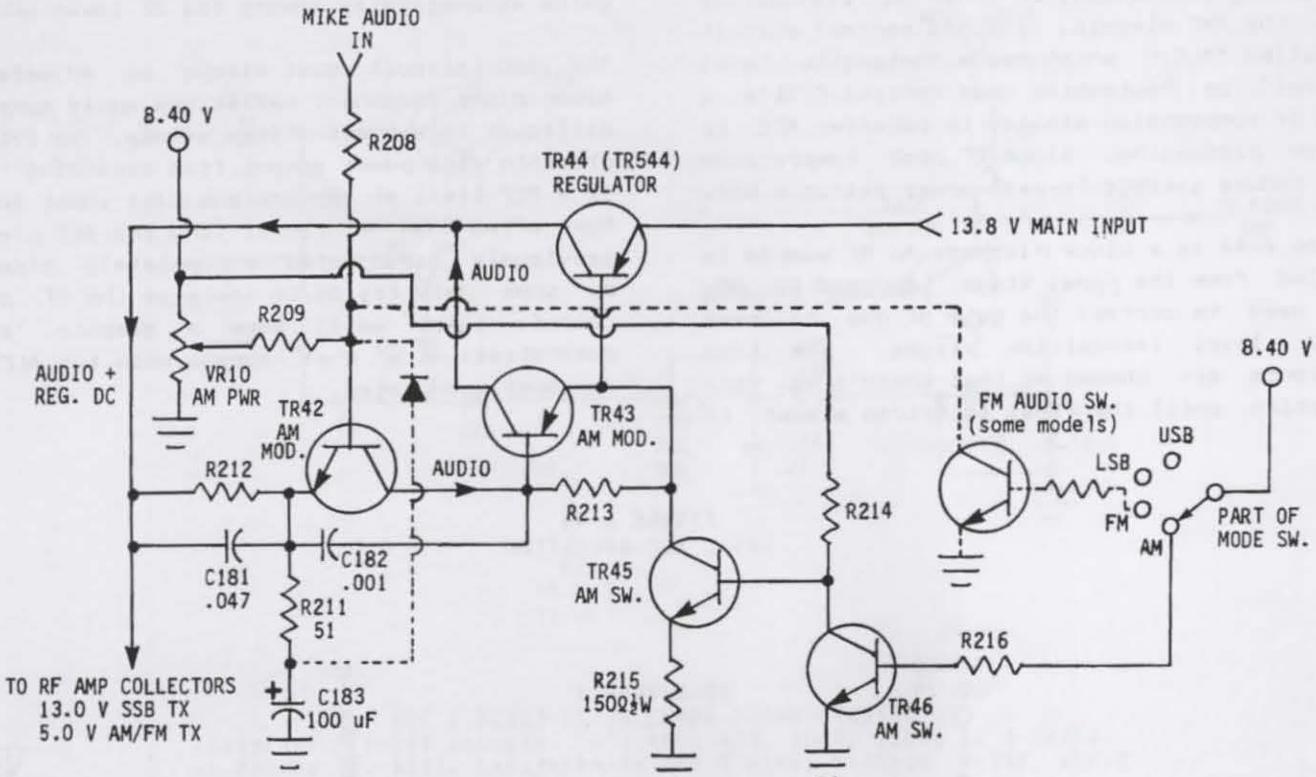
In most of the Cybernet export model chassis (PCMA001S, PTBM121D4X, PTBM133A4X, etc.) the discrete two-transistor Darlington was further simplified by using a single TO-220 plastic Darlington like the 2SD837 or 2SD1192. The schematics call this a "DC SWITCH BUFFER," but the functions are more accurately described as "DC REGULATOR/AM MODULATOR." (See Page 174.)

Switching control of the AM/SSB voltages and audio paths can be made using a section of the MODE switch, or by transistor switching typical of the newer Uniden chassis. (PB010, PB015, PB062, PB122, PC833, PC879, PC893, PC965, PC999.) Transistor switching is cheaper, since a MODE switch with fewer poles can be used. The circuit is a bit more complicated but works on exactly the same principle. The following describes this circuit, shown in Figure 6-43.

TR44 (TR544 in some models) is the main series-pass transistor, which connects to the 13.8 VDC main input and acts as a variable resistance to supply DC voltage to the RF Driver and Final collectors. The more negative its base, the harder it conducts and the more its collector voltage drops, which is the AM condition. The conduction of TR44 is controlled by TR42 and TR43, which double as AM modulators, and by switch TR45 (and TR46 in some models) which disable the regulation and audio for SSB. Base bias on TR42 is determined by VR10 and the mike audio. The audio path goes from TR42 to TR43 and out the collector of TR43 to the RF stages, being amplified along the way. Since the DC supply to the RF amp collectors will change at an audio rate, amplitude modulation results.

In the initial SSB condition TR45 is conducting via the constant base supply through R214, and R215 establishes its collector voltage (and therefore the base voltage of TR44) at about 13.0 VDC. Note R215 is a 1/2-watt type, since it's passing a fair amount of current. With the base of TR44 at 13.0 V and emitter at 13.8 V it will conduct, supplying about 13.6 V to the RF stages. The emitter of modulator TR43 is also at 13.0 VDC; its base is at about 13.2 VDC via

FIGURE 6-43
AM/SSB POWER CONTROL USING DISCRETE TRANSISTOR REGULATION
(Cobra 146GTL, President AX144, Realistic TRC451, Uniden PC244, etc.)



pullup R213. This keeps TR43 turned off so no modulated audio can pass to the RF stages.

On AM the reverse happens: TR45 turns off as its base voltage drops when TR46 conducts. TR42 conducts more and its collector goes lower, pulling down the bases of TR43 and TR44. They conduct, pulling down the DC supply to about 5.0 VDC. With TR43 now on, modulated audio can pass to the RF amps. C183 decouples audio, making it take the desired path through TR43. Note the small unbypassed emitter resistance (R211) of TR42; this increases stability by degeneration and lowering of stage gain. C182 rolls off the higher audio frequencies. In some models a diode (dotted lines) is added to clamp modulation peaks and isolate RF from the DC.

In the Uniden export models having FM, an extra NPN transistor (dotted lines) is turned on in the "FM" mode only. Its collector is across the modulated AM input and will shunt the audio to ground to prevent any simultaneous amplitude modulation. This switch is only for AM audio and has no effect on the power regulation part of the circuit, which is still needed for FM.

Because of the high current flow through the AM regulator, this circuit is a common failure. Symptoms include:

1. Blows main radio fuse.
2. No modulation on AM; SSB (and possibly FM) are OK.
3. Excess carrier power on AM (or FM).
4. Weak carrier power on AM (or FM).
5. No power adjustment possible.
6. No Transmit on AM (or FM); SSB OK.
7. Downward modulation due to poor regulation.*

*The Cybernet export models all suffer from this problem. There's no cure. I've personally tried everything from ripping out the associated wires and replacing them with heavier ones, to replacing the plastic Darlington with two discrete transistors of higher ratings. The only solution is not to exceed 4 watts maximum AM carrier power, regardless of the worthless POWER switch and its phony 7-watt "HI" position.

AUTOMATIC LEVEL CONTROL (ALC)

To prevent the splatter that results from overdriving a linear amplifier, some form of gain control must be used. This is similar to preventing overmodulation in an AM transmitter with the AMC circuit. The SSB control circuit is called "ALC," which means "Automatic Level Control" or "Automatic Load Control." It's a form of compression similar to receiver AGC or speech processing, since RF peak compression does reduce average-to-peak power ratios a bit.

Figure 6-44 is a block diagram. An RF sample is coupled from the Final stage, changed to DC, and used to control the gain of one or more lower level transmitter stages. The time constants are chosen so that there's no gain reduction until the Final is driven almost to its maximum linear capability, after which the ALC attacks rapidly to reduce gain. As shown, the ALC feedback voltage may be applied to the mike audio stage, an IF stage, or even the mixer with equal effect; lowering any of their gains automatically lowers the RF power output.

The ALC circuit must always be adjustable, since minor component variations would make it difficult to set with fixed values. The trimmer prevents the power output from exceeding the 12 W PEP limit at the maximum mike input level. More often than not you'll find the ALC circuit previously misadjusted or completely disabled by some jerk trying to increase the RF power output. Later we'll show a graphic 'scope demonstration of what happens when the ALC is improperly adjusted.

FIGURE 6-44
BASIC ALC OPERATION

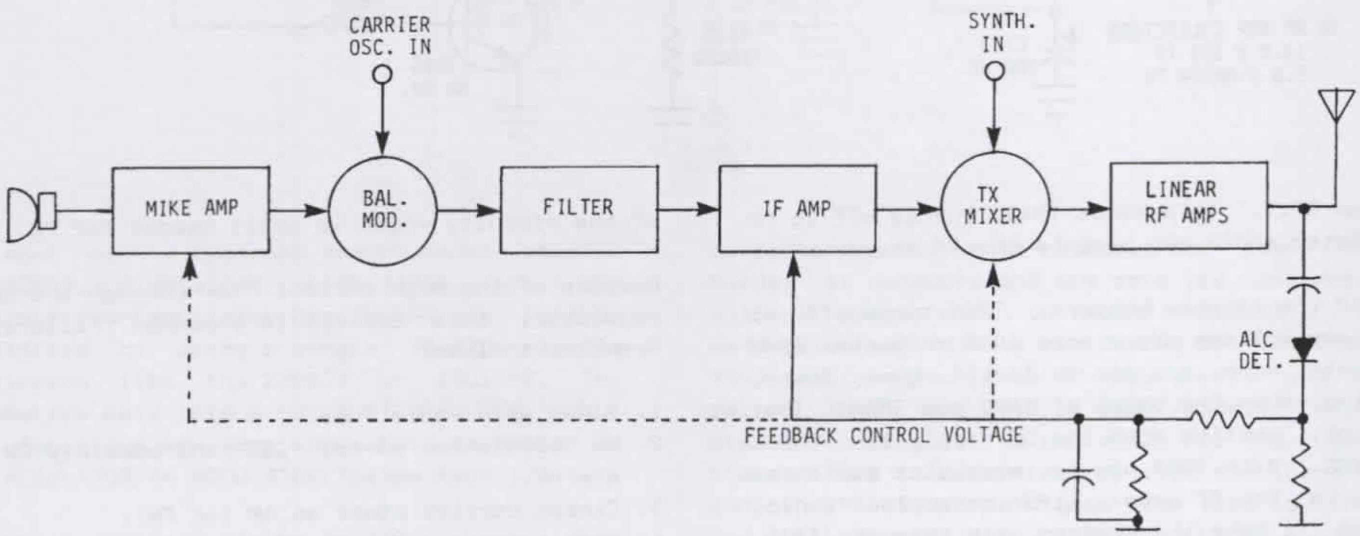


Figure 6-45 shows the simplest type of ALC circuit. In this model the sample comes from the Driver, but most circuits sample the Final. C123 couples the RF to the detector. This sampling capacitor is always very small to minimize amplifier loading and impedance changes. D37 conducts on positive RF peaks and D38 conducts on negative peaks, so the ALC voltage is negative-going and will lower the conduction of IF Amp TR13. C124, C125 and R94 form an RF filter and establish a suitable time constant for 27 MHz. VR9 sets the level at which the ALC attacks. Since TR13 is also used in the Receive mode, diode T/R switching via R95/D39/D31 is included for mode isolation.

Figure 6-46 shows how a Zener diode may also be used in an ALC circuit. Gain is controlled directly at the Transmit Mixer IC rather than at an IF amp. D8 is the ALC Detector, and RV2 sets the ALC threshold. R41, C58, C59, R172, and C901 are all part of the attack/delay time

FIGURE 6-45
ALC USING DIODE DETECTORS

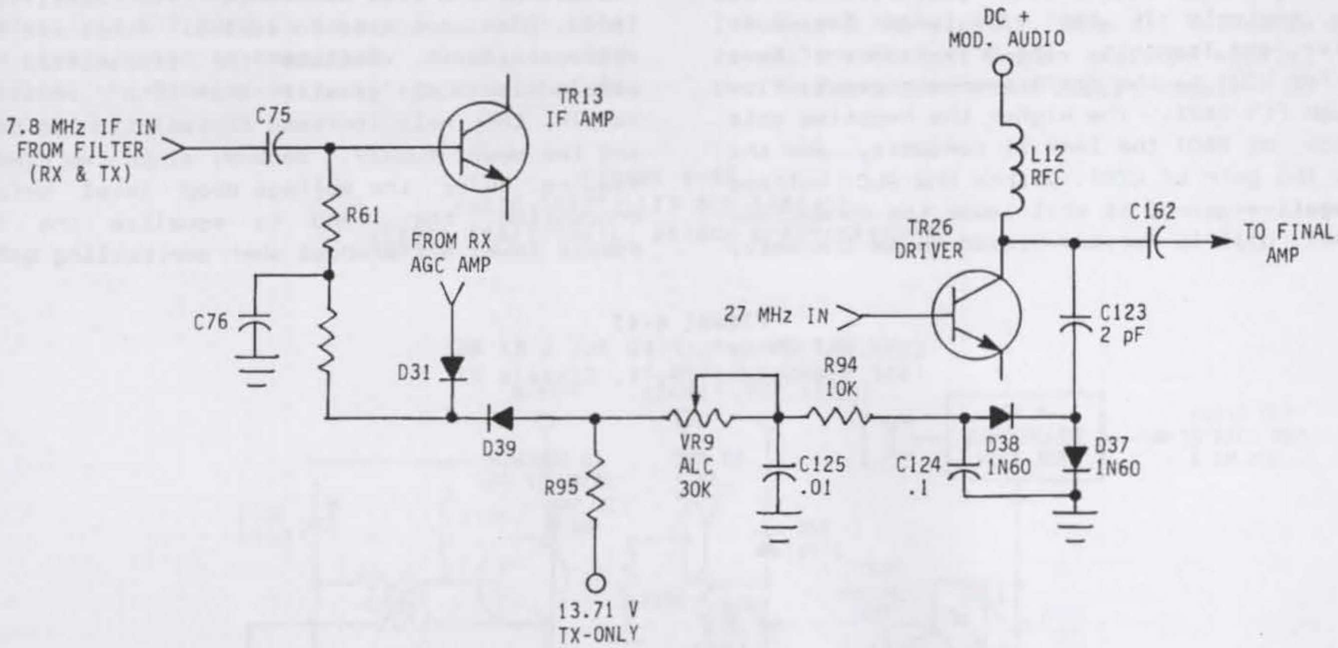
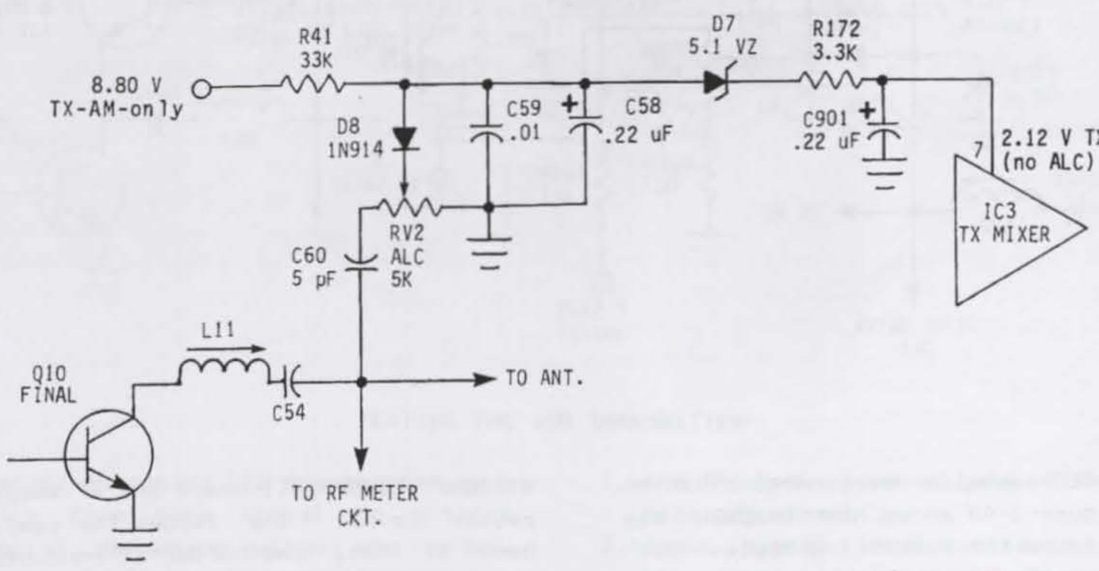


FIGURE 6-46
ALC CIRCUIT USING ZENER DIODE SENSING
(Cybernet PTBM058 chassis: Colt 480, 485, 1000, 1200, GE 3-5825A,
JC Penney 981-6247, Lafayette Telsat SSB140, Midland 79-892, etc.)



constants. D7 is a 5.1 V Zener diode which is normally cut off on AM through the forward bias of the 8.80 V AM-Only Transmit source. A Zener conducts when its voltage is exceeded in the reverse-bias direction. For SSB, the conduction of D7 can be used to control IC3. When the negative RF peaks exceed 5.1 V plus the 0.6 V for D8 and the preset level, D7 and D8 conduct.

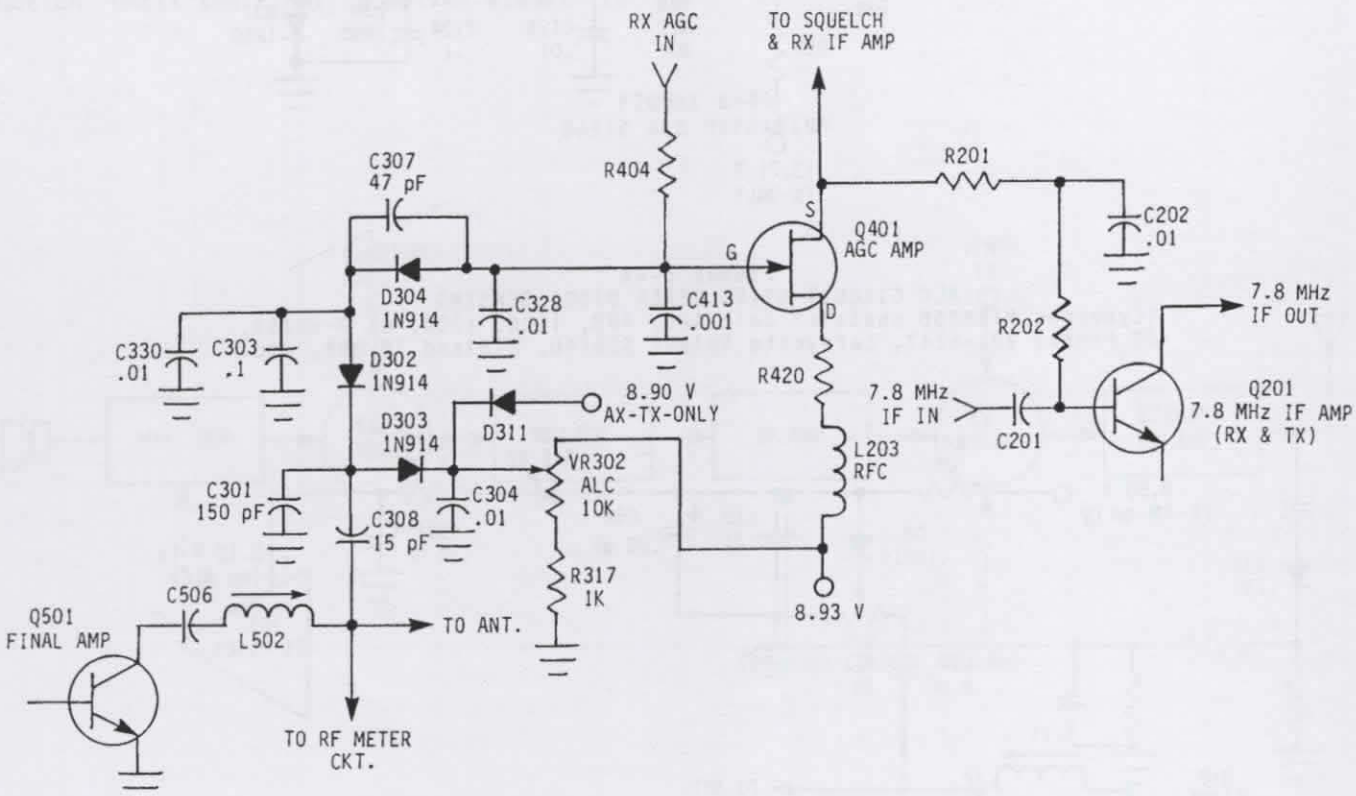
IC3 Pin 7 connects internally to the base of an output transistor, so the normal 2.12 V bias is pulled down and lowers the chip's RF gain.

NOTE: There'a a slight difference between the Cybernet PTBM048 and PTBM058 chassis in the ALC circuit. In the PTBM048 version (Boman CB950, HyGain 2705, RCA 14T302, etc.) Zener D7 is used to control SSB IF amp Q14 rather than IC3; both chassis types are otherwise identical.

Sometimes ALC is combined with receiver AGC, as in Figure 6-47. Q401 is the AGC amp, which in turns controls IF amp Q201 used for both Receive and Transmit. The only source of base bias for Q201 is the drain-source current flow through FET Q401. The higher the negative gate voltage at Q401 the less it conducts, and the lower the gain of Q201. Since the ALC voltage is negative-going, it will lower the conduction of Q401. D311 is forward-biased on AM Transmit, which cuts off isolation diode D303 so the circuit will only work on SSB.

The various shunt capacitors are for RF filtering and time constants. Two rectifiers (D302, D304) are used in series. There are two reasons: first, because the transmitted RF sample is much greater than the received sample, they help increase RF isolation to Q401 and the power supply. Second, since two diodes require twice the voltage drop level before conduction, they tend to equalize the T/R sample level differences when controlling Q401.

FIGURE 6-47
COMBINATION AMPLIFIED ALC & RX AGC
(SBE Sidebander IV, V, Console V)

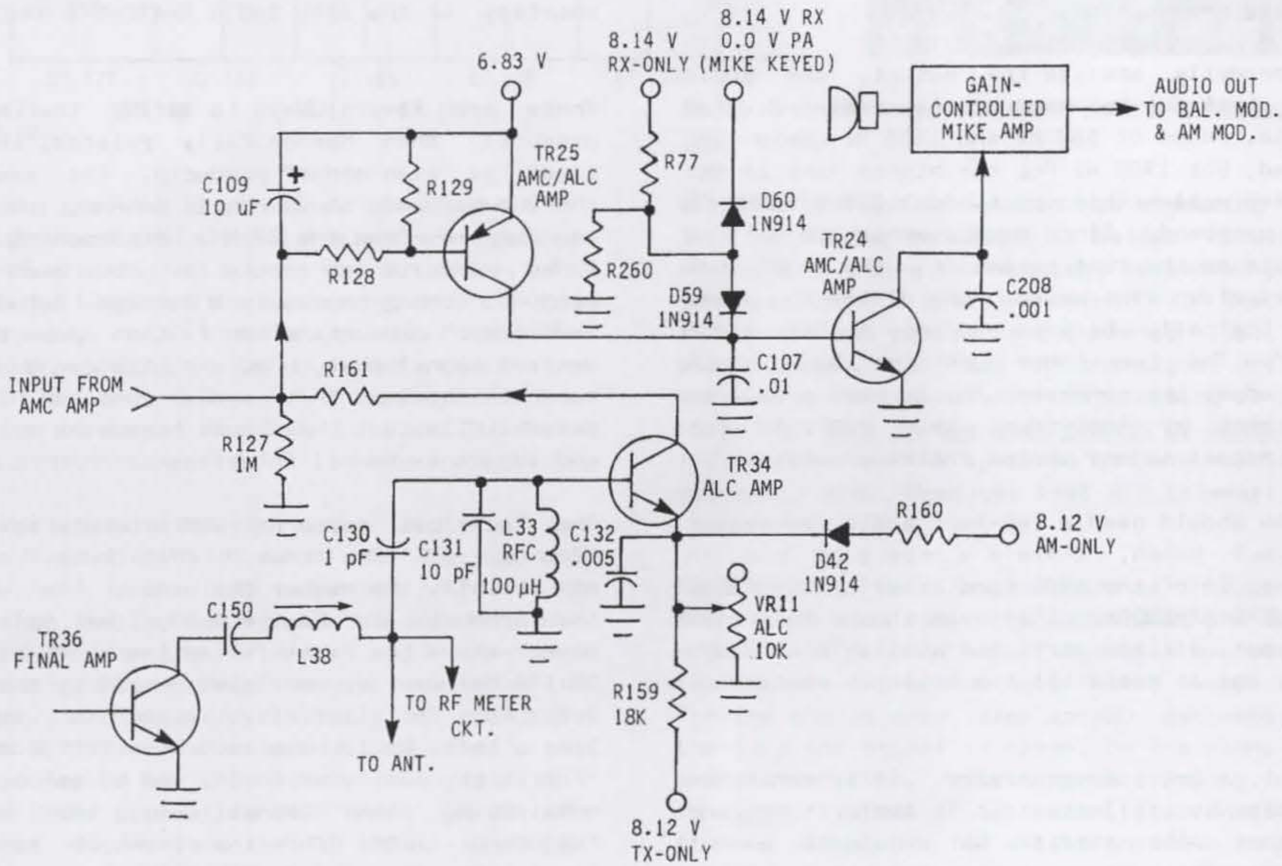


The previous ALC examples use control of IF or RF stages. Figure 6-48 shows how feedback may be used directly on the modulating audio. With SSB there's no RF output without modulation anyway, so audio control is just as effective. The ALC is shared with the AMC input, and both control the same shunt transistor across the mike line. The amplified ALC used here has much better control compared to the simpler diode detectors. TR34 is an RF amp, indicated by L33 and its lack of base bias. A 10:1 voltage divider (C130/C131) keeps the RF sample at the proper level. The larger the sample at the base of TR34, the harder it conducts and the further its collector voltage is lowered. The collector voltage swing is stretched out by the long time constant of C109/R127 to control the rest of the shunt amplifier circuit, TR25/TR24.

VR11 sets the conduction level; the lower the emitter voltage, the sooner TR34 conducts. The negative-going collector voltage of TR34 makes

TR25 conduct harder, supplying more base current to TR24. And the harder TR24 conducts, the more audio shunted to ground, reducing its level to the Balanced Modulator and therefore the RF output power. TR24 is also conducting on Receive via R77/R260 to help insure that the mike audio chain is completely disabled; D59 isolates the Receive-only voltage from the PA and mike keying circuits. Since limiting isn't required for the PA, the cathode of switch D60 is held LOW to keep TR24 inoperative in that mode. On AM, D42/R160 turn off TR34 by raising its emitter bias, thus disconnecting it from the shared AMC circuit. This ALC method is used in all the current Uniden American models, and the Uniden/Uniden clone export models.

FIGURE 6-48
AUDIO-CONTROLLED ALC CIRCUIT
(Cobra 148/2000GTL, Uniden Grant/Madison)



TESTING THE SSB TRANSMITTER

Since a properly operating SSB transmitter is a linear device from mike socket to antenna socket, special measuring methods are needed. Test equipment includes an oscilloscope, a peak-reading RF wattmeter, and if you're really lucky, a spectrum analyzer. In this section you'll learn the importance of linearity and how to test for it. There's only <u>one</u> reason for transmitter non-linearity: excess input signal relative to the bias level. And this in turn can only be caused by:

1. Insufficient base or grid bias. (Improper bias adjustment.)
2. Input signal level too large relative to bias level. (Improper ALC setting.)
3. Final amplifier not loaded heavily enough. (Improper tuning or alignment.)

The cures for these problems are obvious and can be easily fixed by any good, conscientious technician. If you're a true professional, don't let them leave your shop dirty.

The Two-Tone Test

The standard method for checking amplifier linearity is the "two-tone" test, where two RF frequencies of equal amplitude are applied to the linear amplifier, and the output is observed on a 'scope or spectrum analyzer for spurious products. Since an SSB transmitter has no RF output without an audio input, this means two audio tones can be applied at the mike input. For each audio frequency there should only be a single RF frequency. No amplifier is perfectly linear and some mixing will occur, but these mixing products should be much weaker than the main output.

To correctly analyze the output, the audio tones must not be harmonically related. For example, tones of 800 Hz and 1600 Hz could not be used, but 1900 Hz for the higher tone is OK. Both are well within the typical 300-2500 Hz CB audio passband. Since measurements are only as reliable as the test equipment, the tones must be very clean sine waves; any distortion would then logically be produced only in the radio itself. The two tones must also have equal amplitudes; the generator should have a balance adjustment or individual gain controls for this. Actual 'scope photos follow shortly.

If you should need a two-tone audio generator for your bench, there's a very good one in Chapter 25 of the 1986 (and later) ARRL RADIO AMATEUR'S HANDBOOK. They even show a full-size PC layout, all the parts are available at Radio Shack, and it meets all the criteria mentioned.

Without a two-tone generator, it's sometimes possible to use just a single audio tone and unbalance the carrier by an equal amount instead. This gives exactly the same result. But I find the carrier supression is so good in most IC Balanced Modulators that you can't unbalance them enough to match tone and carrier levels, limiting the use of this method to certain older SSB radios only.

The test equipment set-up is identical to that described in CHAPTER 5 (Figure 5-60), except that two audio tones are injected at the mike input instead of just one, and a peak-reading type of RF wattmeter is used. The transceiver is connected to a dummy load, and the 'scope across the RF output with a suitable coupler. The 'scope should have a 30 MHz bandwidth to view the 27 MHz RF signal directly.

Measuring Intermodulation Distortion (IMD)

The spectrum analyzer is the most accurate way to measure RF amplifier distortion. While the oscilloscope measures signal amplitude as a function of time, the spectrum analyzer measures amplitude as a function of frequency. By definition then it must have a tremendous bandwidth compared to a 'scope, which is why prices start at about $10,000! It shows a graphic display of all mixing products and their strengths relative to the carrier. Since one picture's worth a thousand words, I've reprinted some spectrum photos in this section, courtesy of the ARRL RADIO AMATEUR'S HANDBOOK.

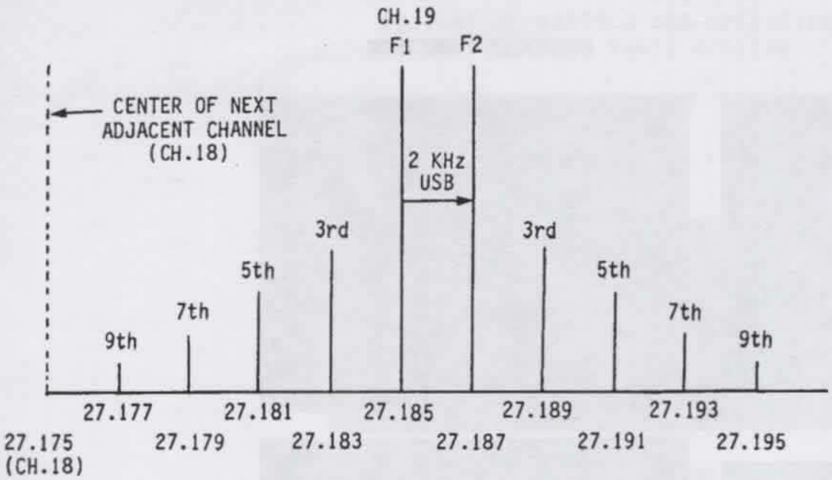
There are several ways to define the mixing products. When harmonically related, they're known as "even-order" products. For example, the 2nd harmonic of 27 MHz is 54 MHz, which is so far away from the 27 MHz fundamental that tuned circuits can remove it. Thus even-order products aren't generally a problem. But IMD or "odd-order" products often fall so close to the desired signal that tuned circuits can't always separate them, so they're also radiated. If not severely limited, they cause bleedover splatter and adjacent-channel interference.

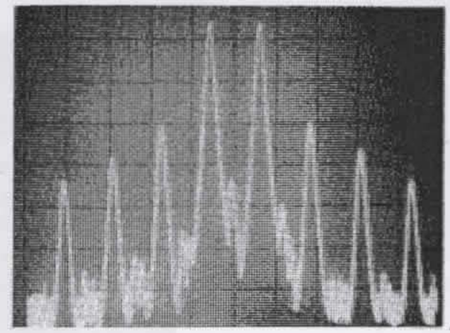
The technical names for IMD products are the "3rd Order," "5th Order," "7th Order," and so on. Usually the higher the order, the weaker the product. In Figure 6-49, the left-hand sketch shows the first few mixing products of a 27.185 MHz carrier modulated on USB by a single 2 KHz tone for simplicity; a complex waveform like a voice would have many more IMD products. "F1" is the center of Ch.19, and by temporarily unbalancing the transmitter, the second frequency ("F2") for the two-tone test is simulated. The 3rd Order products are ±2 KHz from F1 and F2, the 5th Order are ±4 KHz away, etc. While the SSB bandwidth is supposed to be limited to about 2.5 KHz, it's obvious that beyond the 5th Order, products start spilling over into the adjacent CB channel. If they're strong enough, interference results.

Good engineering specifies that 3rd Order IMD products be down at least -30 dB below one tone of a two-tone test input. Most CBs don't offer published specs. The FCC minimum specs are:

3rd & 5th Order: -25 dB or better.
7th & 9th Order: -35 dB or better.

FIGURE 6-49
IMD MIXING PRODUCTS





(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)

Now let's see what that means. In Figure 6-49, the right-hand photo shows the actual spectrum of an HF transceiver out to the 7th Order. The two large blips in the center result from the two inputs; note they're exactly the same amplitude, which is why the spec says, "one tone of a two-tone input." Spreading out from these two tones are the 3rd, 5th, and 7th Order mixing products.

Each horizontal scale division is 1 KHz, and each vertical division is 10 dB. The top edge of the photo is the 0 dB reference point, which means that the two tone peaks are actually down about -6 dB from the PEP output. (If they were in phase and combining, they'd have twice the voltage and twice the current of a single tone; a 4:1 power ratio equals 6 dB. That's why the two inputs can't be harmonically related.) The 3rd Order product is down about -30 dB, the 5th about -37 dB, and the 7th about -43 dB. So in this example, the FCC specs are easily met.

Effects of Amplifier Non-Linearity

To emphasize again the importance of proper alignment, review the photos of the test conditions in Figure 6-50. On the left are the two-tone 'scope patterns most of us would see. On the right are the graphic effects shown on a spectrum analyzer. Photo "A" shows a properly adjusted transmitter. The only noticeable IMD products are the 3rd Order, which are way down. In Photo "B" the bias was disconnected and the amplifier now approaches the Class C condition. Note the extremely strong 3rd Order products, with the 5th and 7th orders now appearing too. This particular condition is called "crossover" distortion, since the envelope crossover points are no longer a sharply-defined "X." The cure is to increase the resting current; i.e., the bias voltage. In Photo "C" the signal drive is excessive, which causes flat-topping or peak clipping. This is the most common CB condition, and you can see the spectrum has now splattered out quite wide. Readjust that ALC trimmer!

For those of you inexperienced at interpreting SSB 'scope displays, the additional photos of Figure 6-51 should help. A couple are similar to Figure 6-50, but using a faster sweep time. The top photos show voice speech patterns. On the left the signal is clean. On the right it's being overdriven, causing peak clipping. This is very typical in CB transmitters where the ALC was disabled. The slight increase in power output comes at the expense of everybody else near the frequency. Don't allow it.

Photo "A" shows proper transmitter adjustment, with a sharp "X" at the crossovers and straight envelope sides. Photo "B" is the same pattern but with hum on the signal, probably due to poor grounding in the test set-up. In Photo "C" the two tones were unequal, since they don't form a sharp "X" at the crossover points. The frequency response of some transmitters may not be flat across the whole voice range, so one tone may require a higher input level until you get the Photo "A" pattern. That's why the audio generator levels must be adjustable.

FIGURE 6-50
DISPLAY OF VARIOUS AMPLIFIER CONDITIONS VS. SPECTRAL EFFECTS
(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)

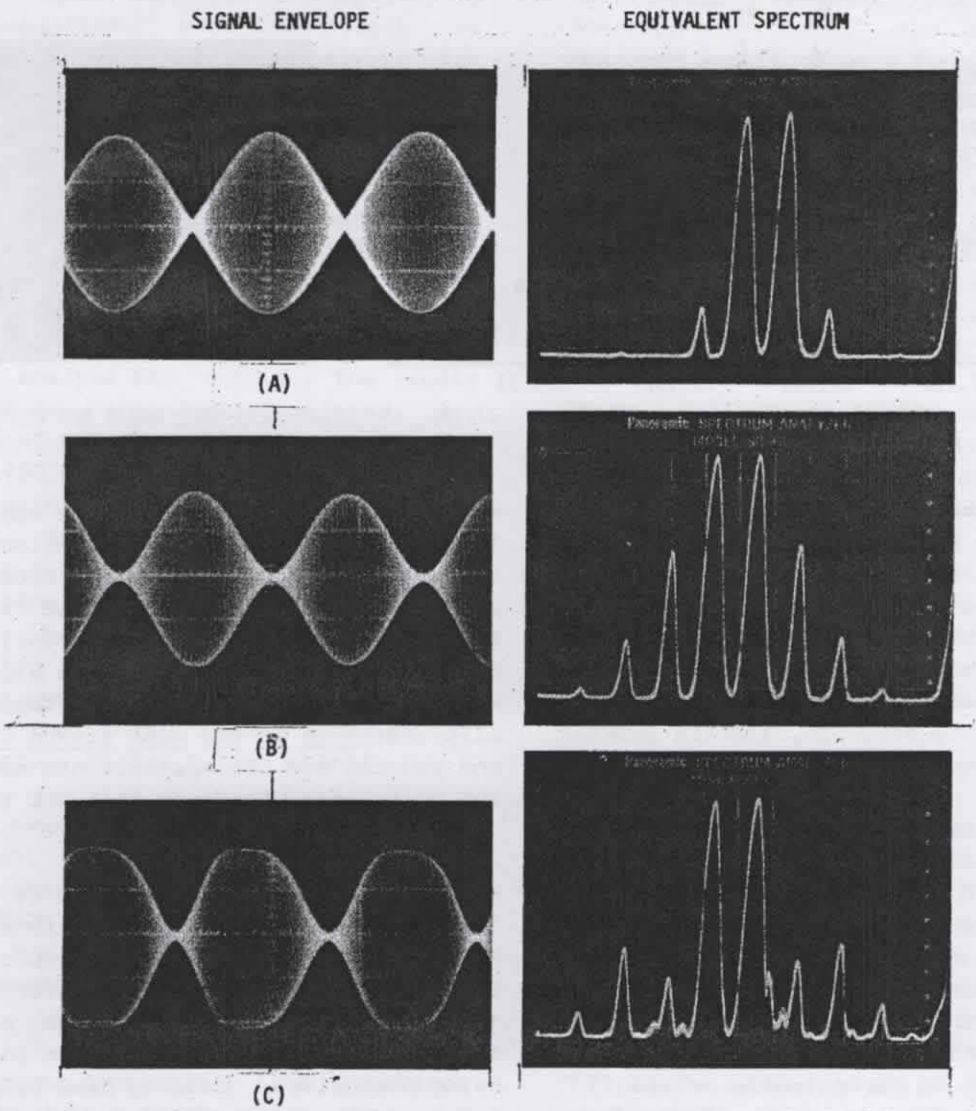
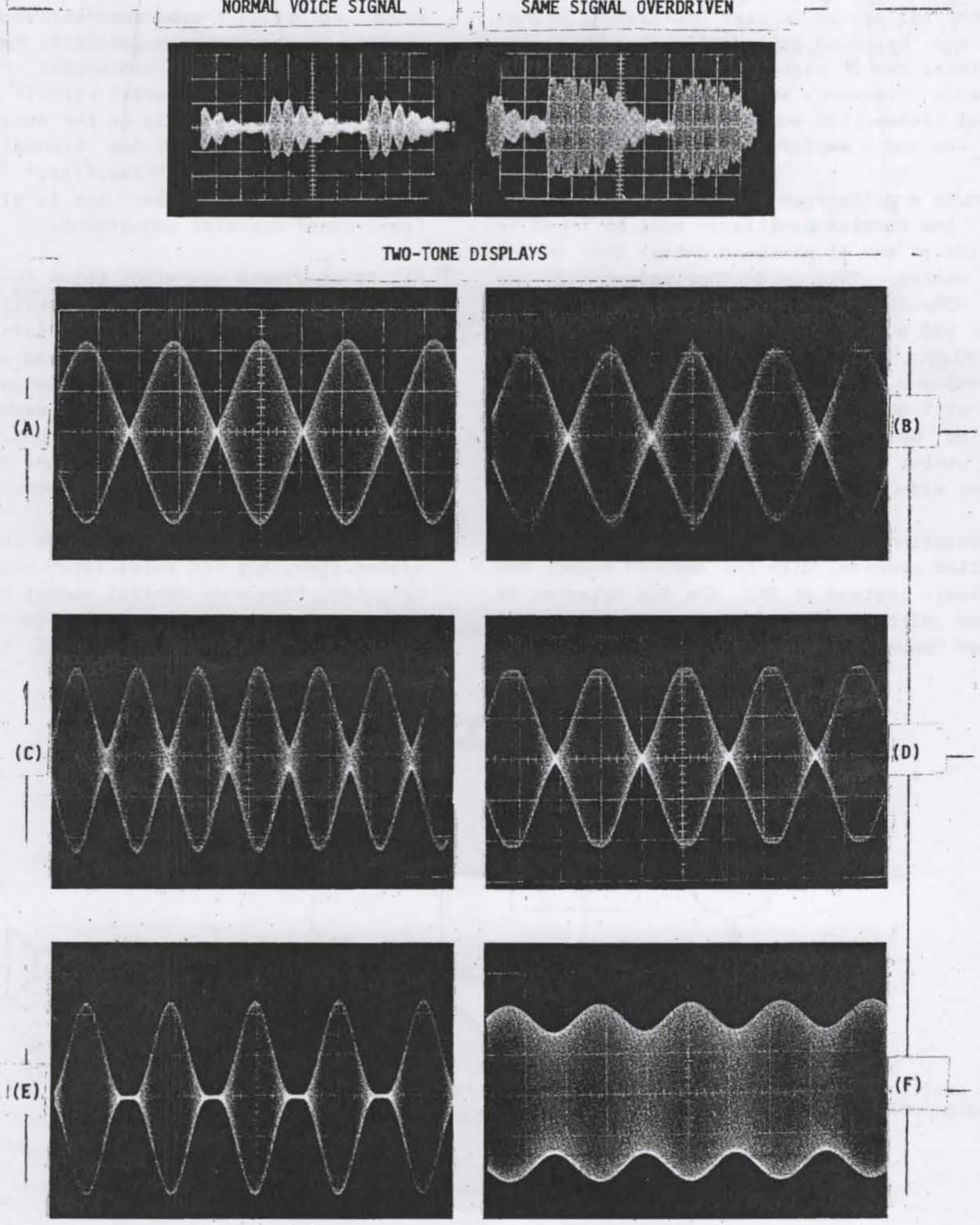


Photo "D" shows the start of flat-topping on the peaks, and the envelope sides are no longer perfectly straight. The amplifier is no longer linear and is being overdriven or underloaded; readjust the ALC or the input/output tuning of the Final, respectively. Crossover distortion appears in Photo "E," evidenced by rounding of the crossover points and the bright horizontal lines between the envelopes. The cause is insufficient bias, which should be readjusted to the manufacturer's specs. Most transistor CB Driver and Final stages idle at about 30 ma and 50 ma respectively; sometimes the adjustment's in terms of base voltages, about 0.60-0.75 VDC.

Photo "F" clearly shows undermodulation due to insufficient audio input. The level of the tone generator should be increased, or the "SSB MIC GAIN" trimmer in the radio (if present) should be adjusted. This photo could also represent a single tone modulating a partially suppressed carrier. It illustrates how a single tone might be used for SSB testing, assuming the audio and unbalanced carrier levels could be made equal.

At the end of this chapter we show a complete multimode transceiver alignment. Refer back to these 'scope photos to make sure your SSB test procedures and adjustments are done correctly.

FIGURE 6-51
DISPLAY OF VARIOUS SSB OPERATING CONDITIONS
(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)



An SSB receiver has some minor differences from AM, as shown in Figure 6-52. On AM a carrier and one or two sidebands couple from the IF amp to a diode envelope detector, which rectifies the signal to give an output corresponding to the modulation envelope. For SSB the incoming IF signal contains one sideband and nothing else. To recover audio, the IF must be mixed with the reinserted Carrier Oscillator signal which was balanced out during transmission. When these two RF signals mix, they produce a difference frequency which corresponds to the original transmitted audio. This signal is then fed to the audio amplifiers in the usual way.

To produce a difference frequency in the audio range, the Carrier Oscillator must be tuned to one side of the IF passband rather than to the exact center. This is another reason for the use of USB/LSB offsets. For example to detect a 1.5 KHz USB audio tone, the receiver might mix a 7.800 MHz IF with a USB Carrier Oscillator of 7.7985 MHz, producing the audio difference signal of 7.800 MHz - 7.7985 MHz = 1.5 KHz. AM can also be received on SSB by tuning to the exact center of the carrier or "zero-beat;" only one sideband will actually be detected.

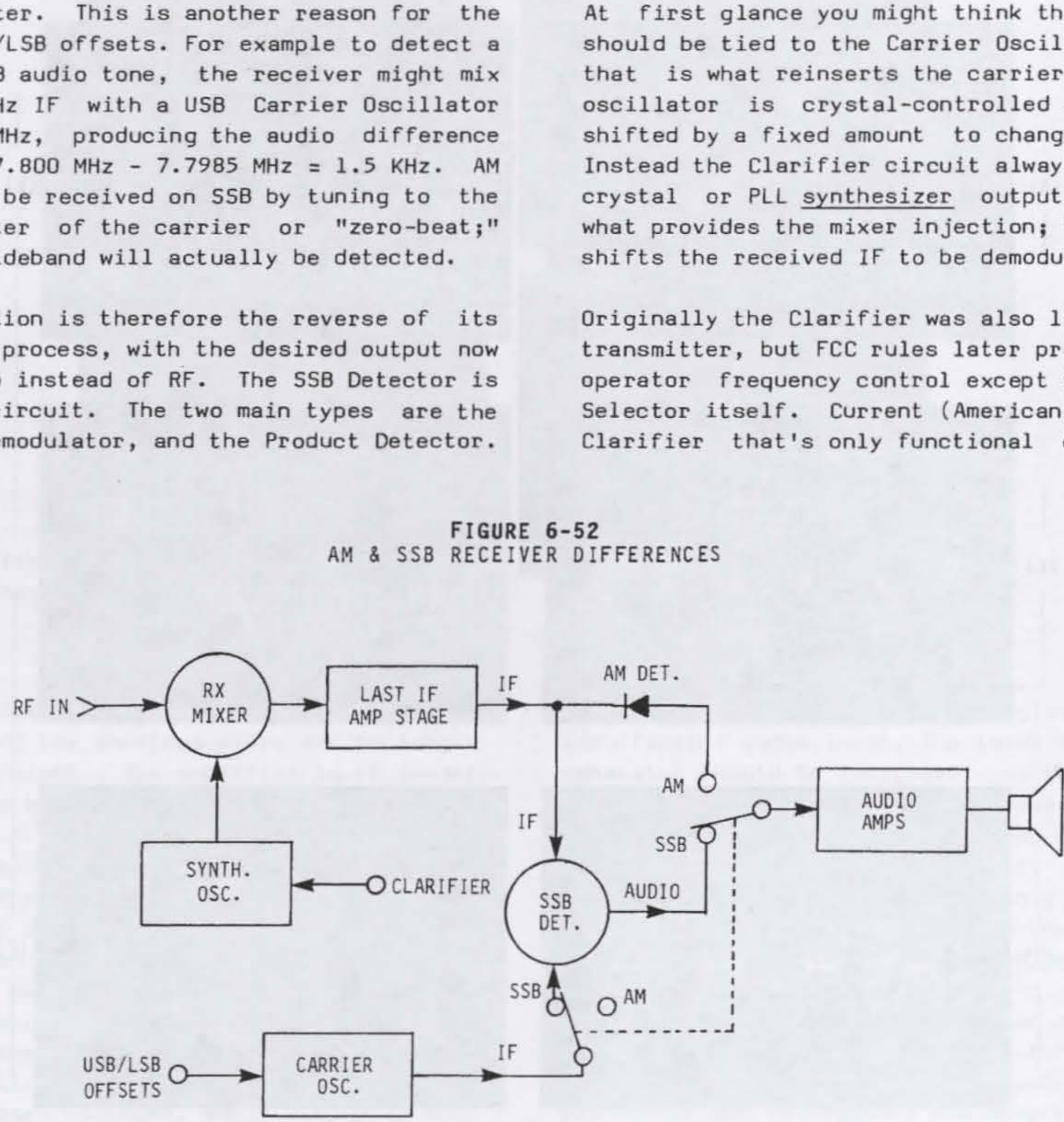
SSB reception is therefore the reverse of its modulation process, with the desired output now being audio instead of RF. The SSB Detector is a mixer circuit. The two main types are the Balanced Demodulator, and the Product Detector. (The Product Detector is also sometimes called a "synchronous" or "heterodyne" detector.) They're found about equally if you include all the older 23-channel CBs; modern radios favor just the Product Detector circuit.

Because the received frequency must be exactly the same as that transmitted for a voice to sound natural, and because no two SSB radios picked at random are likely to have exactly the same oscillator frequencies (within the required few Hz), a special circuit is included to shift the IF slightly so the recovered audio precisely matches what was transmitted. This circuit is called the "Clarifier," "Fine-Tune," "Slider," or "Voice Lock," and is always made a front-panel operator adjustment.

At first glance you might think the Clarifier should be tied to the Carrier Oscillator, since that is what reinserts the carrier; but this oscillator is crystal-controlled and is only shifted by a fixed amount to change sidebands. Instead the Clarifier circuit always shifts the crystal or PLL synthesizer output, which is what provides the mixer injection; this in turn shifts the received IF to be demodulated.

Originally the Clarifier was also locked to the transmitter, but FCC rules later prohibited any operator frequency control except the Channel Selector itself. Current (American) CBs have a Clarifier that's only functional on Receive.

FIGURE 6-52
AM & SSB RECEIVER DIFFERENCES



You'll find the Clarifier circuit to be a major CB repair headache, as countless amateurs keep trying to modify it back to the old way!

Balanced Demodulators

This type of SSB detector circuit is basically a double-balanced diode mixer having two slightly different IF inputs. It has the advantages of wide dynamic range, low noise, and good separation between inputs. Because it's balanced, the carrier and a lot of the harmonic products resulting from the strong L.O. injection are highly suppressed. Diode mixers do have loss though, about 8 dB for the ring, so you'll find radios using this circuit also tend to have more audio amplifier stages. These are generally the older, pre-IC models using three or four discrete audio amps and a push-pull audio power amp.

Figure 6-53 is typical. This works just like the transmitter BM, where the bridge is being unbalanced at the modulation rate. An input

FIGURE 6-53
BALANCED DEMODULATOR SSB DETECTOR
(Pearce-Simpson Bengal SSB)

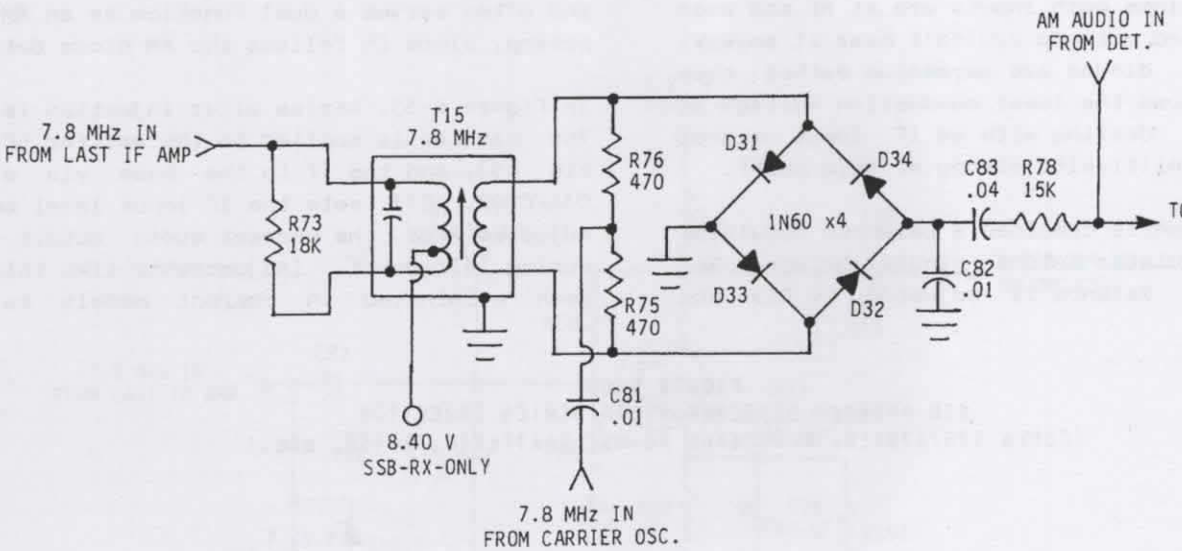
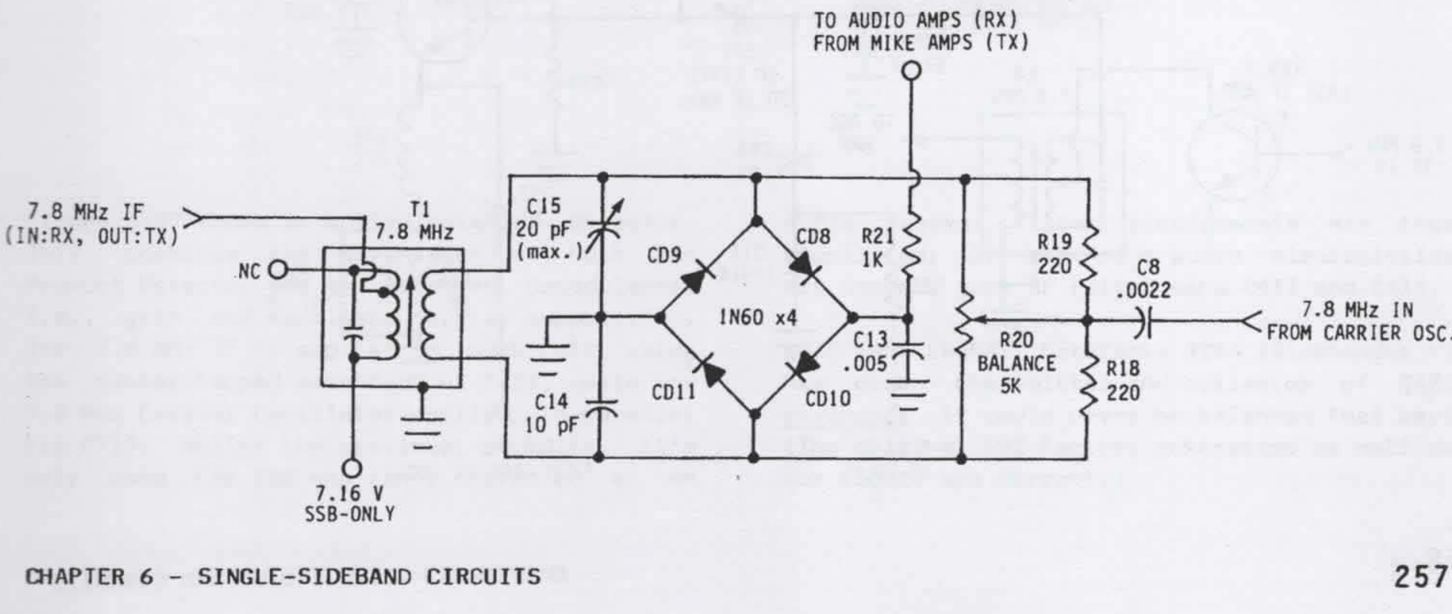


FIGURE 6-54
COMBINATION BALANCED MODULATOR/DETECTOR
(Browning LTD, Cobra 132/135, 132A, Tram D60)



transformer (T15) is used to make the IF operate in push-pull; the Carrier Oscillator is applied in parallel via C81 and is removed by the push-pull configuration. R73 lowers the Q of T15 to help maintain stability. The Carrier Oscillator has the strongest input signal, so it controls diode conduction. Matched resistors R75 and R76 balance the carrier input. As the modulated IF is applied, the bridge becomes unbalanced at a rate that corresponds to the modulated intelligence. Audio is coupled out through C83. C82 shunts any residual RF so the output is pure audio. AM audio joins it at R78, since both modes share common audio power amps.

There are two notable differences from the transmitter version. First, no BALANCE control is needed, since both inputs are at RF and even if some leaked out you couldn't hear it anyway. Second, the diodes are germanium rather than silicon because the lower conduction voltage is needed when dealing with an IF input signal that's only millivolts strong at this point.

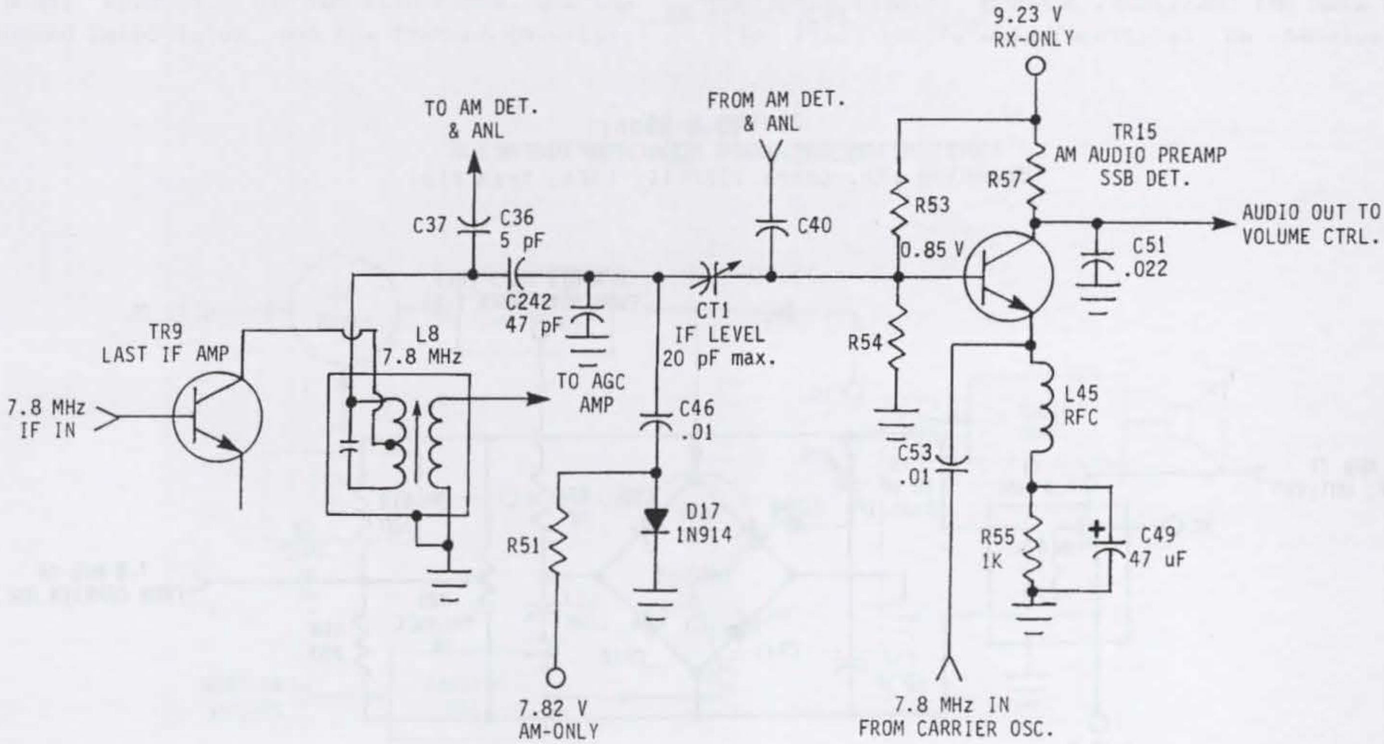
Some older models combined a Balanced Modulator and a Demodulator into a single bridge. See Figure 6-54. Balance is adjusted by C15 and R20. Both the mike audio input and the receiver audio output are coupled via R21, which when combined with C13 forms an RF filter to insure there's only audio at this point. The diodes are germanium again for maximum sensitivity.

Product Detectors

The Product Detector is the modern SSB method, since it offers some voltage gain which can be followed by simpler audio chains using audio power ICs. Because of its high gain less L.O. injection is needed, which reduces IMD in the audio output. In this circuit the Carrier Oscillator is added to the incoming IF, and the product of mixing them together is the audio difference. The stage uses an NPN transistor and often serves a dual function as an AM audio preamp, since it follows the AM diode detector.

In Figure 6-55, series mixer injection is used. The carrier is applied to the emitter of TR15 via C53, and the IF to the base via divider C36/C242. CT1 sets the IF input level and is adjusted for the correct audio output level during alignment. (Adjustments like this have been eliminated in current models to save

FIGURE 6-55
SSB PRODUCT DETECTOR USING SERIES INJECTION
(Cobra 138/139XLR, President Adams, Realistic TRC458, etc.)



costs.) TR15 is lightly biased (0.85 VDC) to perform as a mixer on SSB. L45 keeps the carrier injection point well above RF ground for mixing purposes, while R55/C49 bias TR15 for audio amplification on AM. C51 removes RF from the output. On AM, R51 turns on D17 and shunts the SSB IF path to ground through C46.

Figure 6-56 uses shunt mixer injection. Both inputs are applied to the base of TR13, because the emitter is being used for the squelch circuit; when enough positive squelch control voltage develops at the emitter it turns off TR13. Otherwise its operation is the same as in Figure 6-55. C24/R30 bias TR13 for AM audio amplification, and C25 removes residual RF. Note how D10 was added in series with AM shunt switch D11 for better power supply isolation.

FIGURE 6-56
SSB PRODUCT DETECTOR USING SHUNT INJECTION
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)

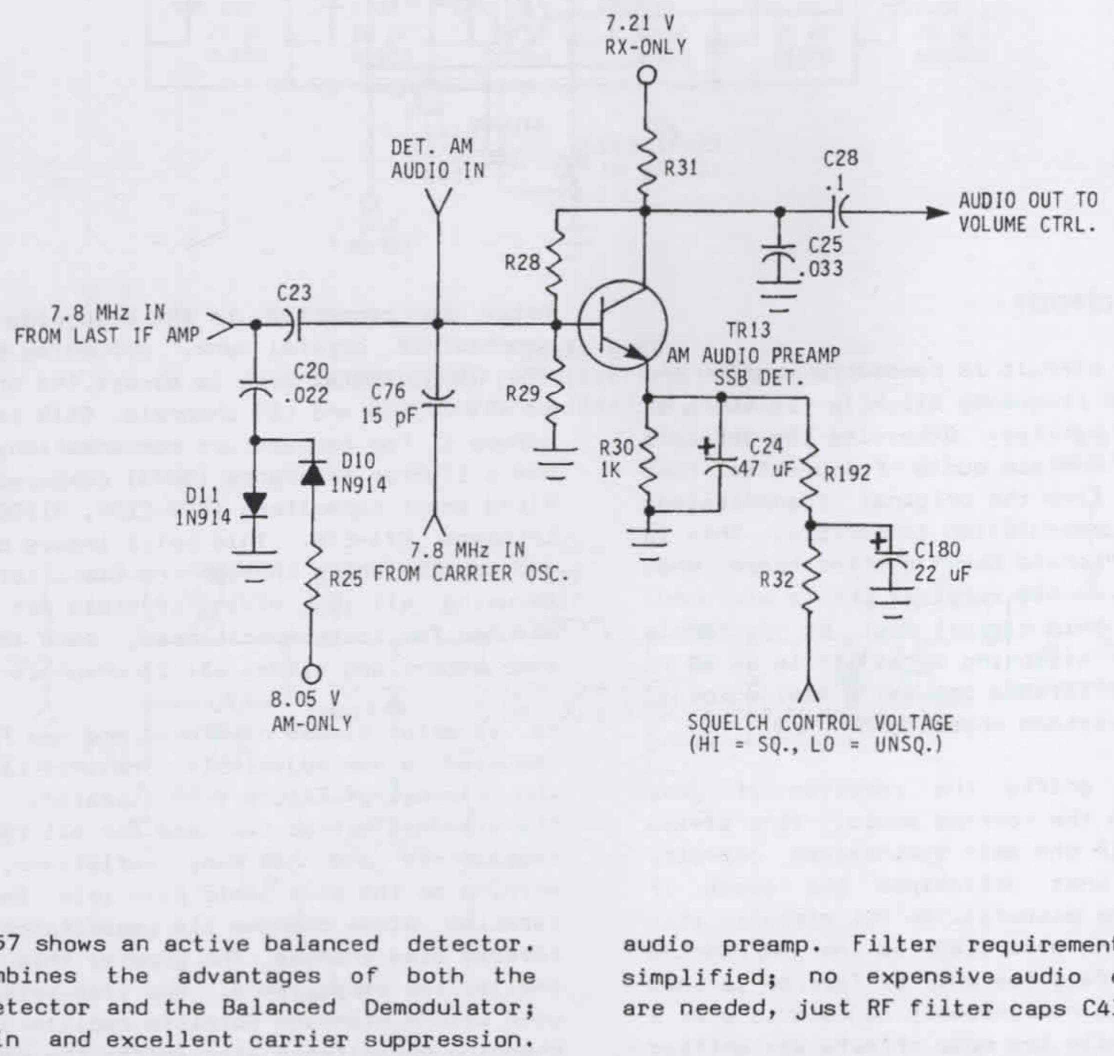
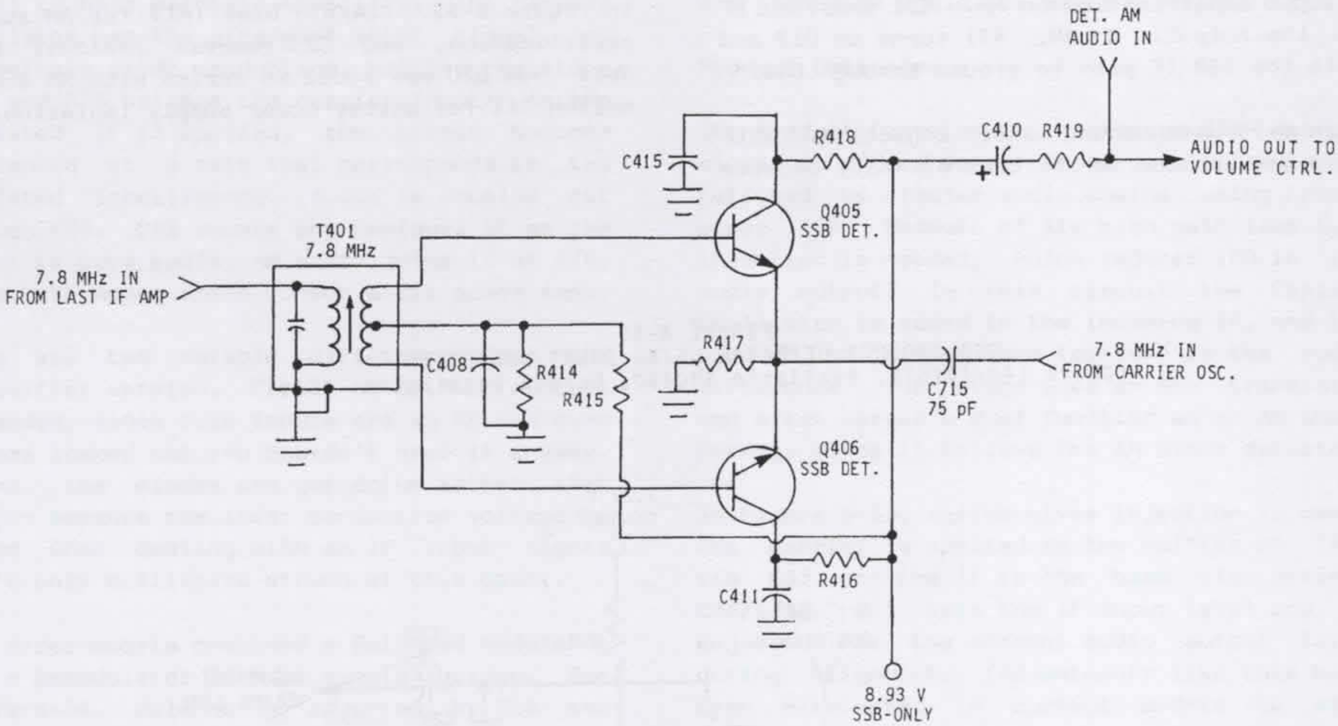


Figure 6-57 shows an active balanced detector. This combines the advantages of both the Product Detector and the Balanced Demodulator; i.e., gain and excellent carrier suppression. The 7.8 MHz IF is applied in push-pull using the center-tapped secondary of T401, with the 7.8 MHz Carrier Oscillator applied in parallel via C715. Unlike the previous circuits, it's only used for SSB and isn't shared as an AM audio preamp. Filter requirements are thus simplified; no expensive audio electrolytics are needed, just RF filter caps C411 and C415.

NOTE SAMS ERROR: Fotofacts #264 (Sidebander V) has drawn the emitter and collector of Q405 reversed; it could never be balanced that way! (The original SBE factory schematics as well as our figure are correct.)

FIGURE 6-57
BALANCED SSB PRODUCT DETECTOR
(SBE Sidebander IV, V, Console V)



THE CLARIFIER CIRCUIT

The Clarifier circuit is needed to shift the L.O. injection frequency slightly relative to the reinserted carrier. Otherwise the detector output would contain audio frequencies that were different from the original transmission, making proper demodulation impossible. This is the familiar "Donald Duck" chatter heard when you listen to an SSB receiver that's mistuned. By definition this circuit must be extremely stable, since mistuning by as little as 40 Hz can make the difference between a real voice or your favorite cartoon character!

The Clarifier shifts the receiver IF just enough to match the correct audio. It's always associated with the main synthesizer circuit, since that's what determines the exact IF developed at the mixer(s). In PLL circuits it's connected to the same stage as the AM/USB/LSB offsets and in fact the only difference is that the Clarifier is continuously adjustable over a small range, while the mode offsets are shifted by fixed amounts.

Figure 6-58 is an example from the 23-channel era using an air-variable capacitor. The stator of CL is bolted to the front panel, while its rotor is connected to the cold side of one synthesizer crystal bank, grounding them for RF. This crystal bank is always the one common to all 23 USB and LSB channels. C113 is shunted across CL for temperature compensation; note it has a tighter tolerance (N470) compared to the fixed shunt capacitors (C99-C104, N1500) across trimmers CT1-CT6. This helps insure stability and smooth tuning through the Clarifier range. Assuming all six mixing crystals are closely matched for load capacitances, each shifts the same amount and slides all 23 channels equally.

As varactor diodes developed and new FCC rules required a non-adjustable Transmit Clarifier, the circuit of Figure 6-59 appeared. This is the standard method now used for all CB crystal oscillators and has many variations, always working on the same basic principle. Recall the varactor diode changes its capacitance as the reverse bias changes. The greater this bias the smaller the capacitance, and vice-versa. When used with a standard Colpitts oscillator, this changing capacitance also shifts the oscillator frequency slightly.

Crystal X3 can be shifted by both varactor D35 and CT1. (CT1 is the fixed USB offset.) D51 and D52 are steering diodes used to isolate T/R

FIGURE 6-58
EARLY 23-CH. CLARIFIER USING AIR-VARIABLE CAPACITOR
(Courier Spartan SSB)

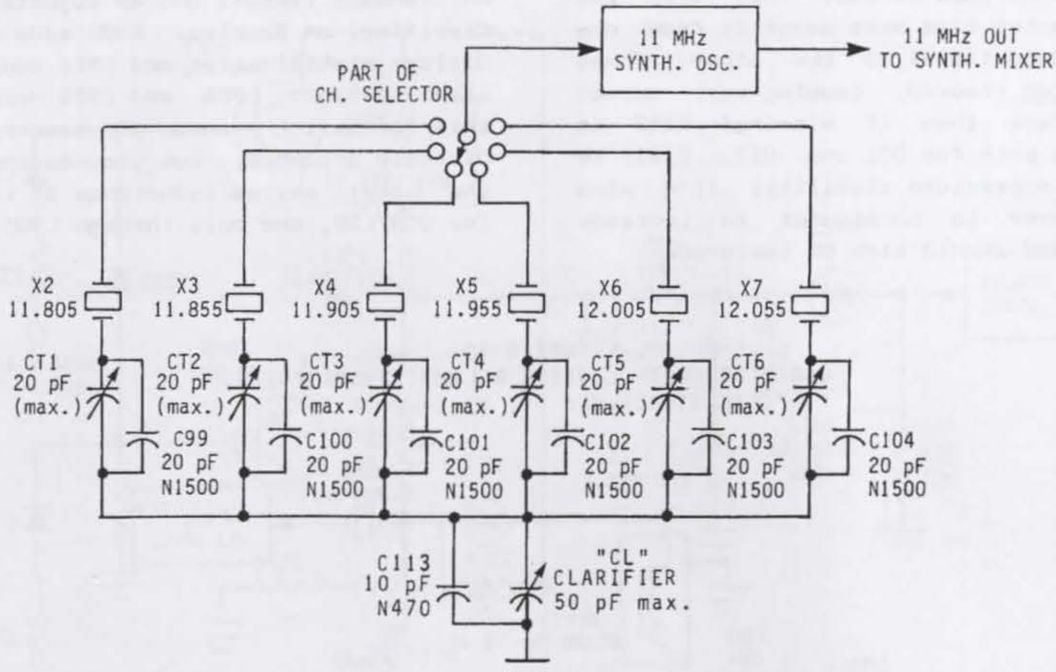
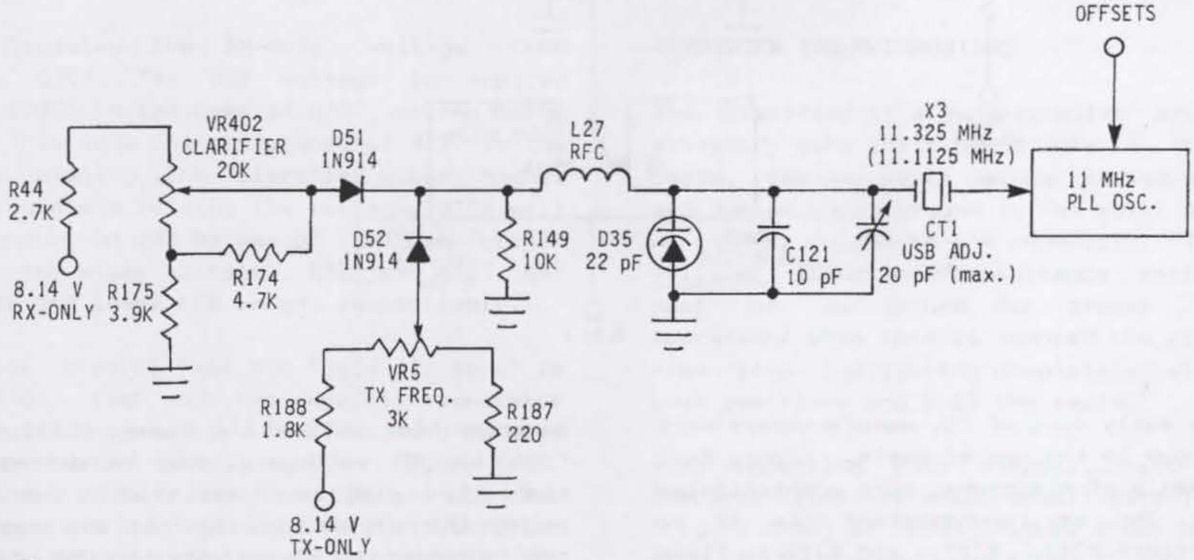


FIGURE 6-59
MODERN CLARIFIER CIRCUIT USING VARACTOR
(Uniden Grant/Madison, etc.)

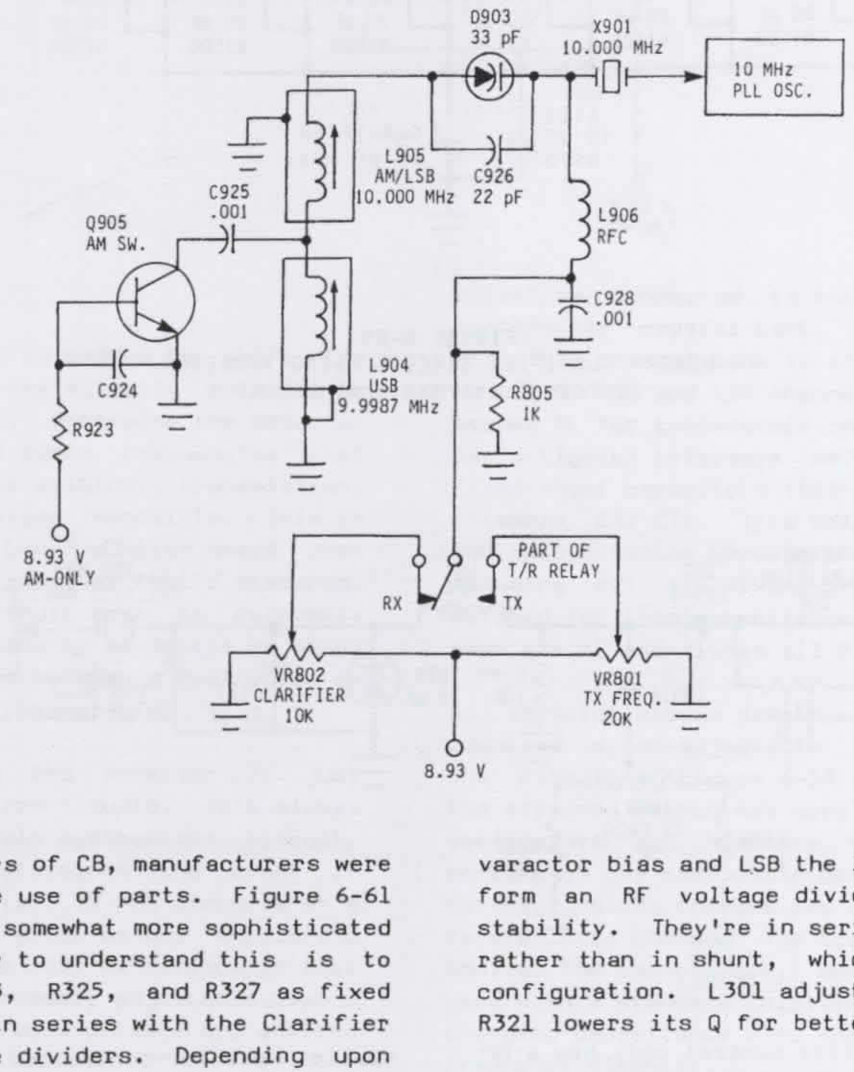


functions; the Clarifier control only has a DC voltage applied in the Receive mode via R44. On Transmit the fixed internal trimmer VR5 sets the frequency, being supplied with Transmit-only voltage via R188. Thus on Receive, D51 applies operator-controlled varactor bias while simultaneously cutting off D52.

On Transmit, D52 applies the preset bias and cuts off D51 and the front panel control. L27 is an RF choke which isolates the DC supply and keeps RF on the crystal side of the circuit. Parts R44/R174/R175 and R187/R188 form voltage dividers for each mode which help to keep the Clarifier action more linear; they taper the changing varactor bias more smoothly from one end of the knob travel to the other. These parts are <u>often</u> removed, causing very uneven tuning. Replace them if missing! R149 is the grounding path for D51 and D52. C121 is crucial for temperature stability; it's also commonly removed in an attmept to increase slide range, and should also be restored.

Figure 6-60 shows a circuit using relay rather than electronic Clarifier control switching. Instead of diodes a set of relay poles controls the varactor voltage. A preset bias is applied on Transmit (VR801) and an adjustable bias (the Clarifier) on Receive. R805 adds some voltage-divider stabilization and C926 adds temperature stabilization. L906 and C928 decouple RF. In this circuit the anode of varactor D903 isn't directly grounded, but grounds instead through the total series inductance of L905 and L904 for USB/LSB, and only through L905/C925 for AM.

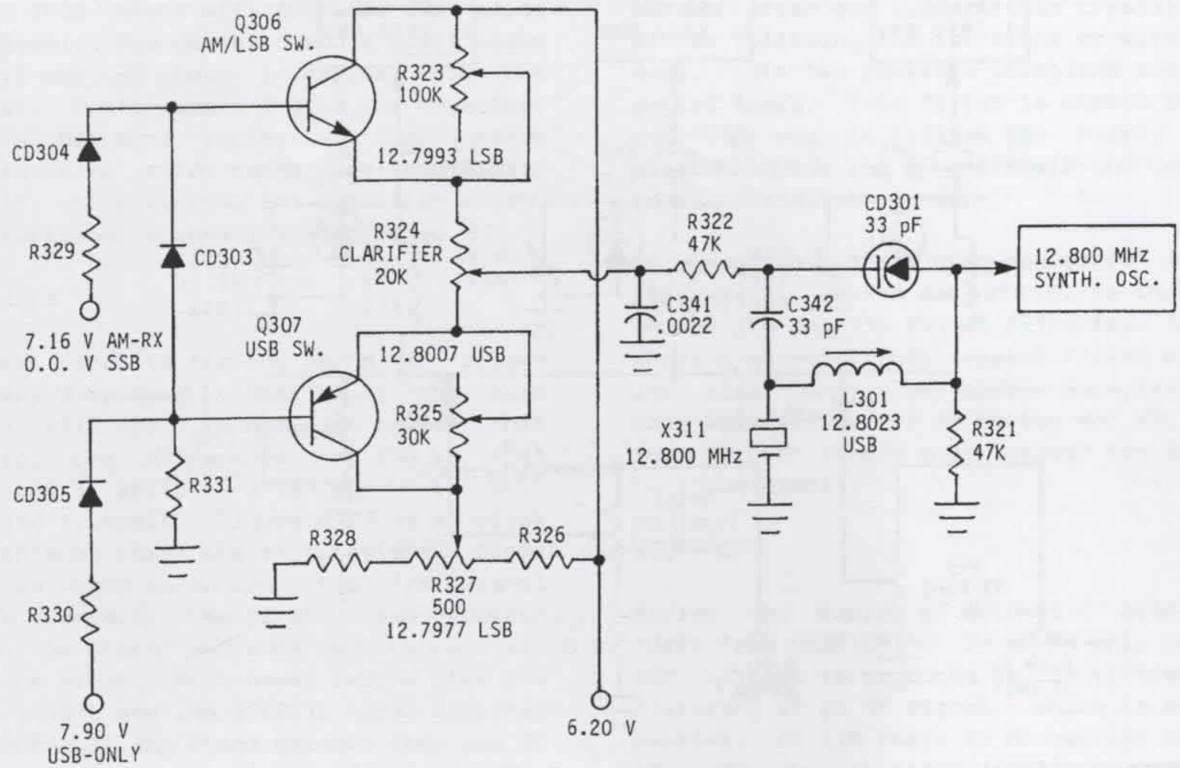
FIGURE 6-60
CLARIFIER CONTROL USING RELAY T/R SWITCHING
(SBE Sidebander IV, V, Console V)



During the early days of CB, manufacturers were more generous in the use of parts. Figure 6-61 is an example of a somewhat more sophisticated Clarifier. The way to understand this is to first consider R323, R325, and R327 as fixed resistors. All are in series with the Clarifier pot to form voltage dividers. Depending upon the mode, this means the wiper of the Clarifier will be more or less above ground potential. The higher the wiper above ground, the higher the varactor bias and therefore the higher the crystal frequency. Thus USB needs the most varactor bias and LSB the least. CD301 and C342 form an RF voltage divider to increase the stability. They're in series with the crystal rather than in shunt, which is the more common configuration. L301 adjusts the USB offset and R321 lowers its Q for better stability.

On AM and LSB, Q307 is conducting and shorting out R325. This places the Clarifier wiper closer to ground, lowering its voltage and the crystal frequency. On AM Q306 turns on and shorts out R323, raising the wiper voltage.

FIGURE 6-61
TRANSISTOR-SWITCH CLARIFIER MODE CONTROL
(Browning LTD, Cobra 132/135, 132A, Tram D60)



CD303 isolates the AM-only voltage from reaching Q307. For USB voltage is applied through CD305 to the base of Q307, which turns it off. This adds the resistance of R325 to the circuit, placing the Clarifier wiper higher above ground and raising its voltage. Q306 will also conduct on USB by way of CD303, further raising the wiper voltage. R323 and R327 set the upper and lower LSB range, respectively.

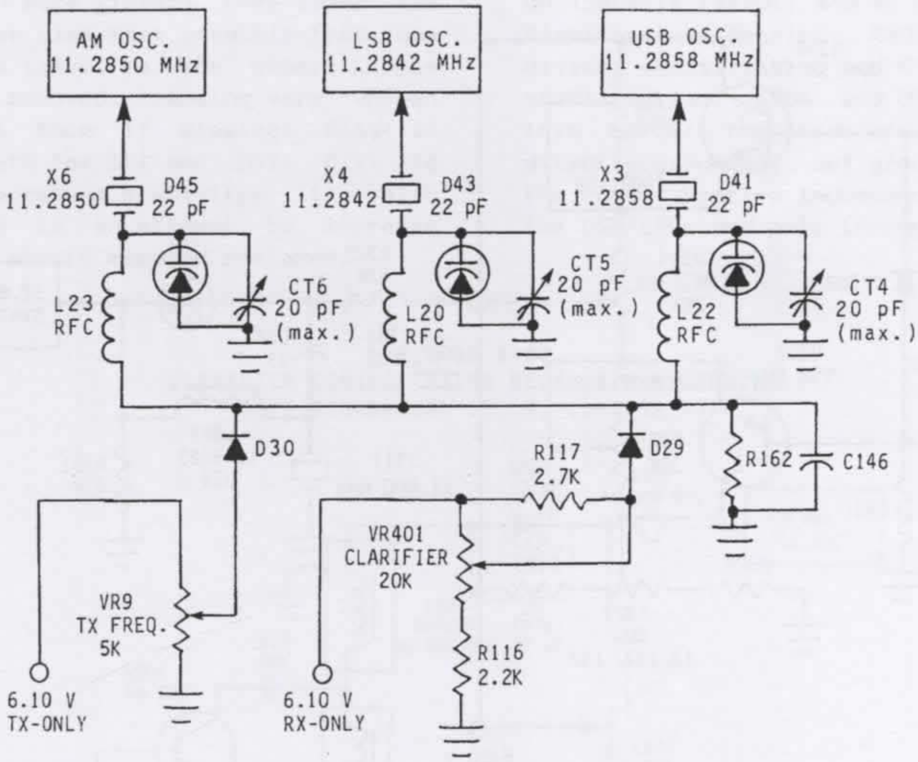
One final circuit from the "good old days" is Figure 6-62. Each mode has separate transistor oscillators, crystals, varactors, and related parts; otherwise it's just like Figure 6-59. The cathodes of D45, D43, and D41 are all tied to a common bus that connects to the Clarifier and Transmit frequency trimmer adjustment. The Clarifier is powered by a 6.1 V Receive-only source, while VR9 uses a 6.1 V Transmit-only supply. D30 and D29 isolate each source from the other. R116 and R117 are part of the Clarifier's voltage divider to insure smooth knob action; replace them when missing!

CLARIFIER TROUBLESHOOTING

The Clarifier is a major problem area, since everybody gets their hands into it. They remove parts, change parts values indiscriminately, and jumper wires around to the point where it's no longer close to the schematic. There's a <u>critical</u> inductance/capacitance ratio which must be maintained for proper Clarifier operation! When this is ignored the circuit may even stop oscillating completely at certain knob positions and kill the radio.

When repairing this circuit, you'll often discover that the shunt stabilizers like C121 (Figure 6-59) or C926 (Figure 6-60) have been removed to increase the range of the Clarifier circuit. It's true that without having to divide the capacitance between the varactor and its shunt, the varactor has a greater effect. But it does this at the cost of a very touchy, unstable, and non-linear Clarifier control that tends to drift.

FIGURE 6-62
CLARIFIER USING SEPARATE OSCILLATORS FOR EACH MODE
(Cobra 138/139XLR, President Adams, Realistic TRC458, etc.)



Another common modification is the shorting of any or all voltage divider resistors around the Clarifier pot. This does have the effect of increasing the varactor bias, but at the cost of lost knob symmetry; the shift becomes logarithmic at one end of the knob range and crams a huge amount of up or down slide into a tiny amount of knob travel. And it leaves no significant series resistance except the Clarifier pot itself to limit power supply current, sometimes causing sudden regulator failure. (The MB3756 is often prone to this.)

When the complaint is "No Clarifier Control," first check for a changing DC bias voltage at the varactor's anode when the knob is turned through its range. If it's missing, or there's a fixed voltage that doesn't change at all, trace the DC path back to its source to locate the problem. You'll often find the cause to be an improper modification by some amateur. Most of the customer complaints about poor Clarifier operation will be traced to previous meddling rather than an outright component failure. When gross circuit and component changes are found, restore them to normal!

CLARIFIER SERVICE NOTES:

1. Always replace ceramic disc capacitors in critical circuits with the proper type. For temperature compensation or offsets, use "NPO" types rather than the general purpose "Z5U" type. The NPO version has a superior dielectric which is much more stable with changing temperatures. When the capacitor has an "N" number, like "N220," this refers to the maximum capacitance change, specified in parts-per-million (ppm) per °C. and is negative (N); the higher the temperature, the lower the capacitance. In this example, the downward drift is only 220 ppm per °C. rise in temperature.

2. Crystal load capacitance (C_L) has a direct effect on the amount of frequency shift. The smaller the C_L, the greater the effect of any external capacitors and inductors on frequency shift. For American CBs, the crystal associated with the Clarifier will generally have a 20 pF C_L rather than the standard 32 pF synthesizer crystal. Replace faulty crystals with those having similar characteristics. (See #3 for exceptions.)

3. Since most people will continue to modify Clarifiers, the smart way to do it and avoid the headaches is to copy the export radio method. Replace the crystal in the Clarifier circuit with one having a C_L of only 10 pF and the highest accuracy available, usually .001%. This alone will increase the slide considerably. You can also add a small value (2.2-4.7 µH) RF choke in series with the varactor. Don't exceed 8 V on the varactor. While a bit more expensive, these steps will maximize slide range and oscillator stability while keeping the Clarifier smooth and symmetrical across its knob range.

IF AMPLIFIERS

Theory and circuits for the AM/FM IF stages were already discussed in CHAPTER 4; the same principles will apply to SSB, so review that section too. One difference for SSB is that part of the IF strip is often common to both Receive and Transmit. Figure 6-63 is a block diagram showing these shared functions. Diode steering is used to control the T/R signal paths. On Transmit, the first IF amp (dotted lines) may be shared and adds some extra gain ahead of the mixer. Most newer radios like the Cobra 140/142GTL and 148/2000GTL types dispense with the extra IF amp stage because they use IC mixers that already have plenty of gain.

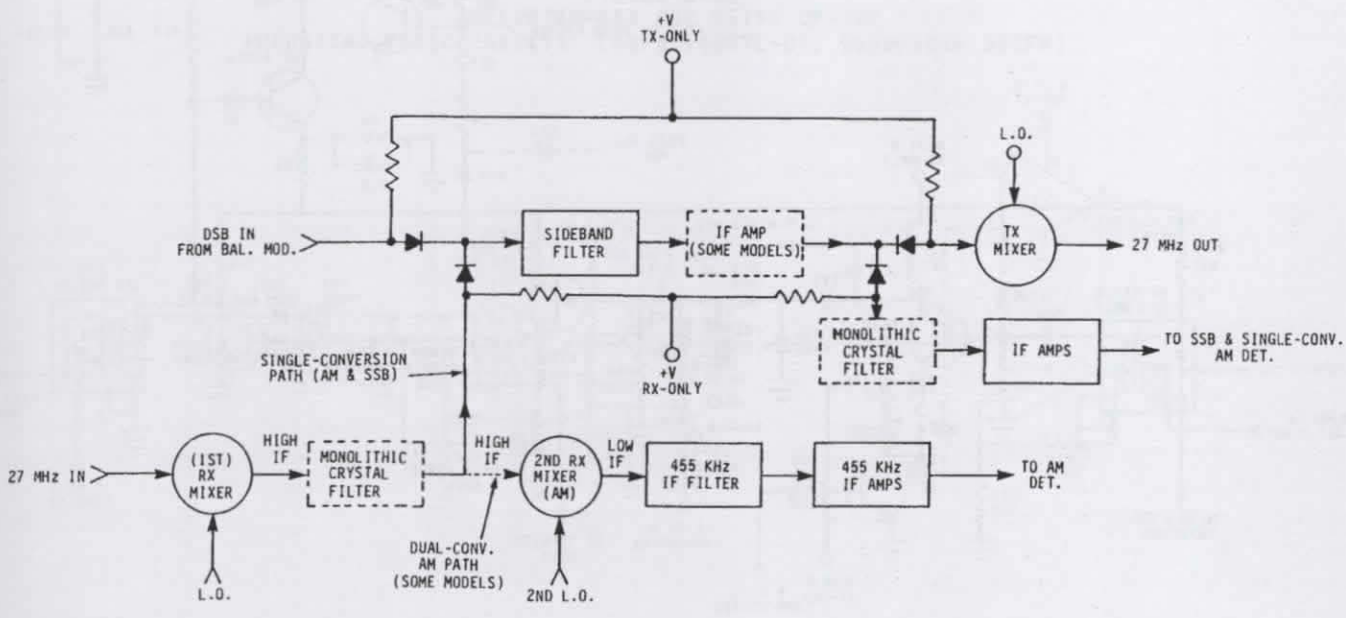
On Receive, the main sideband filter is placed in the SSB signal path to provide selectivity as well as removing the unwanted sideband. In many older models it's often the only way to establish selectivity, since nearly all SSB reception is single-conversion. The newer models often add a monolithic crystal filter, either following the 1st mixer or within the IF amps. Its two possible locations are shown in dotted lines. This filter is common to both AM and SSB when it follows the mixer, or when placed inside the IF amp chain and the AM mode is also single-conversion.

As shown, when AM is dual-conversion it takes a separate IF path. A second L.O. is included and AM has its own 455 KHz IF filtering. In fact if there's no monolithic crystal filter after the 1st mixer (many older models especially), the only selectivity for AM is the 455 KHz filter. The AM path rarely goes through the SSB filter in these models.

SSB AGC

Review the basics of Automatic Gain Control (AGC) from CHAPTER 4. In an AM-only radio, the AGC voltage is produced by rectification and filtering of an RF signal, which is mainly the carrier. On SSB there is no carrier to develop the AGC voltage. And you couldn't use the

FIGURE 6-63
SSB T/R SIGNAL PATHS
(SINGLE- & DUAL-CONVERSION)



reinserted carrier from the Carrier Oscillator, because it's constant and doesn't vary in strength with the received SSB signal.

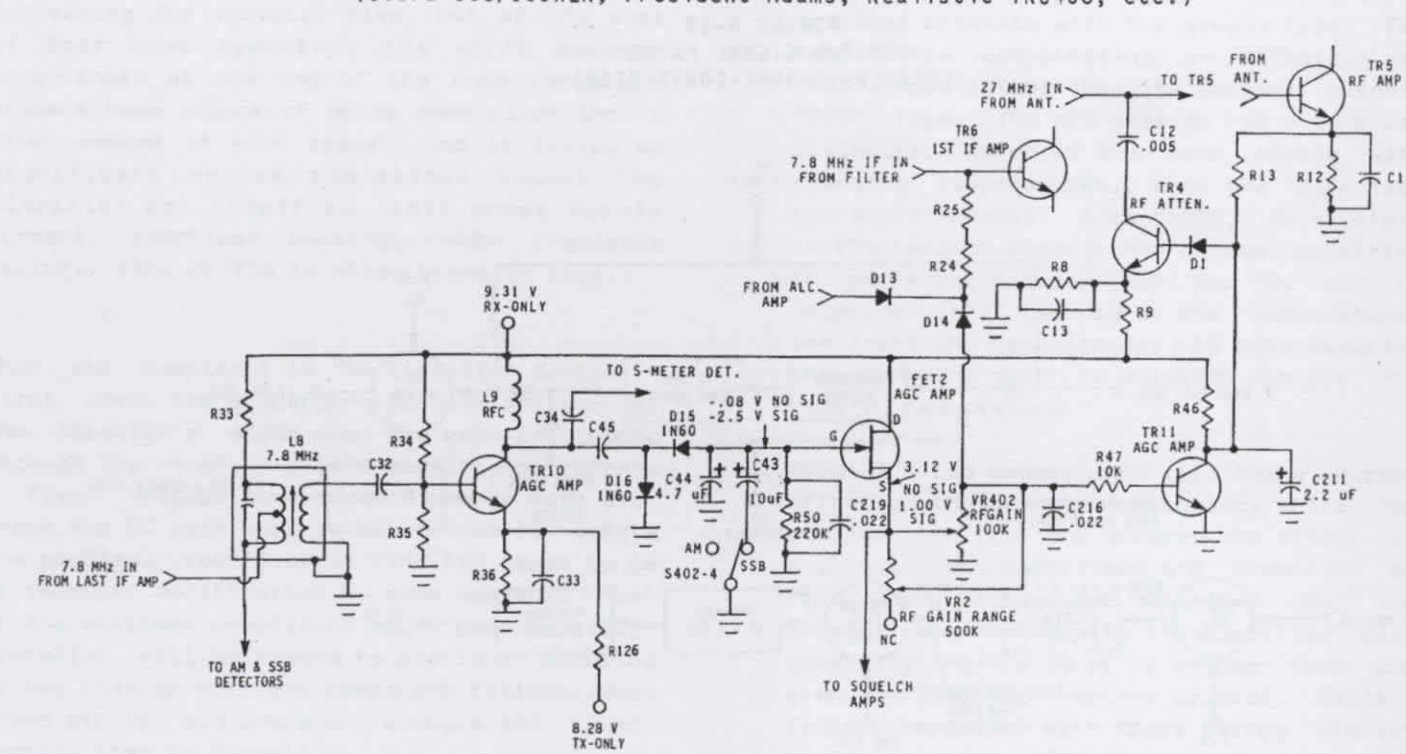
Instead, "RF-derived" AGC is used. The sample comes from the last IF stage before detection, where the incoming signal strength does change. Furthermore since there's no SSB audio until a signal is received, and since signals of very different strengths may be received at the same time, good AGC is especially important. More complex circuits with DC amplifiers for greater sensitivity and different AM/SSB time constants are used. This superior AGC control voltage is also used for the S-Meter and squelch circuits, where it improves AM performance too.

Virtually all SSB CB radios use either an FET or an op-amp to generate the amplified AGC control voltage. That's because both devices have extremely high input impedances to prevent loading of the sampled IF, and because they handle strong signals with less distortion than bipolar transistors. The FET AGC circuits are usually fed to a second, bipolar DC amplifier.

Analysis of Typical AGC Circuit

Every SSB model using discrete AGC transistors works basically the same way. Figure 6-64 shows one popular AGC system and the stages it controls. This circuit is sophisticated and typical of the better SSB equipment, but not very difficult to understand when approached logically. It's powered by a single AM/SSB Receive-only source. TR10 is actually an IF amplifier. In SAMS it's called an "AGC/S-Meter" amplifier, since it only controls those two functions. R126 disables it on Transmit so that IF amp TR6 (which is also used on SSB-Transmit) will be controlled only by the ALC circuit. The IF signal is amplified by TR10 and applied to D15 and D16. D16 clamps on positive signal peaks and D15 conducts on negative peaks, resulting in a gate voltage on FET2 that's negative-going with increasing signal strength. C219 has a low impedance at RF and charges very quickly to establish the fast attack time. C44 has a low impedance to audio, and discharges slowly to establish the basic AM time delay. Both charge and discharge through R50. C43 is switched in only for SSB, adding another 10 µF

FIGURE 6-64
AMPLIFIED SSB AGC USING DISCRETE TRANSISTORS
(Cobra 138/139XLR, President Adams, Realistic TRC458, etc.)



to lengthen the decay time more. (SSB requires a slower AGC decay than AM so it can follow the normal syllabic changes in speech before acting to control gain.) The attack time must be fast enough to prevent strong signals from blasting through too loudly at first. In this particular circuit you'd calculate about 5 mS attack time and 3.3 seconds delay, typical SSB values.

Current flows through FET2 from the drain to the source. (Remember, this is conventional current, not the actual electron movement.) Voltage divider VR2 (internal trimmer) and VR402 (panel control) set the desired gain. As the incoming signal gets stronger more negative gate voltage develops, moving the FET towards pinchoff. This decreases its current flow and therefore its source voltage, which controls several other circuits. It drives the squelch directly, which has its own DC amplifiers.

FET2 also controls TR6, the 1st IF amp. FET2's source voltage provides the only bias for TR6 on Receive, while the ALC provides its only bias on Transmit. As the signal strength increases, the base bias on TR6 decreases, reducing its gain. Another controlled circuit is front-end gain via TR11, TR4, and TR5. TR11 is an additional DC amp stage used to improve the dynamic range of the RF amp.

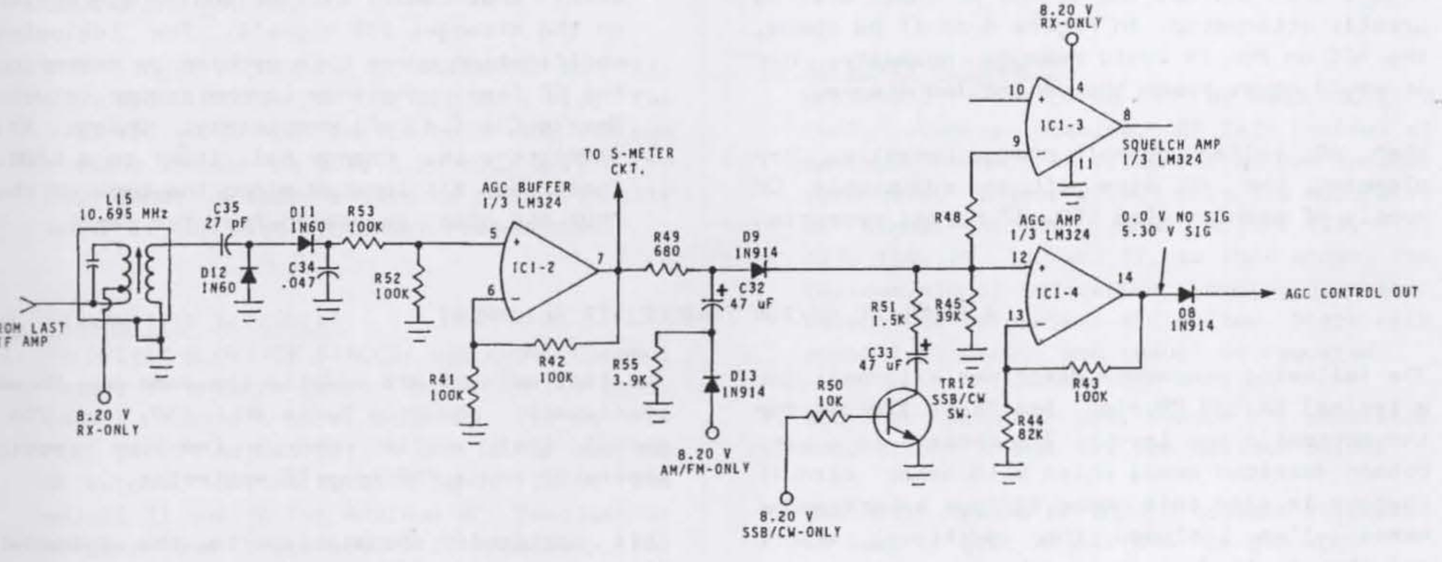
As the signal strength increases, FET2's source voltage and therefore the base voltage of TR11 decreases. TR11 conducts less so its collector pulls up higher via R46. TR11 controls TR4 and therefore makes it conduct harder. Since TR4 is shunted directly across the antenna input, it grounds more 27 MHz RF via C12/R8/C13. At the same time the emitter voltage of RF amp TR5 increases, which lowers its gain. C216 and C211 filter the remaining RF and audio respectively. D13 and D14 isolate the AGC and ALC. D1 clamps on extremely strong signals to protect TR4.

AGC Using Op-Amps

Another amplified AGC method uses op-amps. The newer Uniden radios in particular favor this method. Figure 6-65 shows this circuit, redrawn from the Japanese schematic for simplicity. IC1 is a quad op-amp. Two sections are used for AGC and one for squelch; the fourth amp isn't used. The 10.695 MHz IF signal is sampled from the last IF stage at L15's secondary and coupled via C35 to a voltage doubler detector, D11/D12. C35 is a small value to avoid loading down L15. C34 provides RF decoupling. The positive AGC voltage is applied to the non-inverting input of IC1 Pin 5. This IC section actually has no gain because R41, R42, R52, and R53 are all equal; it's used as a buffer/voltage follower to help protect against the loading effects of the diode detectors across the IF stage at L15.

The output from Pin 7 is coupled through R49/D9 to Pin 12, the input to the high-gain voltage amplifier section. Separate AM/FM and SSB/CW delay values are used, and are controlled by appropriate voltage sources. For AM/FM, D13/R55 will shunt C32 across the AGC line. For SSB/CW,

FIGURE 6-65
AMPLIFIED SSB AGC USING OP-AMP
(Uniden PB010 chassis: Cobra 148GTL-DX, Superstar 360FM)



TR12 shunts C33 and R51; note the extra 1.5 KΩ lengthens the capacitor discharge time for the slower decay needed on SSB. D9 isolates the two switches. The S-Meter and squelch amp inputs (Pin 9) are also being driven from this line.

The amplified AGC at Pin 14 is coupled through isolation diode D8 to the controlled circuits, which are like the previous example. A very large AGC voltage range is possible with this circuit. In a test I measured 0.0 V at Pin 14, no signal input, up to 5.30 V with an extremely strong input signal. Note how the non-inverting inputs of both amps are used, since in this case the AGC voltage must change in direct proportion to signal strength. This is one of those circuits where AGC is positive-going and will increase with stronger signals.

AGC TROUBLESHOOTING

While SSB AGC circuits are more sophisticated, fault-finding is still very logical. Like AM radios, the problems fall into two general categories. When there's no AGC at all, signals come blasting through, usually distorted. The other problem is just the opposite: excessive gain reduction that produces a "No Receive" or a "Weak Receive" symptom.

Using your signal generator and DC voltmeter, measure the AGC bus with different signal input levels to see if the voltage is changing. In those circuits like Figure 6-64 the voltage is negative-going, while in those like Figure 6-65 it's positive-going. If the voltage is changing as it should, then troubleshoot the associated gain-reduction circuits. For example if TR4 in Figure 6-64 shorts, the 27 MHz RF input will be greatly attenuated. In Figure 6-65 if D8 opens, the AGC on Pin 14 would measure normally, but it would never reach the controlled stages.

When AGC voltage doesn't change normally, try clamping the AGC line with an adjustable DC supply of perhaps ±0-5 VDC. If normal reception is restored, you've isolated the problem to the AGC loop itself. The most likely suspects are the active devices. Trace the voltage from the sampling point through each stage until it's lost. Since the amplified AGC also drives the S-Meter and squelch, a faulty AGC stage could simultaneously affect these circuits.

SERVICE TIPS:

1. Figure 6-65 illustrated the PB010 chassis, but all the following Uniden SSB chassis use exactly the same AGC circuit.

   PB010: Cobra 148GTL-DX late, Superstar 360FM
   PB015: Midland 7001 (new American version)
   PB042: President Jackson
   PC833: Cobra 146GTL, Midland 6001 (late), 79-260, President AR-144 and AX-144, Sears 663.3810, Uniden PC244
   PC879: Cobra 148GTL-DX (early version)
   PC893: President McKinley (export model), Stalker 9-FDX
   PC965: Realistic TRC451, new Pearce-Simpson "Super Cheetah" (Australian)
   PC999: President Grant (export)
   Also Uniden copies and clones: Galaxy 2100, Super Galaxy, Excalibur Samurai and base, Superstar 3600, 3900, Ranger AR3300, etc.

2. The TA75902/TA6324/NJM2902 AGC/Squelch chip is a common failure. Exactly the same chip, different manufacturers. It can be directly replaced with an LM324. (Such as Radio Shack #276-1711.) I strongly suggest installing a 14-pin DIP socket if replacement is needed!

3. The Uniden Jackson (PB042) has an AGC design error that causes extreme audio distortion on the stronger SSB signals. The following modification cures this problem by restoring the RC time constants to the proper values: Remove C31 (.47 µF) completely. Change R43 (10K) to a 1K. Change R41 (150K) to a 270K. These are all located along the back of the 2902 AGC chip, as viewed from the front.

A COMPLETE AM/SSB TRANSCEIVER ALIGNMENT

The following procedure describes alignment for a typical AM/SSB CB rig. See Pages 270-271 for the schematic and layout. The chassis is a very common American model which with minor circuit changes is also sold under various export model names. I've included the additional export adjustments to demonstrate their similarities.

The test set-ups are exactly the same as those previously shown on Pages 80, 139, and 204, except that you'll need a two-tone audio generator and a PEP type RF wattmeter.

This particular chassis type is the Cybernet PTBM048A0X (also PTBM058C0X), found under many models like the G.E. 3-5825A, HyGain 2705 (V), J.C. Penney 981-6247, JIL Citizen SSB-M6/MPL-5, Lafayette Telsat SSB-120/140, Midland 78-976 or 79-892, or RCA 14T302. Export versions include the Colt 485DX, which is an 80-channel model. I chose the Colt 485DX schematic and procedure because it uses a separate oscillator PC board with two loop mixing crystals (40 channels per crystal) instead of the single-crystal American version. The alignment parts layout is for the American version, which is all I had available to print; the only real difference is that CT1 and CT2 shown on the main chassis would be on the separate oscillator board (TC1-4) instead.

A. SYNTHESIZER ALIGNMENT

1. REFERENCE OSC.: Set to Ch.40 USB LOW Band, Clarifier midrange. Frequency counter to TP2. (IC1 Pin 3.) Adjust CT3 for 10.240 MHz ±50 Hz.

2. 'Scope to TP3 (IC2 Pin 4.) Adjust T1 on the PTOS003A0X board for maximum RF voltage.

3. LOW BAND OSC.: Frequency counter to TP3 as above. Adjust trimmer TC2 on PTOS003A0X board for 20.105 MHz ±40 Hz. Switch to LSB; adjust TC1 for 20.1035 MHz ±40 Hz.

4. HIGH BAND OSC.: Switch to HIGH Band and USB. Adjust trimmer TC3 on PTOS003A0X board for 20.330 MHz ±40 Hz. Switch to LSB; adjust TC4 for 20.3285 MHz ±40 Hz.

5. CARRIER OSC.: Return to LOW Band, Ch.1 USB. Move frequency counter to TP5. (Junction of L15/C70/C71.) Adjust CT5 for 10.695 MHz ±50 Hz. Switch to LSB and adjust CT4 for 10.692 MHz ±50 Hz.

6. VCO: Input of Digital DC Voltmeter to TP1. (Junction R1/R2.) Adjust VCO core slug for 3.60 VDC ±0.10 VDC. Switch to Ch.40; voltage reading should be 1.40-2.30 VDC. Switch to HIGH Band; reading should be proportionally lower at the higher channel frequencies.

B. TRANSMITTER ALIGNMENT

1. PREDRIVER & DRIVER STAGES: USB mode. Connect 'scope to antenna jack. Return to LOW Band. Inject single tone of 2400 Hz, 2.5 mV into MIKE jack. Adjust T2, T5 and T6 for maximum RF output. Switch to HIGH Band, Ch.40 and adjust T1 and T4 for maximum RF. Readjust or stagger-tune transformers if necessary for an even power spread across all 80 channels.

2. FINAL BIAS: Remove audio input. Insert DC Ammeter between emitter of Q10 and ground. Adjust RV1 for 35 ma ±10 ma.

3. Connect 'scope to emitter of Q7. Reinject 2400 Hz, 10 mV audio tone into MIKE jack. Adjust T11 for maximum RF output.

4. Inject two-tone, 10 mV audio signal at MIKE jack. Adjust RV11 (SSB MIKE GAIN control) for 12 watts PEP. (Or for 68 V P-P on 'scope at the ANT. jack.)

5. Reconnect 'scope and wattmeter to ANT. jack. Disable ALC circuit by turning RV2 full counterclockwise. Adjust T6, L7, L11, and L13 for maximum RF output.

6. CARRIER BALANCE: Remove audio input tone. Adjust RV4 and RV5 for minimum RF indication at ANT. jack. Recheck carrier suppression on LSB, which should be the same.

7. ALC: Inject a two-tone, 25 mV audio signal. Adjust RV2 for 12 watts PEP. 'Scope pattern should look like earlier photos; i.e., no distortion with correct two-tone test input.

8. AM CARRIER POWER: Remove audio tone input. Switch to AM, Ch.40, LOW Band. Adjust VR4 for 3.7 watts carrier output.

9. AMC: Inject a 2400 Hz, 25 mV audio signal. Adjust RV12 for maximum modulation of 95%.

10. RF POWER METER: Adjust RV3 so panel meter agrees with external wattmeter reading.

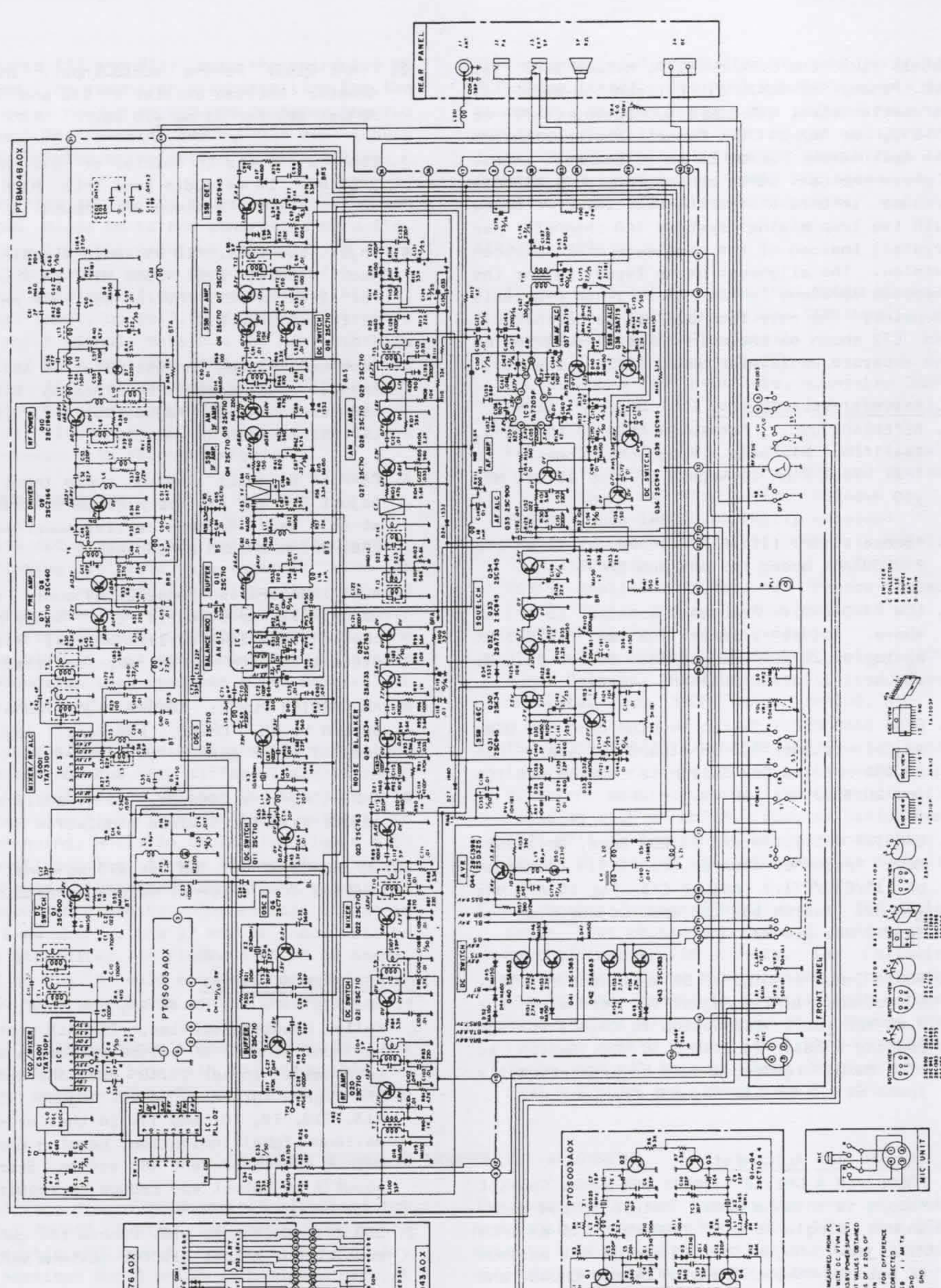
C. RECEIVER ALIGNMENT

1. RF/IF STRIP: Set Ch.40 AM, LOW Band, SQUELCH fully counterclockwise, RF GAIN control at maximum. Connect AC voltmeter across speaker terminals. Inject 27.405 MHz, 30% modulated RF signal into ANT. jack. Adjust T15, T14, T13, T10, T9, T8, and T7, in that order, for maximum signal indication, keeping generator output low to prevent AGC action. Start with about 1 µV output and reduce as required.

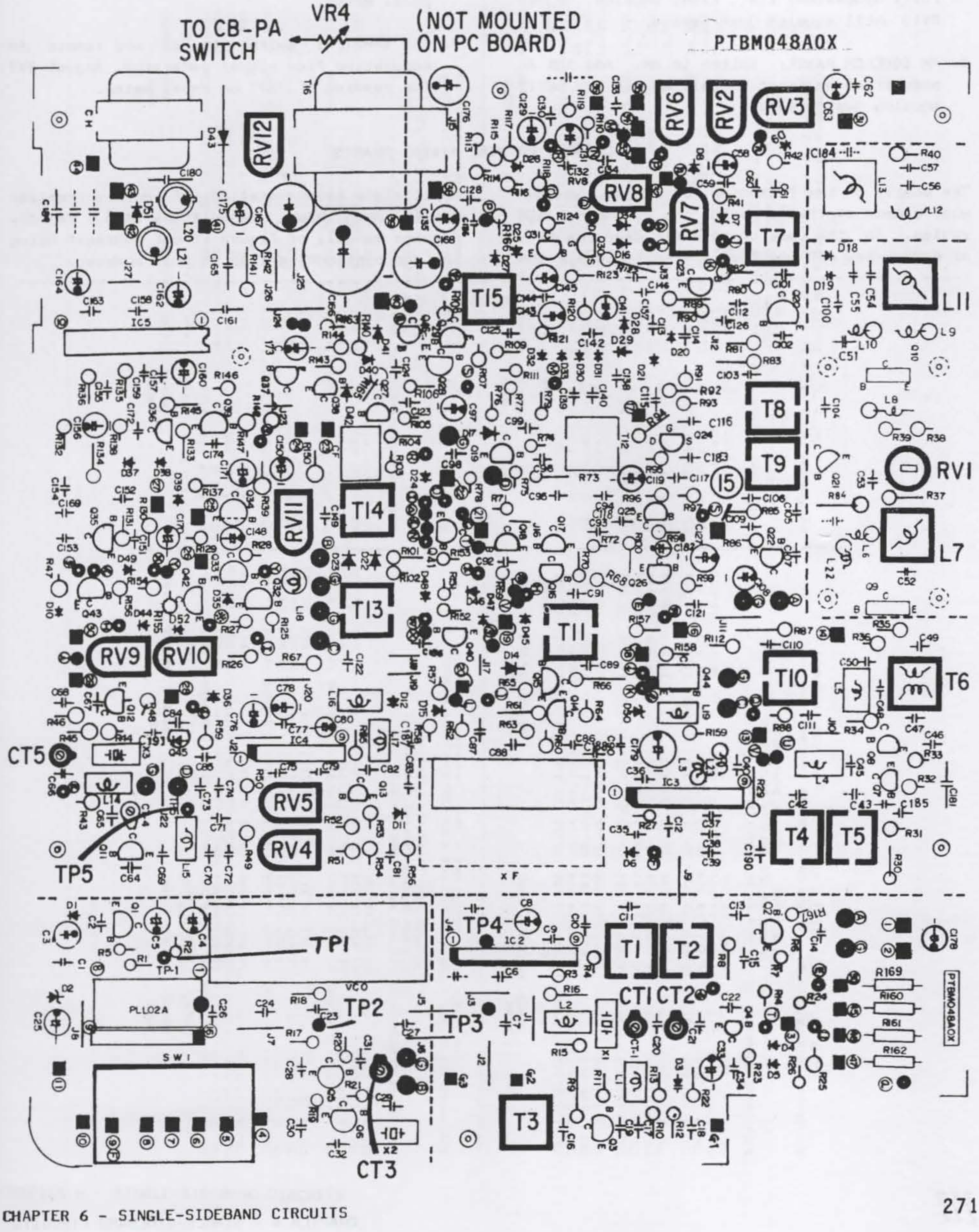
2. SSB IF: Switch to USB. Remove the generator modulation. Adjust T12 for maximum output.

3. SSB AGC: Remove RF input. Connect Voltmeter to base of Q20. Adjust RV8 for 2.0 VDC.

SCHEMATIC DIAGRAM FOR TRANSCEIVER DESCRIBED IN TEXT
(Courtesy the manufacturer.)



ALIGNMENT LOCATIONS FOR TRANSCEIVER DESCRIBED IN TEXT
(Courtesy the manufacturer.)



4. SSB SQUELCH RANGE: Inject a 500 µV RF signal at ANT. jack, no modulation. SQUELCH control fully clockwise; i.e., tight squelch. Adjust RV10 until squelch just breaks.

5. AM SQUELCH RANGE: Switch to AM. Add 30% AM modulation to input signal. Adjust RV9 until squelch just breaks.

6. AM S-METER: Reduce RF generator output to 100 µV. Adjust RV6 for reading of "S9" on panel meter.

7. SSB S-METER: Switch to USB and remove AM modulation from signal generator. Adjust RV7 for reading of "S9" on panel meter.

23-CHANNEL CRYSTAL MIXING CHARTS

The charts on the following four pages show the most common synthesizers for the 23-channel SSB radios. In the case of specific dead channels or modes, you can use the charts to locate the appropriate bad crystal(s). If your synthesizer isn't among these, consult the SAMS, factory service manual, or figure it out yourself using the descriptions earlier in this chapter.

NOTES

	BOTH RX&TX "A"	AM/USB "B"	LSB "C"		BOTH RX&TX "A"	AM/USB "B"	LSB "C"
Ch. 1 (26.965)	7.779166	14.907	14.904	Ch.13 (27.115)	7.829166	14.907	14.904
Ch. 2 (26.975)	"	14.917	14.914	Ch.14 (27.125)	"	14.917	14.914
Ch. 3 (26.985)	"	14.927	14.924	Ch.15 (27.135)	"	14.927	14.924
Ch. 4 (27.005)	"	14.947	14.944	Ch.16 (27.155)	"	14.947	14.944
Ch. 5 (27.015)	7.795833	14.907	14.904	Ch.17 (27.165)	7.845833	14.907	14.904
Ch. 6 (27.025)	"	14.917	14.914	Ch.18 (27.175)	"	14.917	14.914
Ch. 7 (27.035)	"	14.927	14.924	Ch.19 (27.185)	"	14.927	14.924
Ch. 8 (27.055)	"	14.947	14.944	Ch.20 (27.205)	"	14.947	14.944
Ch. 9 (27.065)	7.812500	14.907	14.904	Ch.21 (27.215)	7.862500	14.907	14.904
Ch.10 (27.075)	"	14.917	14.914	Ch.22 (27.225)	"	14.917	14.914
Ch.11 (27.085)	"	14.927	14.924	Ch.23 (27.255)	"	14.947	14.944
Ch.12 (27.105)	"	14.947	14.944				

Additional Crystals: 11.730 MHz AM RX Oscillator;
11.275 MHz AM/USB Carrier Oscillator;
11.272 MHz LSB Carrier Oscillator

Synthesis: (3 x "A") + "B" - 11.275 MHz = AM/USB carrier frequency;
(3 x "A") + "C" - 11.272 MHz = LSB carrier frequency.

	BOTH RX&TX "A"	AM/USB "B"	LSB "C"		BOTH RX&TX "A"	AM/USB "B"	LSB "C"
Ch. 1 (26.965)	7.7766	14.907	14.904	Ch.13 (27.115)	7.8266	14.907	14.904
Ch. 2 (26.975)	"	14.917	14.914	Ch.14 (27.125)	"	14.917	14.914
Ch. 3 (26.985)	"	14.927	14.924	Ch.15 (27.135)	"	14.927	14.924
Ch. 4 (27.005)	"	14.947	14.944	Ch.16 (27.155)	"	14.947	14.944
Ch. 5 (27.015)	7.7933	14.907	14.904	Ch.17 (27.165)	7.8433	14.907	14.904
Ch. 6 (27.025)	"	14.917	14.914	Ch.18 (27.175)	"	14.917	14.914
Ch. 7 (27.035)	"	14.927	14.924	Ch.19 (27.185)	"	14.927	14.924
Ch. 8 (27.055)	"	14.947	14.944	Ch.20 (27.205)	"	14.947	14.944
Ch. 9 (27.065)	7.8100	14.907	14.904	Ch.21 (27.215)	7.8600	14.907	14.904
Ch.10 (27.075)	"	14.917	14.914	Ch.22 (27.225)	"	14.917	14.914
Ch.11 (27.085)	"	14.927	14.924	Ch.23 (27.255)	"	14.947	14.944
Ch.12 (27.105)	"	14.947	14.944				

Additional Crystals: 11.730 MHz AM RX Oscillator;
11.275 MHz AM/USB Carrier Oscillator;
11.272 MHz LSB Carrier Oscillator

Synthesis: (3 x "A") + "B" - 11.275 MHz = AM/USB carrier frequency;
(3 x "A") + "C" - 11.272 MHz = LSB carrier frequency.

	BOTH RX&TX "A"	LSB "B"	AM/USB "C"		BOTH RX&TX "A"	LSB "B"	AM/USB "C"
Ch. 1 (26.965)	23.330	14.907	14.910	Ch.13 (27.115)	23.480	14.907	14.910
Ch. 2 (26.975)	"	14.917	14.920	Ch.14 (27.125)	"	14.917	14.920
Ch. 3 (26.985)	"	14.927	14.930	Ch.15 (27.135)	"	14.927	14.930
Ch. 4 (27.005)	"	14.947	14.950	Ch.16 (27.155)	"	14.947	14.950
Ch. 5 (27.015)	23.380	14.907	14.910	Ch.17 (27.165)	23.530	14.907	14.910
Ch. 6 (27.025)	"	14.917	14.920	Ch.18 (27.175)	"	14.917	14.920
Ch. 7 (27.035)	"	14.927	14.930	Ch.19 (27.185)	"	14.927	14.930
Ch. 8 (27.055)	"	14.947	14.950	Ch.20 (27.205)	"	14.947	14.950
Ch. 9 (27.065)	23.430	14.907	14.910	Ch.21 (27.215)	23.580	14.907	14.910
Ch.10 (27.075)	"	14.917	14.920	Ch.22 (27.225)	"	14.917	14.920
Ch.11 (27.085)	"	14.927	14.930	Ch.23 (27.255)	"	14.947	14.950
Ch.12 (27.105)	"	14.947	14.950				

Additional Crystals: 11.730 MHz AM RX Oscillator;
11.275 MHz AM/USB Carrier Oscillator;
11.272 MHz LSB Carrier Oscillator

Synthesis: "A" + "B" - 11.272 MHz = LSB carrier frequency;
"A" + "C" - 11.275 MHz = AM/USB carrier frequency.

	BOTH RX&TX "A"	AM/USB "B"	LSB "C"		BOTH RX&TX "A"	AM/USB "B"	LSB "C"
Ch. 1 (26.965)	23.330	14.907	14.904	Ch.13 (27.115)	23.480	14.907	14.904
Ch. 2 (26.975)	"	14.917	14.914	Ch.14 (27.125)	"	14.917	14.914
Ch. 3 (26.985)	"	14.927	14.924	Ch.15 (27.135)	"	14.927	14.924
Ch. 4 (27.005)	"	14.947	14.944	Ch.16 (27.155)	"	14.947	14.944
Ch. 5 (27.015)	23.380	14.907	14.904	Ch.17 (27.165)	23.530	14.907	14.904
Ch. 6 (27.025)	"	14.917	14.914	Ch.18 (27.175)	"	14.917	14.914
Ch. 7 (27.035)	"	14.927	14.924	Ch.19 (27.185)	"	14.927	14.924
Ch. 8 (27.055)	"	14.947	14.944	Ch.20 (27.205)	"	14.947	14.944
Ch. 9 (27.065)	23.430	14.907	14.904	Ch.21 (27.215)	23.580	14.907	14.904
Ch.10 (27.075)	"	14.917	14.914	Ch.22 (27.225)	"	14.917	14.914
Ch.11 (27.085)	"	14.927	14.924	Ch.23 (27.255)	"	14.947	14.944
Ch.12 (27.105)	"	14.947	14.944				

Additional Crystals: 11.730 MHz AM RX Oscillator;
11.275 MHz AM/USB Carrier Oscillator;
11.272 MHz LSB Carrier Oscillator

Synthesis: "A" + "B" - 11.275 MHz = AM/USB carrier frequency;
"A" + "C" - 11.272 MHz = LSB carrier frequency.

	RX&TX "A"	RX&TX "B"	RX&TX "C"		RX&TX "A"	RX&TX "B"	RX&TX "C"
Ch. 1 (26.965)	12.800	15.965	6.000	Ch.13 (27.115)	12.800	16.115	6.000
Ch. 2 (26.975)	"	"	6.010	Ch.14 (27.125)	"	"	6.010
Ch. 3 (26.985)	"	"	6.020	Ch.15 (27.135)	"	"	6.020
Ch. 4 (27.005)	"	"	6.040	Ch.16 (27.155)	"	"	6.040
Ch. 5 (27.015)	12.800	16.015	6.000	Ch.17 (27.165)	12.800	16.165	6.000
Ch. 6 (27.025)	"	"	6.010	Ch.18 (27.175)	"	"	6.010
Ch. 7 (27.035)	"	"	6.020	Ch.19 (27.185)	"	"	6.020
Ch. 8 (27.055)	"	"	6.040	Ch.20 (27.205)	"	"	6.040
Ch. 9 (27.065)	12.800	16.065	6.000	Ch.21 (27.215)	12.800	16.215	6.000
Ch.10 (27.075)	"	"	6.010	Ch.22 (27.225)	"	"	6.010
Ch.11 (27.085)	"	"	6.020	Ch.23 (27.255)	"	"	6.040
Ch.12 (27.105)	"	"	6.040				

Additional Crystals: 7.7975 MHz LSB Carrier Oscillator
7.8015 MHz AM/USB Carrier Oscillator

Synthesis: "A" + "B" + "C" - 7.8 MHz = direct channel frequency.

	BOTH RX&TX "A"	AM/USB "B"	LSB "C"		BOTH RX&TX "A"	AM/USB "B"	LSB "C"
Ch. 1 (26.965)	11.000	8.1665	8.1635	Ch.13 (27.115)	11.150	8.1665	8.1635
Ch. 2 (26.975)	"	8.1765	8.1735	Ch.14 (27.125)	"	8.1765	8.1735
Ch. 3 (26.985)	"	8.1885	8.1835	Ch.15 (27.135)	"	8.1865	8.1835
Ch. 4 (27.005)	"	8.2065	8.2035	Ch.16 (27.155)	"	8.2065	8.2035
Ch. 5 (27.015)	11.050	8.1665	8.1635	Ch.17 (27.165)	11.200	8.1665	8.1635
Ch. 6 (27.025)	"	8.1765	8.1735	Ch.18 (27.175)	"	8.1765	8.1735
Ch. 7 (27.035)	"	8.1865	8.1835	Ch.19 (27.185)	"	8.1865	8.1835
Ch. 8 (27.055)	"	8.2065	8.2035	Ch.20 (27.205)	"	8.2065	8.2035
Ch. 9 (27.065)	11.100	8.1665	8.1635	Ch.21 (27.215)	11.250	8.1665	8.1635
Ch.10 (27.075)	"	8.1765	8.1735	Ch.22 (27.225)	"	8.1765	8.1735
Ch.11 (27.085)	"	8.1865	8.1835	Ch.23 (27.255)	"	8.2065	8.2035
Ch.12 (27.105)	"	8.2065	8.2035				

Additional Crystals: 7.3435 MHz AM RX Oscillator;
7.7985 MHz AM/USB Carrier Oscillator;
7.8015 MHz LSB Carrier Oscillator

Synthesis: "A" + "B" + 7.7985 MHz = AM/USB carrier frequency;
"A" + "C" + 7.8015 MHz = LSB carrier frequency.

	BOTH RX&TX "A"	AM/USB "B"	LSB "C"		BOTH RX&TX "A"	AM/USB "B"	LSB "C"
Ch. 1 (26.965)	11.705	7.4615	7.4585	Ch.13 (27.115)	11.855	7.4615	7.4585
Ch. 2 (26.975)	"	7.4715	7.4685	Ch.14 (27.125)	"	7.4715	7.4685
Ch. 3 (26.985)	"	7.4815	7.4785	Ch.15 (27.135)	"	7.4815	7.4785
Ch. 4 (27.005)	"	7.5015	7.4985	Ch.16 (27.155)	"	7.5015	7.4985
Ch. 5 (27.015)	11.755	7.4615	7.4585	Ch.17 (27.165)	11.905	7.4615	7.4585
Ch. 6 (27.025)	"	7.4715	7.4685	Ch.18 (27.175)	"	7.4715	7.4685
Ch. 7 (27.035)	"	7.4815	7.4785	Ch.19 (27.185)	"	7.4815	7.4785
Ch. 8 (27.055)	"	7.5015	7.4985	Ch.20 (27.205)	"	7.5015	7.4985
Ch. 9 (27.065)	11.805	7.4615	7.4585	Ch.21 (27.215)	11.955	7.4615	7.4585
Ch.10 (27.075)	"	7.4715	7.4685	Ch.22 (27.225)	"	7.4715	7.4685
Ch.11 (27.085)	"	7.4815	7.4785	Ch.23 (27.255)	"	7.5015	7.4985
Ch.12 (27.105)	"	7.5015	7.4985				

Additional Crystals: 7.3435 MHz AM RX Oscillator;
7.7985 MHz AM/USB Carrier Oscillator;
7.8015 MHz LSB Carrier Oscillator

Synthesis: "A" + "B" + 7.7985 MHz = AM/USB carrier frequency;
"A" + "C" + 7.8015 MHz = LSB carrier frequency.

	BOTH RX&TX "A"	AM/USB "B"	LSB "C"		BOTH RX&TX "A"	AM/USB "B"	LSB "C"
Ch. 1 (26.965)	11.805	7.3615	7.3585	Ch.13 (27.115)	11.955	7.3615	7.3585
Ch. 2 (26.975)	"	7.3715	7.3685	Ch.14 (27.125)	"	7.3715	7.3685
Ch. 3 (26.985)	"	7.3815	7.3785	Ch.15 (27.135)	"	7.3815	7.3785
Ch. 4 (27.005)	"	7.4015	7.3985	Ch.16 (27.155)	"	7.4015	7.3985
Ch. 5 (27.015)	11.855	7.3615	7.3585	Ch.17 (27.165)	12.005	7.3615	7.3585
Ch. 6 (27.025)	"	7.3715	7.3685	Ch.18 (27.175)	"	7.3715	7.3685
Ch. 7 (27.035)	"	7.3815	7.3785	Ch.19 (27.185)	"	7.3815	7.3785
Ch. 8 (27.055)	"	7.4015	7.3985	Ch.20 (27.205)	"	7.4015	7.3985
Ch. 9 (27.065)	11.905	7.3615	7.3585	Ch.21 (27.215)	12.055	7.3615	7.3585
Ch.10 (27.075)	"	7.3715	7.3685	Ch.22 (27.225)	"	7.3715	7.3685
Ch.11 (27.085)	"	7.3815	7.3785	Ch.23 (27.255)	"	7.4015	7.3985
Ch.12 (27.105)	"	7.4015	7.3985				

Additional Crystals: 7.3435 MHz AM RX Oscillator;
7.7985 MHz AM/USB Carrier Oscillator;
7.8015 MHz LSB Carrier Oscillator

Synthesis: "A" + "B" + 7.7985 MHz = AM/USB carrier frequency;
"A" + "C" + 7.8015 MHz = LSB carrier frequency.

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	8.1590	11.0035	Ch.13 (27.115)	8.3090	11.0035
Ch. 2 (26.975)	"	11.0135	Ch.14 (27.125	"	11.0135
Ch. 3 (26.985)	"	11.0235	Ch.15 (27.135)	"	11.0235
Ch. 4 (27.005)	"	11.0435	Ch.16 (27.155)	"	11.0435
Ch. 5 (27.015)	8.2090	11.0035	Ch.17 (27.165)	8.3590	11.0035
Ch. 6 (27.025)	"	11.0135	Ch.18 (27.175)	"	11.0135
Ch. 7 (27.035)	"	11.0235	Ch.19 (27.185)	"	11.0235
Ch. 8 (27.055)	"	11.0435	Ch.20 (27.205)	"	11.0435
Ch. 9 (27.065)	8.2590	11.0035	Ch.21 (27.215)	8.4090	11.0035
Ch.10 (27.075)	"	11.0135	Ch.22 (27.225)	"	11.0135
Ch.11 (27.085)	"	11.0235	Ch.23 (27.255)	"	11.0435
Ch.12 (27.105)	"	11.0435			

Additional Crystals Used: 7.8025 MHz Carrier Oscillator, all 23 channels, RX & TX.

Synthesis: "A" + "B" + 7.8025 MHz = channel frequency. (Plus mode offsets as required.)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	23.330	14.907	Ch.13 (27.115)	23.480	14.907
Ch. 2 (26.975)	"	14.917	Ch.14 (27.125)	"	14.917
Ch. 3 (26.985)	"	14.927	Ch.15 (27.135)	"	14.927
Ch. 4 (27.005)	"	14.947	Ch.16 (27.155)	"	14.947
Ch. 5 (27.015)	23.380	14.907	Ch.17 (27.165)	23.530	14.907
Ch. 6 (27.025)	"	14.917	Ch.18 (27.175)	"	14.917
Ch. 7 (27.035)	"	14.927	Ch.19 (27.185)	"	14.927
Ch. 8 (27.055)	"	14.947	Ch.20 (27.205)	"	14.947
Ch. 9 (27.065)	23.430	14.907	Ch.21 (27.215)	23.580	14.907
Ch.10 (27.075)	"	14.917	Ch.22 (27.225)	"	14.917
Ch.11 (27.085)	"	14.927	Ch.23 (27.255)	"	14.947
Ch.12 (27.105)	"	14.947			

Additional Crystals Used: 11.275 MHz Carrier Oscillator, all channels and modes.

Synthesis: "A" + "B" - 11.275 MHz = channel frequency. (Plus mode offsets as required.)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	11.740	7.4225	Ch.13 (27.115)	11.890	7.4225
Ch. 2 (26.975)	"	7.4325	Ch.14 (27.125)	"	7.4325
Ch. 3 (26.985)	"	7.4425	Ch.15 (27.135)	"	7.4425
Ch. 4 (27.005)	"	7.4625	Ch.16 (27.155)	"	7.4625
Ch. 5 (27.015)	11.790	7.4225	Ch.17 (27.165)	11.940	7.4225
Ch. 6 (27.025)	"	7.4325	Ch.18 (27.175)	"	7.4325
Ch. 7 (27.035)	"	7.4425	Ch.19 (27.185)	"	7.4425
Ch. 8 (27.055)	"	7.4625	Ch.20 (27.205)	"	7.4625
Ch. 9 (27.065)	11.840	7.4225	Ch.21 (27.215)	11.990	7.4225
Ch.10 (27.075)	"	7.4325	Ch.22 (27.225)	"	7.4325
Ch.11 (27.085)	"	7.4425	Ch.23 (27.255)	"	7.4625
Ch.12 (27.105)	"	7.4625			

Additional Crystals Used: 7.8025 MHz Carrier Oscillator.

Synthesis: "A" + "B" + 7.8025 MHz = channel frequency. (Plus mode offsets as required.)

	RX/TX "A"	RX/TX "B"		RX/TX "A"	RX/TX "B"
Ch. 1 (26.965)	11.700	7.4625	Ch.13 (27.115)	11.850	7.4625
Ch. 2 (26.975)	"	7.4725	Ch.14 (27.125)	"	7.4725
Ch. 3 (26.985)	"	7.4825	Ch.15 (27.135)	"	7.4825
Ch. 4 (27.005)	"	7.5025	Ch.16 (27.155)	"	7.5025
Ch. 5 (27.015)	11.750	7.4625	Ch.17 (27.165)	11.900	7.4625
Ch. 6 (27.025)	"	7.4725	Ch.18 (27.175)	"	7.4725
Ch. 7 (27.035)	"	7.4825	Ch.19 (27.185)	"	7.4825
Ch. 8 (27.055)	"	7.5025	Ch.20 (27.205)	"	7.5025
Ch. 9 (27.065)	11.800	7.4625	Ch.21 (27.215)	11.950	7.4625
Ch.10 (27.075)	"	7.4725	Ch.22 (27.225)	"	7.4725
Ch.11 (27.085)	"	7.4825	Ch.23 (27.255)	"	7.5025
Ch.12 (27.105)	"	7.5025			

Additional Crystals Used: 7.8025 MHz Carrier Oscillator, all 23 channels, RX & TX.

Synthesis: "A"+ "B" + 7.8025 MHz = channel frequency. (Plus mode offsets as required.)

	BOTH RX&TX "A"	AM/LSB "B"	USB "C"		BOTH RX&TX "A"	AM/LSB "B"	USB "C"
Ch. 1 (26.965)	37.600	10.1815	11.0885	Ch.13 (27.115)	37.750	10.1815	11.0885
Ch. 2 (26.975)	"	10.1715	11.0785	Ch.14 (27.125)	"	10.1715	11.0785
Ch. 3 (26.985)	"	10.1615	11.0685	Ch.15 (27.135)	"	10.1615	11.0685
Ch. 4 (27.005)	"	10.1415	11.0485	Ch.16 (27.155)	"	10.1415	11.0485
Ch. 5 (27.015)	37.650	10.1815	11.0885	Ch.17 (27.165)	37.800	10.1815	11.0885
Ch. 6 (27.025)	"	10.1715	11.0785	Ch.18 (27.175)	"	10.1715	11.0785
Ch. 7 (27.035)	"	10.1615	11.0685	Ch.19 (27.185)	"	10.1615	11.0685
Ch. 8 (27.055)	"	10.1415	11.0485	Ch.20 (27.205)	"	10.1415	11.0485
Ch. 9 (27.065)	37.700	10.1815	11.0885	Ch.21 (27.215)	37.850	10.1815	11.0885
Ch.10 (27.075)	"	10.1715	11.0785	Ch.22 (27.225)	"	10.1715	11.0785
Ch.11 (27.085)	"	10.1615	11.0685	Ch.23 (27.255)	"	10.1415	11.0485
Ch.12 (27.105)	"	10.1415	11.0485				

Synthesis: "A" - "B" - 453.5 KHz = AM/LSB carrier frequency;
"A" - "C" + 453.5 KHz = USB carrier frequency.

Browning Golden Eagle Mark III

	ALL MODES		ALL MODES		ALL MODES
Ch. 1 (26.965)	16.270	Ch. 9 (27.065)	16.370	Ch.17 (27.165)	16.470
Ch. 2 (26.975)	16.280	Ch.10 (27.075)	16.380	Ch.18 (27.175)	16.480
Ch. 3 (26.985)	16.290	Ch.11 (27.085)	16.390	Ch.19 (27.185)	16.490
Ch. 4 (27.005)	16.310	Ch.12 (27.105)	16.410	Ch.20 (27.205)	16.510
Ch. 5 (27.015)	16.320	Ch.13 (27.115)	16.420	Ch.21 (27.215)	16.520
Ch. 6 (27.025)	16.330	Ch.14 (27.125)	16.430	Ch.22 (27.225)	16.530
Ch. 7 (27.035)	16.340	Ch.15 (27.135)	16.440	Ch.23 (27.255)	16.560
Ch. 8 (27.055)	16.360	Ch.16 (27.155)	16.460		

Additional Crystals Used:

31.400 MHz RX oscillator all 23 channels.

5.6465 MHz AM Carrier Oscillator.
5.6480 MHz LSB Carrier Oscillator.
5.6450 MHz USB Carrier Oscillator.

5.0485 MHz AM Synth. Osc. all 23 channels
5.0470 MHz LSB Synth. Osc. all 23 channels.
5.0500 MHz USB Synth. Osc. all 23 channels.

Synthesis: The 16 MHz channel crystal + both the 5 MHz crystals (each mode) = the on-channel frequency. Example: For Ch. 1 AM, it is 16.270 MHz + 5.6465 MHz + 5.0485 MHz = 26.965 MHz.

Tram D201 & D201A

The D201A is simply an expanded version of the D201, with extra mixing crystals added to get 40 channels. Otherwise both models are exactly the same in all other circuitry.

	BOTH RX&TX "A"	AM/LSB "B"	USB "C"		BOTH RX&TX "A"	AM/LSB "B"	USB "C"
Ch. 1 (26.965)	4.400	16.3085	16.3115	Ch.21 (27.215)	4.400	16.5585	16.5615
Ch. 2 (26.975)	4.410	"	"	Ch.22 (27.225)	4.410	"	"
Ch. 3 (26.985)	4.420	"	"	Ch.23 (27.255)	4.440	"	"
Ch. 4 (27.005)	4.440	"	"	Ch.24 (27.235)	4.420	"	"
Ch. 5 (27.015)	4.400	16.3585	16.3615	Ch.25 (27.245)	4.430	16.5585	16.5615
Ch. 6 (27.025)	4.410	"	"	Ch.26 (27.265)	4.400	16.6085	16.6115
Ch. 7 (27.035)	4.420	"	"	Ch.27 (27.275)	4.410	"	"
Ch. 8 (27.055)	4.440	"	"	Ch.28 (27.285)	4.420	"	"
Ch. 9 (27.065)	4.400	16.4085	16.4115	Ch.29 (27.295)	4.430	"	"
Ch.10 (27.075)	4.410	"	"	Ch.30 (27.305)	4.440	"	"
Ch.11 (27.085)	4.420	"	"	Ch.31 (27.315)	4.400	16.6585	16.6615
Ch.12 (27.105)	4.440	"	"	Ch.32(27.325)	4.410	"	"
Ch.13 (27.115)	4.400	16.4585	16.4615	Ch.33 (27.335)	4.420	"	"
Ch.14 (27.125)	4.410	"	"	Ch.34 (27.345)	4.430	"	"
Ch.15 (27.135)	4.420	"	"	Ch.35 (27.355)	4.440	"	"
Ch.16 (27.155)	4.440	"	"	Ch.36 (27.365)	4.400	16.7085	16.7115
Ch.17 (27.165)	4.400	16.5085	16.5115	Ch.37 (27.375)	4.410	"	"
Ch.18 (27.175)	4.410	"	"	Ch.38 (27.385)	4.420	"	"
Ch.19 (27.185)	4.420	"	"	Ch.39 (27.395)	4.430	"	"
Ch.20 (27.205)	4.440	"	"	Ch.40 (27.405)	4.440	"	"

Additional Crystals: 5.8015 MHz AM RX Oscillator;
6.2565 MHz AM/LSB Carrier Oscillator;
6.2535 MHz USB Carrier Oscillator

Synthesis: "A" + "B" + 6.2565 MHz = AM/LSB carrier frequency;
"A" + "C" + 6.2535 MHz = USB carrier frequency.
IF = 6.2565 MHz SSB & 1st AM; 455 KHz 2nd AM.