Receiver Testing

By Charles T. Rauch, Jr. W8JI

We certainly enjoy talking about how good our receivers are. Unfortunately most talk centers around hearsay, useless parameters, or very subjective "feel good" reviews.

The only readily available detailed measurements come from ARRL and RSGB reviews. **While the ARRL and RSGB generally do a good job of reviewing equipment, they unfortunately publish somewhat meaningless wide-spaced data in receiving tests.** Even with excellent wide-spaced performance, close-spaced performance can be horrible!

Worse yet, reviews push important data back to the "expanded reports" and the data generally available to the casual non-technical reader is most "fluff and feel-good exaggerated hype". We can read that in advertisements, we don't need to see it in an independent review. The single worse review I ever read, outside of reviews in magazines that actually don't test the radios, was the IC-7800 review in QST. That review should go down in history as a way to ***NOT*** write a review. A person using the IC-7800 actually wrote the IC-7800 worked much better than a receiver he never even compared it to! How can a person know one receiver works better than another receiver, unless they have them side-by-side listening to the same signals at the same time? Another comment was he "seemed to hear" clicks and QRM further away than normal (although he didn't have both receivers up at the same time), and the fact he had more QRM meant the receiver was so much better it could hear QRM other receivers did ***NOT*** hear!

Hey, my HQ-180 hears QRM that my other receivers don't hear. It hears BC stations that aren't really there, it hears QRM from people 10kHz up the band that isn't there on other receivers. I don't think that is a feature, but maybe I am wrong. Maybe people enjoy QRM.

Radio manufacturers, knowing magazines focus on wide-spaced performance, do only what is necessary to pass the tests and look good on paper.

Why Test at Wide Spacing?

Most manufacturers and many magazines test at wide spacing and focus on those results. I think that is wrong and I bet if you think about it you will agree with me.

How many of you are bothered by signals 40kHz up the band? If you have the same experience I do, it's the people 1-2 kHz away on CW and 2-10 kHz away on SSB that tear things up.

Keep this in mind! A 2 kHz IM3 test evaluates performance with unwanted signals two and FOUR kHz away. A 20 kHz test checks for problems with a signal twenty and FORTY kHz away.

When we have on-the-air interference problems working weak signals, it is almost always with stations a few kHz or less away. Why would most of us care about a test or data at 20kHz or wider, when the bothersome signals are a few kHz up or down from us? Wide-spaced tests inflate performance, and give us meaningless numbers for real-world performance.

Wide-spaced testing only evaluates RF amplifier and first mixer performance. Common design problems are easily and often missed when wide spacing is used. The weakest link is almost always downstream of the first mixer. There are several specific examples:

1.) Receivers using DSP-based filtering systems for primary narrow selectivity.

2.) Receivers with poor 2nd mixer design (the R4C)

3.) Design errors in noise blankers, such as the **Yaesu's noise amplifier** design error

It's no wonder receivers have shown very little performance improvement over the years. Manufacturers evaluate performance on nearly useless wide-spaced measurements. They obviously only want to pass the wider test signal frequency spacing tests, because that is what we look at. Looking at 10kHz or wider tests, we all assume things are getting better. In actual use, most of our problems come from signals nearly on the same frequency, not 10kHz and especially not 50kHz away!

The only truly valid performance test is one where BOTH test signals are within the roofing-filter bandwidth. When close-spaced performance is good, wide-spaced performance is just as good or better. This is true for older radios and modern radios.

We also need to be factual in performance assessments. Too many feelings get in the way of being objective.

Receiver Myths

PIN Diode Modifications

Save your money. PIN diode replacement never has changed performance in any receiver I've listened to or measured. PIN diode modifications don't change distortion, blocking, noise, or any other parameter. A normal signal diode with proper bias is just as good.

PIN diodes function as "RF switches" or "linear RF resistors" only when the carrier lifetime exceeds the period of an RF cycle by a large margin. Most of the diodes used in PIN modifications do not have long enough carrier lifetime to even behave like a low-distortion linear resistance, let along a pure switch. They really aren't any better than manufacturers stock diodes, with the PIN diodes barely being linear at 30MHz let alone at 455kHz. The whole "PIN diode thing" would be laughable if it wasn't costing people money!

If you have even measured a real difference, please e-mail and tell me what radio it was and what the test conditions were. If you are only going by emotion or feeling, don't bother reporting that. If I spent several hours and/or a few hundred dollars changing diodes and could not A-B the change, I'd probably think things got better also.

Drake R4C

The R4C is elevated to a status far above the realities of its actual performance. The R4C, like many DSP radios, has a wide performance variation between close and wide spaced tests.

This is especially true with the early S/N MOSFET mixer R4C's. With a wide-test, all R4C's look "good". That's because a wide test only checks the tube-type RF-amplifier and vacuum tube 1st mixer. Even though the R4C RF amp does better with higher screen voltage and the first mixer suffers from very low injection, the first two stages are still reasonable.

The problem is in the Drake 2nd mixer. The second mixer in the Drake ranges from poor to useless. The MOSFET mixer versions of the R4C are identifiable by looking at the MODE switch. If the MODE switch has CW 1.5, .5, and .25 positions the receiver has a tube (6BE6) 2nd mixer. If it is labeled CW1 and CW2, it has the horrible MOSFET mixer.

A few Drake website claims there is little or no difference between early serial number R4C's using MOSFET 2nd mixers and later R4C's using vacuum tube 2nd mixers. Nothing could be further from the truth. Worse yet, these pages steer people into a wide 6- or 8-kHz roofing filter for weak signal CW work, a very foolish choice as we will see by actual measurements. For serious CW work, the Sherwood Engineering 600-Hz roofing filter is an absolute must! R4C's have far too much filter leakage to be useful on crowded bands using CW with a wide roofing filter.

Roofing Filters

In order to significantly improve close-spaced performance a roofing filter has to attenuate signals on *adjacent* channels. We could have strong and weak signals CW alternating every 500Hz across the dial, assuming our transmitters were cleaned up. In the case of CW a roofing filter, to be useful, needs to be about 500Hz wide or less.

For SSB, we could consider channel width 3kHz. A roofing filer really needs to eliminate the adjacent channel up and/or down, and that means a roofing filter that passes only 3kHz or less.

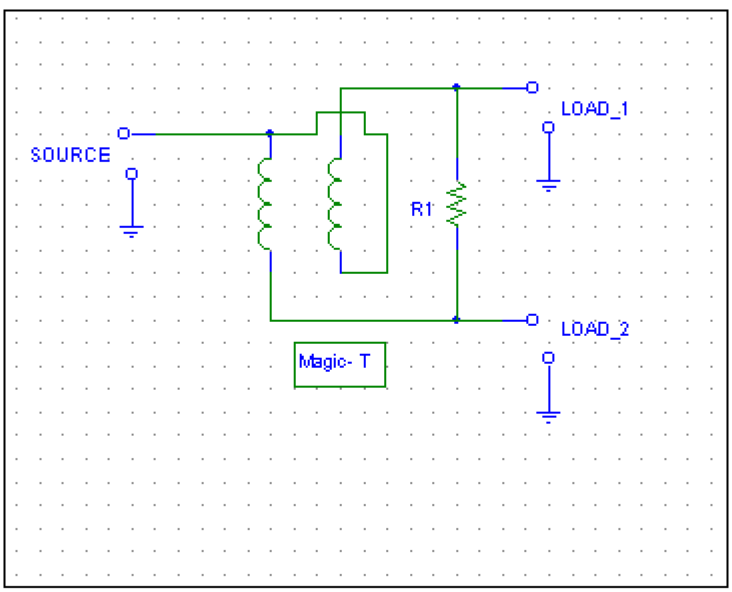
While the typical wider roofing filters do a good job knocking down problems caused by signals up or down the band several kHz, they don't do anything for signals within the bandwidth of the roofing filter.

Testing Radios

TEST SETUP

My test setup uses two low-noise crystal oscillators. One oscillator is fixed on 1840-kHz, the other oscillator is selectable at 1840.5, 1842, or 1850-kHz (***note***: I now use variable frequency generators). Both oscillators use low-noise CATV transistors, and provide 20dBm output. These oscillators each feed a 1dB per step attenuator, with a total attenuation of 160dB available.

The attenuated outputs are fed to a "Magic T" combiner. "Magic T's", like every low-loss passive combiner system, are load impedance sensitive. Any mismatch reduces generator port-to-port isolation. In many cases, marginal generator-to-generator isolation can cause IMD in the signal sources. This generator-sourced IMD corrupts readings, changing IMD performance. To reduce combiner mismatch, the output of the magic "T" feeds a small ~3dB attenuator.



Signal level from each individual source can be varied in 1dB steps from +20dBm to -140dBm. +13.5dBm is the maximum level available, after combiner system losses of 6dB are added, for a final receiver signal range of +13.5 to -146.5 dBm. This range is ideal because my own transmitter is typically +15dBm on my closest receive antennas, while my daytime 250Hz bandwidth noise floor is near -140dB. Most of my receivers have sensitivities in the -140dBm range, allowing them to marginally get down to noise floor in the daytime. (Noise increases 10-20dB at night, on quiet nights, because of distant noise sources that propagate via sky-wave.)

Note: *Most setups use a single attenuator after the combiner, I chose not to do that. To reduce generator IMD, I decided to attenuate each signal source with carefully matched attenuators. If a test requires 30dB of attenuation, generator-to-generator isolation will be the sum "magic T" isolation and each attenuator pad isolation. In this case, generator-to-generator isolation would be well over 90dB, far more than I could obtain with the "Magic T" alone.*

The Magic-T combiner also has a 3dB 50-ohm output attenuator. This pad helps stabilize load impedances seen by the "Magic T", insuring return loss is at least 6dB. Total attenuation through the "Magic T", including the internal attenuator pad, is 6.5dB. The port-to-port cross talk of the magic "T" can be nulled with a small trim pot. This adjustment is only necessary when doing tests with near-zero attenuation and a mismatched receiver.

MEASUREMENTS

Since virtually every receiver overloads in stages after the attenuator or pre-amplifier, there probably is no compelling reason to measure receivers with the attenuator on. Adding an attenuator will not increase the dynamic range, it will simply move the raw measurement numbers higher. In other words, we don't care what the absolute numbers are...we can always add or remove gain external to the receiver. What we do care about is *dynamic range* of the system, both for blocking (a strong signal makes the weak signal disappear or get noisy) and intermodulation products. The lower the dynamic range numbers, the worse the receiver will be.

Measurements involve three basic procedures, all measured in dBm (dB milliwatts).

MEASURING MDS

A conventional signal generator is used to measure Minimum Discernable Signal (MDS). This point is where the signal is just clearly audible, about 3dB out of the noise floor.

MEASURING BDR

Blocking Dynamic Range is measured by setting one oscillator (or the signal generator) to a test frequency either 2 or 10 kHz above the interfering signal. This test is equivalent to having a single strong station come on a certain amount away from a very weak station you are trying to copy, and making your receiver lose volume or have a hiss that increases compared to the weak signal's level.

To minimize generator noise, the low-noise crystal oscillators are used for the strong signal. This creates a "perfect" zero bandwidth strong signal with virtually no broadband noise.
The level of the strong signal is adjusted until the slightest detectable change in S/N ratio occurs. The difference between the MDS and the level causing the blocking is the blocking dynamic range. This will be the ratio of the weakest to strongest signal the receiver can handle without losing a noticeable amount of weak-signal sensitivity, if the strong signal is a perfect signal and the weak signal is right at noise-floor.

MEASURING IMDR

Intermodulation dynamic range, or two-tone dynamic range, is measured by running two equal strength signals (from the low-noise oscillators) into the receiver with a certain test spacing.
This test is equivalent to having two strong signals very near each other, with just the right spacing to cause a mixing product to fall on top of a noise-floor signal you are trying to copy.
When the signal level of the mixing product is just audible above the noise floor, the ratio of the strong signals to the MDS (minimum discernable signal) becomes the IM dynamic range.
Poor IMDR performance shows up as splatter on SSB and as bloops, bleeps, and random musical thumps or phantom signals on CW.