present-day receivers — some problems and cures

Some thoughts on and cures for problems encountered in modern amateur communications receivers

The modern-day communications receiver is going through a continuous evolution that has brought about significant improvement in certain operating features. Among these are greatly improved frequency stability and setability, better selectivity, a slow and consistent tuning rate from band to band, and a wide-range automatic gain control system that functions on CW and single sideband. At the same time, unfortunately, the design philosophies which have made the above advances possible have also reduced the typical receiver's ability to simultaneously handle weak desired and strong undesired signals. This absolute reduction in receiver dynamic range has occured at the same time the number of high-power signals on the amateur bands has been increasing.

Insufficient dynamic range in a receiver can result in one or more stages being over-driven into nonlinearity by undesired strong signals. The result is internally-generated intermodulation distortion (IMD) products. These undesired products can occur in any mode of operation, but are easiest to identify on CW. Two CW signals which are overdriving a receiver will generate IMD products, but only when both stations are transmitting simultaneously. In the extreme situation, not only may IMD occur, but one signal alone can block, deaden, or desensitize the receiver.

In a pileup or contest situation, many strong CW stations can cause serious receiver overload, intermodulating with each other, and resulting in multiple phantom signals; it will appear as if several operators are randomly tapping their keys, or that you are listening to the Novice band with a diode detector without a BFO.

Two or more ssb signals with the correct frequency relationship can also intermodulate with each other and result in IMD products on top of the station you are listening to. The interference, however, will be unintelligible. IMD can also occur from a single ssb station on an adjacent channel as the individual speech frequencies mix with their own harmonics. Generally speaking, transmitted IMD from an rf power amplifier will be worse than that internally generated in the receiver, with the result that the transmitted IMD may cover up a receiver's shortcomings. An operator may never be certain whether the unintelligible signals he hears are being generated within his receiver, or coming from the outside — there is enough rf interference to contend with without the receiver creating its own!

The improvements mentioned in the first paragraph have been generally obtained by using a double- or triple-conversion scheme, plus a nonbandswitched master oscillator (PTO or VFO). Depending on the design technique, the first i-f may have a bandwidth of as much as 500 kHz, as in the Heath SB-104, or as narrow as 6 kHz in the Drake R-4B. Assuming that most of a receiver's selectivity occurs at the second intermediate frequency, you might think that the wider the bandwidth of the first i-f, the greater the chance of picking up more strong signals which could overload the second mixer. Of greater importance than this bandwidth, however, is the *net gain* between the antenna and the mixer that drives the narrow crystal or mechanical filter.

The Collins R-390A, for example, has three mixers and two separate gain stages ahead of its mechanical

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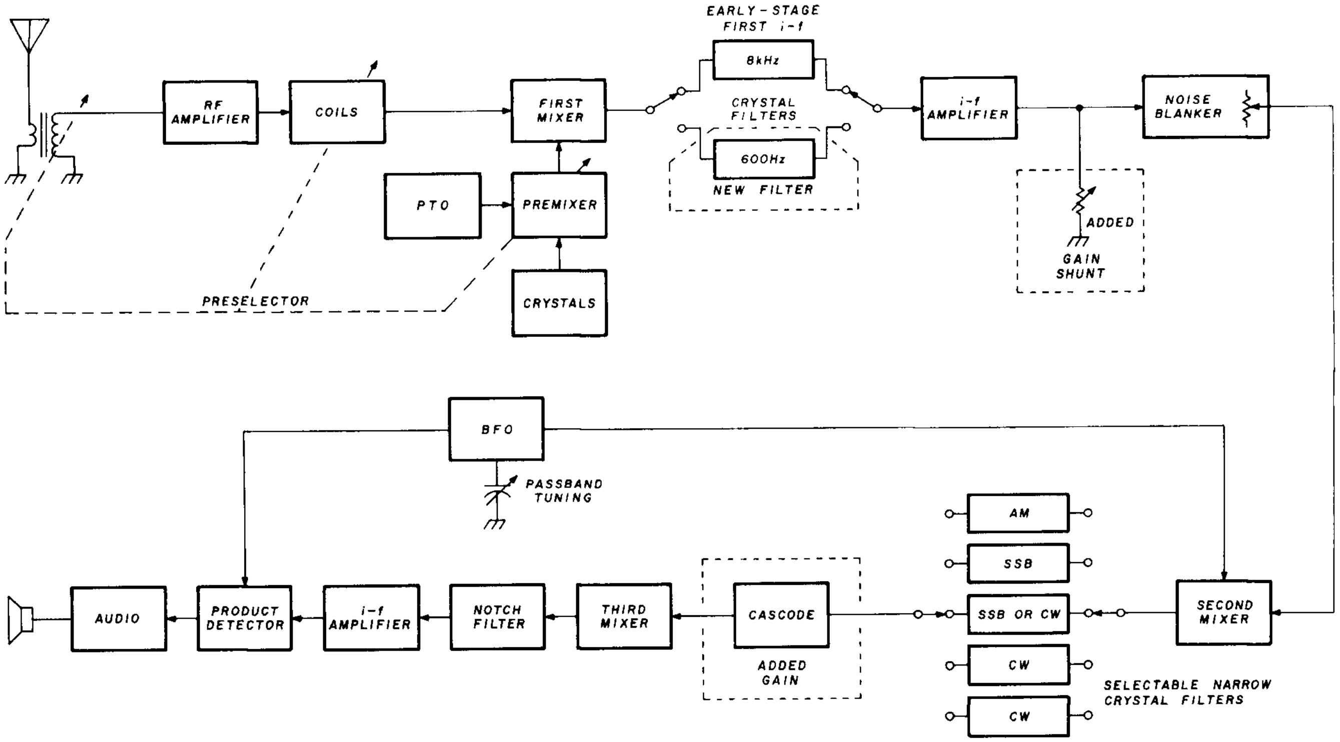


fig. 1. Block diagram of the Drake R4C receiver showing the gain redistribution. A shunt across the first i-f amplifier will reduce its gain the same amount as is added after the narrow i-f filters.

filters; it also has a set of elaborate, mechanically-tracked tuned circuits which have high *Q* and high insertion loss. Thus the net gain from the antenna to the major selectivity-determining elements is low enough to maintain good dynamic range.

Another receiver, the Heath SB-303, has a 500-kHz wide first i-f *window*, but unlike the R-390A, it has little selectivity ahead of its narrow filters and too much gain. This results in higher susceptibility to overload from strong signals anywhere in the band, which then cause undesired IMD products to be generated within the receiver.

One topic that has received considerable attention by amateurs in recent years has been that of receiver performance and design. Many approaches have been covered, from the initial design of the "super receiver" to modification of existing equipment; but to the person with just a casual interest, the reasons behind some designs may not be readily apparent. In fact, the problems themselves may not be noticeable to the ordinary amateur. This article is another in a continuing series that shows you how to recognize the problems in typical modern receivers; in addition, it discusses modifications applied to one receiver and the motives behind these changes.

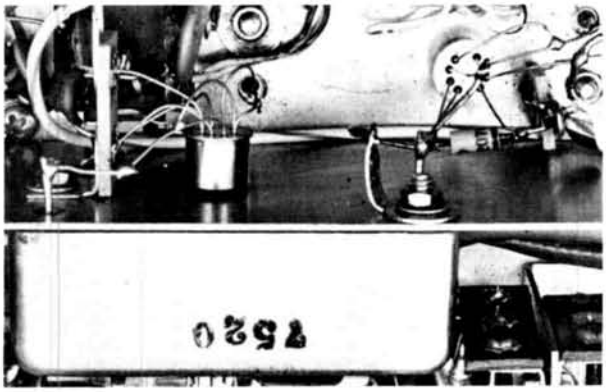
Of major importance is the reason for the modification. The intent of this article *is not* to prove that one particular receiver is superior to another for whimsical reasons, but to realistically and fairly compare different receivers by presenting test results on comparable circuits. On the basis of the test results, design changes were made in one receiver in an attempt to improve overall performance. You will notice while reading the article that the results are given in very specific terms; this will help you to better understand the basics of receiver performance standards. With this knowledge, *you* will be able to judge the merits of the different receivers on the market and choose one according to your own needs. **Editor**

At the opposite end of the bandwidth scale is the Drake R-4C with its 8-kHz wide first i-f filter at 5645 kHz. This four-pole crystal filter does an excellent job of keeping most of the undesired signals in the band from passing on to a second high-gain mixer. However, any undesired strong signals that *do* pass through this 8-kHz *window* can proceed to the second mixer with disasterous results. The net gain from the antenna to the narrow second i-f crystal filter can be as high as 50 dB when a desired weak signal (S1) is being received; this puts an impossible demand on the i-f stages, since the 1-dB compression point of the second mixer output has occured with any signal 30 dB over S9. An undesired signal, outside the narrow selectivity but inside the first i-f *window*, that is S9+40 dB (−33 dBm or 5 mV across the 50-ohm antenna input) for example, would have to be linearly amplified to a level of +17 dBm (1.58 volts across the 50-ohm narrow-filter input) and then be rejected by the filter. To supply this power level to the filter, the high-impedance plate of the second mixer would have to linearly swing more than 40 volts to yield a signal that is as great as 15 volts rms; even if this level could be produced in a low noise mixer, which is highly unlikely, the filter could be damaged.

What actually results when there are two undesired signals at S9 + 40 dB with the correct frequency relationship, over loading the second mixer, is a spurious third-order IMD signal that is greater than S9 in strength. This would certainly be strong enough to obliterate the desired weak signal!

One possible reason why such net-gain design errors are overlooked is our present method of testing receiver dynamic range. This subject has received considerable attention lately in *ham radio*[1,2,3] and *QST*.[4] An increasingly popular method of testing for dynamic range has been developed by Wes Hayward, W7ZOI, and is used by the ARRL.[5] Basically, it consists of applying two *well-isolated*, equal-strength signals, 20-kHz apart, to a receiver's input and then adjusting their level so that the undesired third-order IMD products generated within the receiver are just equal to the noise floor of the receiver. The difference in level between the noise floor and the test signals gives the receiver's dynamic range. The higher the receiver's dynamic range, the better it can handle both desired weak and undesired strong signals at the same time.

The choice of 20-kHz spacing for the two test signals is arbitrary and in many cases satisfactory. In a receiver which has all its significant selectivity far down the i-f chain, this signal spacing is relatively unimportant. If the early-stage bandwidth is narrower than the test signal spacing, however, its selectivity will partially or completely reject one or both of the test signals, resulting in a highly inflated dynamic range reading. We feel these measurements should cover worst-case conditions since real-life interference on the amateur bands may be spaced less than 20 kHz.



Installation of the 600-Hertz first i-f filter. The filter is installed on a vertical shield near the original 8-kHz filter. The devices with 8 leads are TO-5 size relays that are used to select the appropriate filter.

Third-order IMD products, with 20-kHz spacing, will occur 20 kHz below the low frequency test signal and 20 kHz above the high frequency test signal. When the receiver is tuned to a third-order internally-generated spurious IMD signal, the test signals are 20 and 40 kHz up or down the band. The 25-kHz-wide crystal filter in the first i-f of the Signal-One transceiver, to name just one example, will greatly attenuate the test signals before they can reach the following stages. Thus, 20-kHz spacing will test only the front end and first mixer. What is needed is spacing narrow enough so that both test signals can pass through any selectivity prior to the narrow filter. We feel a spacing of 2 kHz will satisfy this requirement, and at the same time be wide enough so the narrow filter will adequately reject the test signals when the receiver is tuned to an IMD product.*

The Drake R-4C, with its 8-kHz-wide first i-f filter, shows an inflated 20-kHz dynamic range of 83 dB. This reading has remained quite consistent over several receivers, including one we tested at the ARRL laboratory.† When the test signals are placed 2 kHz apart, however, so they *both* pass through the 8-kHz filter, the dynamic range drops to around 58 dB.

improving receiver performance

There are three ways to improve a receiver's dynamic range. If the second mixer cannot handle the required level, one option is to replace it with a mixer that will do the job. Unfortunately, as WB4ZNV discovered,[6] the process of replacing an active mixer with the superior passive double-balanced mixer is a laborious task, even if it does improve the receiver's overload characteristics. Oscillator injection levels and impedances are usually not compatible with existing circuitry.

Another remedy is to redistribute the gain in the receiver, reducing it ahead of the overloaded stage and building it up again after the narrow filter. A third method is to insert more early-stage selectivity into the receiver so strong interfering signals are not as likely to get past the first mixer. We chose to inves-

*When performing a 2-kHz IMD test, one very important factor must be taken into consideration: the noise sidebands of the signal generators. General test equipment, oscillators, or VFOs are more than adequate for testing, until a receiver's dynamic range nears 100 dB. At this point it will be impossible to accurately measure true receiver IMD products if the signal generators are producing excessive low-level spurs and noise. At this time there are only two or three generators that have the necessary sideband suppression; one manufactured by Hewlett-Packard and another by Rohde and Schwartz.

†The ARRL laboratory uses a pair of AN/URM-25 signal generators to perform IMD tests. A 2-kHz IMD test produced results within 2 dB of those obtained by the authors while using the high quality, low-noise sideband Rohde and Schwarz XUA signal generator.

tigate the latter two options, using our own R-4Cs.

The initial gain redistribution began with a 20-dB reduction of the signal level as seen by the second mixer. This gain loss was then restored after the narrow filters at the high-impedance grid of the third mixer. The original amplifier used a single jfet plus a step-up transformer to provide the necessary gain, but the circuit suffered from instability problems and noise. It was then decided to relocate the added gain outboard from the receiver and insert it at a convenient 50-ohm point, the output of the switchable second i-f crystal filters (see **fig. 1**).

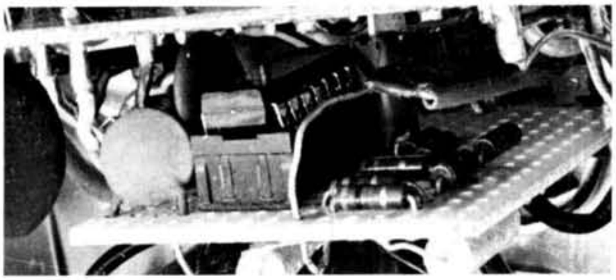
A cascode jfet amplifier, with 50-ohm input and output impedances (**fig. 2**), was built and inserted into the i-f chain just prior to T-6. The coax cable that connects T-6 and the mode switch was lifted at the switch end; two lengths of miniature coax (RG-174/U) were then run out through a slot in the rear of the receiver. The first length is connected to the lugs on the mode-switch wafer, while the second is spliced into the cable that feeds the transformer.

This amplifier can possibly be located inside the receiver. Regardless of its location, it should be mounted in a metal box or other well-shielded enclosure. Two toroidal transformers provide the necessary impedance changes, their associated trimmer capacitors forming resonant circuits. While both trimmers can simply be peaked for maximum signal, the input may be fine-tuned for the best compromise signal-to-noise ratio among the switchable narrow filters. (The 2N5950 and 2N5953 jfets may be purchased from G. R. Whitehouse Company, Amherst, New Hampshire 03031).

We found the best way to attenuate the signal level into the second mixer was to swamp the output of the first i-f amplifier Q1 (V3/6BZ6 in early receivers). A miniature 5000-ohm multi-turn trimmer, from noise blanker socket pin 4 to ground, made a convenient way to adjust this level. Simply adjust the trimmer to drop the calibrator signal 20 dB on the S-meter; then adjust the gain pot on the cascode amplifier to restore the S-meter to its previous level. On certain receivers it may be necessary to peak T-6 to obtain 20 dB of gain from the cascode amplifier; always readjust both cascode trimmers after making a gain change.

If the noise blanker is installed in the receiver, significant IMD products can occur in its stages, too. Due to noise limitations, however, the blanker cannot be starved a full 20 dB. Instead, after replacing blanker resistor R1 with a 0.001 μF disc capacitor, reduce the gain to the blanker about 12 dB, and then turn down the blanker output pot 8 dB to achieve the 20 dB reduction at the second mixer. Alternately, the gain of blanker transistor Q2 can be decreased by reducing its emitter resistor bypass capacitor, rather than readjusting the blanker output pot.

Take care not to use too much cascode amplifier or blanker gain; otherwise amplified 5645-kHz oscillator leakage can degrade system performance. With the antenna disconnected and the top and bottom covers of the receiver in place, make sure the S-meter does not kick upward more than one-quarter S-unit when the passband tuning is slowly turned through its range. In some receivers it may be necessary to jumper the cable-braid ground point of the Q4 oscillator board with a short clip lead to the shield tray on which the blanker board rests to reduce this oscillator leakage to an acceptable level. It might also be necessary to insulate the frame of the rear carrier-oscillator jack from the chassis ground. Also, if the cascode amplifier breaks into oscillation when the mode switch is between detent positions, reverse the leads of a high impedance winding of one of the toroids.



The new product detector is installed next to the audio transformer and behind the variable capacitor used for passband tuning. The entire assembly is mounted on a 1-3/4 x 1-5/8 inch (4.5x4.1cm) board.

Proper operation of the gain redistribution circuits provided greatly reduced susceptibility to IMD overload problems on both CW and ssb, as was visibly demonstrated with strong nearby DX contest signals; yet the receiver was still able to meet its sensitivity specification. Agc attack distortion was also reduced somewhat. Dynamic range improved from 58 dB to around 70 dB, while using our 2-kHz spacing test method.

i-f filters

As an additional CW remedy we chose to increase the selectivity (possibly on a switchable basis) following the output of the first mixer; the bandwidth is presently determined by an 8-kHz wide four-pole crystal filter. This bandwidth is needed on phone to pass an upper and/or lower sideband signal. A bandwidth of at least this magnitude is also required to pass undistorted noise pulses to the blanker. A noise blanker's usefulness, however, is marginal at best with one or more strong nearby signals, due to its agc greatly increasing the blanking threshold, or possible false triggering. Thus, the need for narrowing first i-f selectivity ahead of the noise blanker, which reduces blanker effectiveness, occurs under conditions which are usually unfavorable to blanking in the first place.

Circumstances could occur where blanking would be necessary at all times, such as when you suffer from a continuous very high level of blankable noise. In these cases, the 8-kHz first i-f filter must remain ahead of the blanker. Then a properly-terminated narrow filter could be inserted just *after* the blanker, but before the second mixer. The signal path can be switched between the narrow filter and an attenuator equal to its loss. While the chance of second mixer overload is greatly reduced with this arrangement, there is no such narrow bandwidth IMD protection for the blanker; this limits the receiver's potential dynamic range considerably below what is otherwise obtainable. It is therefore mandatory to use the cascode gain redistribution system with this special, optional filter arrangement. With this arrangement close-in dynamic range will be in the high 70s.

We decided that the first i-f CW selectivity should be equal to the widest desirable under contest conditions. We then designed a new 600-Hz six-pole filter, keeping in mind package size limitations and insertion loss requirements. We've also developed a miniature relay system which allows instant interchange of our internally-mounted, CW-bandwidth, first i-f filter with the existing 8-kHz phone unit.

The project of minimizing overload in the R-4C was now complete and totally successful. When measured using our worst-case 2-kHz test method, the receiver's dynamic range jumped from an original unacceptable 58 dB to a final excellent 85 dB. This value ranks with the best of the commercially-available amateur gear on the market today, and should be more than adequate for most practical situations. As a side note, a similar arrangement of first i-f filter switching can be used on ssb by inserting a set of 2.6 or 2.3-kHz phone filters in the first i-f for improved phone selectivity.

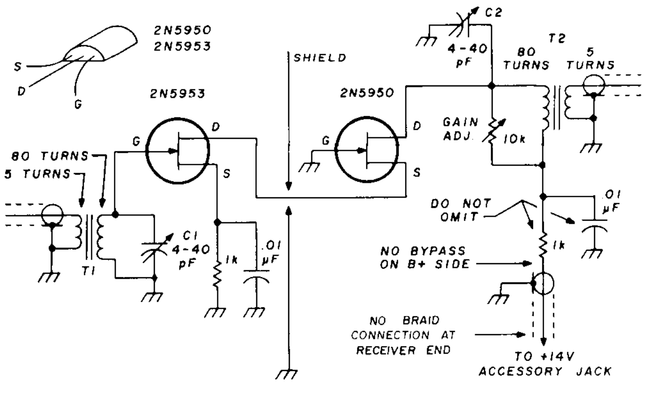


fig. 2. Schematic diagram of the cascode amplifier used for the gain redistribution. There is only one ground return on the circuit, through the input coax cable. The braid on the output coax cable goes to the primary of T6 which is not grounded at that point. T1 and T2 are wound on Micrometals T-50-2 toroidal cores. The high-impedance windings are 80 turns of no. 30 AWG (0.25mm) while the low-impedance windings are 5 turns of no. 24 AWG (0.5mm).

simple receiver testing

While we made use of a considerable amount of test equipment during this project to measure dynamic range, you can make comparative tests using only a crystal calibrator and transmitter vfo, *loosely* coupled into the receiver. Comparative noise floor measurements, with no antenna connected, can be made by measuring the preselector noise peak (above later stage noise) with an ac voltmeter connected to the audio output line.

When making gain redistribution or selectivity changes, adjust the receiver to maintain its original net gain by measuring the calibrator level on some specific frequency. We use 7.2 MHz as our reference frequency. Here the calibrator level should read about 15 to 20 dB over S9 with nothing connected to the antenna input. (Don't readjust the S-meter sensitivity pot.) Two strong test signals, accurately set to a specific S-meter level, will produce a repeatable reference IMD that can also be measured on the S-meter. As improvements are made the IMD, read on the S-meter, will drop. We made our 2-kHz tests at S9 + 40 dB, and ended up reducing the IMD from greater than S9 to less than S3.

filter rejection

The 600-Hz first i-f filter, in addition to greatly reducing the chance of overload, had the extra benefit of eliminating the annoying signal leakage around the narrow second i-f filters. This problem of not being able to realize the ultimate rejection capabilities of a well-designed filter is one that plagues all equipment that, to our knowledge, is presently on the market. It is really quite difficult to even design a test fixture to correctly measure the ultimate rejection of a filter. Obtaining adequate ultimate attenuation, which should be in excess of 100 dB for an eight-pole filter in a receiver or transceiver, requires tedious attention to detail. Current ground loops and stray capacitive coupling are the main problems that must be eliminated. We have had many frustrated amateurs ask us to provide a filter for their receiver or transceiver which would not leak like the factory installed units. Unfortunately, some of the limitations were in the receiver and not the filter. Although replacing or adding to an existing *late* narrow filter can often considerably improve skirt selectivity, the only way to eliminate the last traces of these leakage problems, in existing popular receivers, is to add a filter earlier in the set with a bandwidth closer to that of the main filter. The early filter should preferably be on a different frequency from the later one, such as in the R-4C or 2B.

We tested one all-solid-state American transceiver that had so much leakage around the CW filter that a 2-kHz dynamic range test could barely be made. The IMD was masked by the test signal leakage until special audio filtering was employed.

While discussing filters, we would like to emphasize the importance of a great variety of bandwidths being available to the operator. Most of the equipment on the market has just one standard phone bandwidth, with one CW filter available as an option, and when installed it must be used at all times for that mode. Many of the imported rigs are examples of these limitations. The Yaesu FT-101B has only a six-pole 600-Hz filter, and the Kenwood TS-820 is limited to only a six-pole 500-Hz unit.

By today's standards a six-pole 500-Hz filter is quite broad and has a poor shape factor. One possible reason for offering only these filters is that the design of the equipment was based on the use of an ssb filter having an insertion loss of only 2 to 4 dB. Unless a manufacturer employs special technology in building, say, an eight-pole 350-Hz filter that is more advanced than required for a phone filter, the insertion loss will rise to an unacceptable 14 to 16 dB. It is quite undesirable to have the signal drop 12 dB when the CW filter is used; a compromise is made, and the six-pole filters mentioned above are offered. Even with this trade-off, there is an additional insertion loss of 5 to 7 dB compared to the phone filter, and relatively poor skirt selectivity.

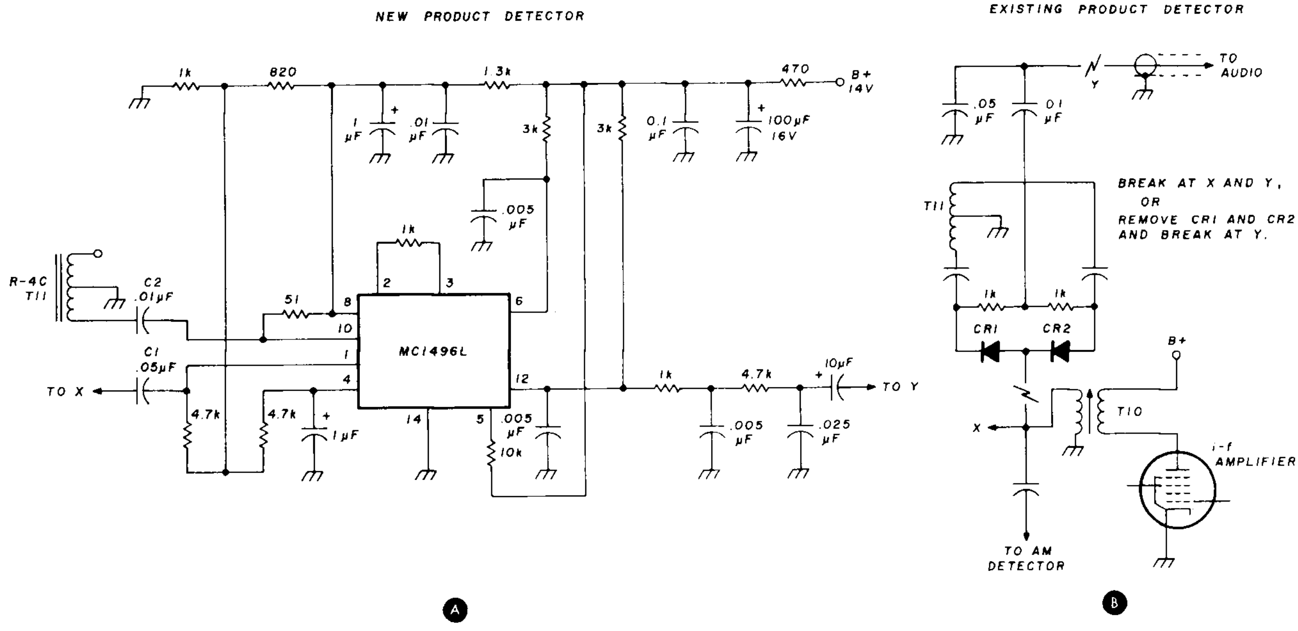


fig. 3. The MC1496L can be used as a product detector as shown in A. The IC plus associated components are mounted on a small circuit board which is installed next to the audio transformer in the receiver. C1 and C2 are critical values and should not be substituted. For smaller size, the 1-µF capacitors may be tantalum. B shows the interconnections between the detector and the receiver.

As a minimum, the receiver net gain should be designed around the lossiest filter, with the losses of the other filters increased to that constant level. Another school of thought suggests that the noise integrated by each of the filters should be the same, requiring increasing gain (or decreasing insertion loss) as narrower filters are selected. To our knowledge, no amateur equipment manufacturer is currently keeping the integrated noise constant, and only the R-4C provides for constant insertion loss with narrow bandwidth filters.

We have noted with interest the comments from some of our Japanese and German filter customers about American rigs such as the R-4C and T-4XC. The cost of these units in their home countries, due to import duties, is 30 to 50 per cent higher than here in the United States, but the discriminating foreign amateur is willing to pay that premium partly because of the excellent filters which are available. Compared with the typical filter in the average set, the Drake eight-pole 250-Hz and the Sherwood eight-pole 125-Hz CW filters are valuable assets. Similarly, an optional 1500 to 1800-Hz ssb filter* can make the dif-

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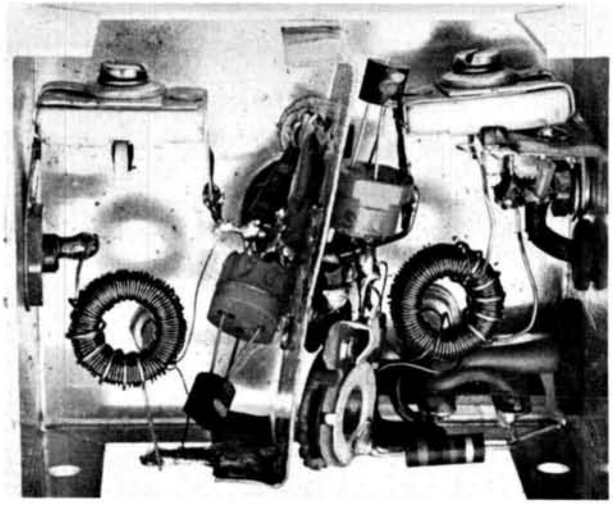
*Drake also offers the FL1500, a 1500-Hz filter. Though publicized as an RTTY filter, it provides exceptional performance, especially under difficult phone contest conditions. **Editor.**



Cascode amplifier used for gain redistribution is installed in a small enclosure. The shield must be in place between the stages of the amplifier.

ference in being able to hold a contact under heavy interference and contest conditions.

It takes some practice to become proficient at using a narrow i-f filter, just as in learning to tune with the wide-skirted audio filters. But during crowded band conditions a 250-Hz filter can often be too broad! One CW operator used the 125-Hz filter in his R-4C almost exclusively during the hectic 160-meter contests.

The entire line of filters for the R-4C is excellent and can be adapted to any receiver or transceiver. A construction article in the 1977 ARRL *Handbook*[7] describes a method of adding bandpass tuning to a receiver lacking this feature. This circuit uses 455-kHz filters and is inserted in the receiver i-f chain by converting down to 455 kHz and back up again. This basic idea can be used with any pair of filter and receiver intermediate frequencies.

You could convert from 3395 kHz up to 5695 kHz and back down again, for example, or down from 9 and up again. As the difference between the two i-f frequencies becomes smaller, the difficulty of the conversion process increases. A Drake R-4B owner who wishes to add R-4C filters to his receiver has to cope with a conversion frequency difference of only 50 kHz. Howard Sartori, W5DA, has developed a circuit for use in his R-4B which can be adapted to any i-f by simply changing one crystal oscillator. It has been used on intermediate frequencies as low as 50 kHz and as high as 30 MHz with excellent results. His circuit is described on page 20 of this issue of *ham radio*. One precaution, when adapting the *Handbook* circuit or W5DA's i-f converter to a transceiver: make sure the transmitted signal does not have to pass through the added filters. Otherwise, with use of the two narrowest filters (the FL-250 and CF-125/8), the transmitter carrier offset frequency adjustment would become quite critical, and keying on the transmitted signal could be too soft.

The Kenwood TS-820, which we have in the lab, has a noise floor and dynamic range in the ssb mode that is virtually identical to that of the Drake R-4C. Both units perform very well on phone; when you want to dig out a weak CW signal on a quiet band, however, the R-4C is significantly better. The R-4C's gain remains constant when a CW filter is switched in, but the TS-820's drops off 5 to 6 dB. Even if a weak received signal is above the noise floor, this gain reduction increases the agc threshold to the point where it may become necessary to manually ride the gain control. The Yaesu FT-101B we tested had a dynamic range, at any test signal spacing, as bad as the unmodified R-4C when measured with the *worst-case* 2-kHz test method. The bulk of the problems in the FT-101B were caused by a bipolar transistor in the noise blanker which was being overdriven.

A receiver's maximum net gain from the antenna to the detector can change significantly from band to band without having much effect on the measured sensitivity. Two sets with similar signal requirements for a given signal-to-noise ratio can have vastly different capabilities in handling weak, fluctuating signals, especially on the 10- and 15-meter bands. As the net gain falls off, more and more signals will fall below the agc threshold. The R-4C, for instance, holds a much more consistent net gain from 80 to 10 meters than the TR-4C. The TS-820 increases the net gain on 10 meters compared to 20 and 15 by changing a capacitive tap on the rf amplifier drain. Its gain, however, is too high on 160 meters, resulting in a higher susceptibility to overload by broadcast stations. When connected to a nearly self-resonant 160-meter vertical antenna at our lab in Denver, the TS-820 grossly overloads with the eighteen local broadcast stations, developing more than 1 volt across its antenna input. Without the 20-dB rf attenuator switched in, the 160-meter band is nothing but a solid mass of S9 + 30 dB IMD products.

The TS-820's front end is not selective enough to cope with this admittedly unusual receiving situation. On 1.8 MHz, the preselector attenuates signals that are 100 kHz off frequency by 18 dB. In comparison, the R-4C attenuates these same signals by 38 dB. On 3.6 MHz, the TS-820's front end is down 8 dB at 100 kHz off frequency, the TR-4C by 12 dB, and the R-4C by 24 dB. When tested on 10 meters, the *500*-kHz attenuation is 8 dB on the TS-820, 8 dB on the TR-4C, and 15 dB on the R-4C.

One way to eliminate the need for a sharp preselector is to use an up-conversion scheme, with the first i-f above 40 MHz. The input may only need a bandpass filter that rejects signals below 1.8 and above 30 MHz. Then image signals would fall above 80 MHz and be virtually eliminated by the bandpass filter. The first mixer must have a much greater signal-handling capability than in present receivers, however, because it would see all stations between 1.8 and 30 MHz. Two strong local signals, one on 14 and the other on 21 MHz, could produce a 7-MHz IMD product.

The R-4C and the TS-820 show a 20-kHz test-signal-spacing dynamic range in the ssb mode of about 80 dB when tested on 20 meters. At this frequency, the preselectors do not significantly enter into the dynamic range test, since they will not attenuate the test signals more than 1 dB. This is not the case on 160 meters, especially with the R-4C. Here, its high-Q front end attenuates the 20-kHz signals enough to raise the dynamic range by 12 dB. On the other hand, some receivers have too much gain on 80 and 160 meters which, even with sharp preselectors, could yield a dynamic range no better (or even worse) than on 20 meters.

While the 20-kHz dynamic range of the R-4C improves on the lower frequencies because of its preselector, the 2-kHz dynamic range measurement remains quite constant at just under 60 dB. Similarly, it is consistently above 83 dB with the 600-Hz first i-f filter that cures its *window* overload problem. The TS-820 does not have this *window* problem since it is a single-conversion design and has no overloadable stages between the wide noise blanker filter and its narrow filter. Any improvement in dynamic range with increasing frequency separation of the test signals can only be attributed to its preselector.

A detailed review of the TS-820 in *CQ-DL*,[8] far more comprehensive than anything published in this country, showed a 6-dB improvement in dynamic range as the test signal spacing was increased from 2 to 50 kHz. It is interesting to note that *CQ-DL* also feels that a close-in 2-kHz spacing is necessary for proper evaluation.*

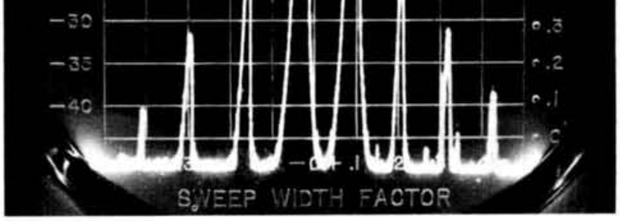
The Atlas 210X, without its noise blanker operational, has a better than average dynamic range of about 90 dB, which would be even better if its double-balanced mixer were properly terminated above the i-f frequency.[2] This could be accomplished with the use of a diplexer, as described by Wes Hayward,[4] or with a power jfet, as related by Ulrich Rohde.[2,3] There is one limitation in the 210X that cannot be easily remedied, however; its potential strong-signal handling capabilities cannot be fully realized due to its noisy conversion oscillator. Since this oscillator has noise sidebands that are only 65 dB down 10 kHz on each side of its center frequency, all the signals passing through the mixer will take on similar noise sidebands. Consider a strong station near a desired signal that is weaker in amplitude. Reciprocal mixing of oscillator noise can cause noise sidebands to be transferred to the strong nearby station and cause interference to the desired signal. Thus, even if the i-f filter's ultimate rejection is actually realized in the receiver circuitry, which is doubtful in practice, this high level of rejection can be negated by wide-band mixer noise. So while it takes two strong signals to cause IMD which can interfere with weak signal reception, a noisy oscillator and one strong signal can cause the same unfortunate results.[9]

The noise blanker in the Atlas 210X also degrades its dynamic range, diminishing the advantage of the double-balanced passive mixer. The 210X transceivers we tested had a dynamic range of between 73 and 81 dB, depending on the band selected. When the blanker was turned on, these numbers dropped by 3 dB.

There is little reason for a noise blanker to include additional gain stages which can degrade receiver performance. The TS-820 has only a 4-diode balanced blanker gate in its i-f chain; therefore, it does not reduce the overload capability or significantly increase the noise floor. Alternately, a balanced mixer or push-pull i-f stage can be gated for noise blanking; this requires no additional gain stages in the signal path.

product detectors

Another area that could use additional work is that of the product detector. As the name implies, its output should be the product of the two input signals. If



IMD generated at the output of the R-4C second mixer by two 5 mV signals at the antenna input. The signal spacing was 2 kHz. The receiver was tuned so that the narrow second i-f filter was positioned away from any test signals or IMD products. Therefore, with no signal reaching the AGC, the receiver gain is at maximum and the S meter reads S1.

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*A recent independent measurement by DJ2LR showed the intercept point of the TS820 to be −12 dBm.

BFO injection is removed, output should go to zero. If this is not the case, as in the Heath HW series, envelope detection is also occurring, which causes audio distortion. On the other hand, the 6GX6 product detector in the Drake R-4, TR-4, and TR-4C, and the 6BE6 in the Drake 2A and 2B, works very well.

Other extraneous outputs can occur even if the detector is acting solely as a product mixer. A detector should be a double-balanced, or other arrangement, which provides good isolation between input and output. The two-diode detector in the R-4B and R-4C is not a double-balanced design and allows the detected audio to leak back and envelope modulate the last i-f stage. This resultant signal is detected in the agc, which then tries to follow it at an audio rate, especially (but not only) when the faster time constants are in use. This audio output sounds slightly distorted, and is noticeable on ssb as well as CW. In addition, BFO injection is marginal, causing additional distortion on AGC attack.

We decided to replace the product detectors in our R-4C receivers, but wanted to use a device that was compatible with the existing drive and impedance levels. The MC1496L active double-balanced mixer looked like a good choice, and with minor circuit changes from the data sheet, was installed in the receiver. The modulation of the i-f by the detected audio was eliminated, resulting in cleaner sounding audio. AGC attack distortion was further reduced.

The MC1496's main drawback is its high number of associated components. Eleven 1/4-watt resistors, nine capacitors, and the IC had to be squeezed on a 1-3/4 by 1-5/8 inch (4.5x4.1cm) board which was nestled between the audio output transformer and the adjacent PC board (see **fig. 3**). All R-4C owners, whether they change product detectors or not, should add a 0.0015 μF capacitor across R83 in the audio amplifier. This corrects a phase error in the feedback circuit, and eliminates an undesirable peak in the audio frequency response which accentuates harmonic distortion. The Kenwood TS-820 and the Atlas 210X both use a double-balanced diode product detector that works quite well, and needs considerably fewer parts, but they are low-impedance devices not easily adapted to some circuitry.

conclusions

We have discussed several popular receivers and noted some of their strengths and weaknesses. Some problems can be corrected in the field, while others go beyond the scope of a weekend project. We've also investigated two ways to improve a receiver's susceptibility to overload, so that it can better handle today's high-level rf environment: redistributing the gain and increasing the early-stage selectivity with an additional filter. The importance of having a wide choice of adequate narrow filter selectivity, without leakage, was also mentioned. While most of our circuit changes have been applied to one specific popular receiver, the Drake R-4C, the ideas can be extended to other sets. A method of checking a receiver's overload capabilities which requires no test equipment was also described. Thus receiver changes can be evaluated as to their effect on dynamic range.

The real key to how a receiver performs is its net gain distribution, particularly in relation to the location of selectivity determining elements. A receiver must have a great deal of gain from its antenna to the speaker to be able to receive weak signals. But if too much gain is placed ahead of a narrow filter, the receiver is bound to overload and generate interference of its own.

How a receiver will perform in real-life situations can be determined in the lab, but only if it is tested in a manner that approximates the real world. We feel that the present 20-kHz signal-spacing method can be quite misleading, and should be augmented with our 2-kHz test procedure. If the two readings are significantly different, then further investigation is warranted.

As we stated at the beginning of this article, receivers have improved in many ways, especially over the past 15 years; at the same time, dynamic range has diminished. Amateur radio operators should be demanding excellence in this critical parameter. Improvements in receiver versatility need not reduce system performance, as we have so often observed. Potential problems can be eliminated in new equipment by state-of-the-art design or by retrofitting existing receivers. All that will be lost is some internally-generated rf interference!

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