Terms Explained for the Sherwood Table of Receiver Performance

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The following definitions apply to data values in the Receiver Test Data table of measurements taken by Sherwood Engineering at www.sherweng.com/table.html. The definitions follow the table columns from left to right.

Noise Floor

Noise Floor establishes a limit for the weakest signal that can be heard by the receiver. (This assumes no additional signal processing to decode or detect the signal.) Noise Floor is measured at a 3 dB S+N/N ratio with a 500 Hz CW filter bandwidth, assuming the radio has a CW filter. (There is a note with the measured value if the radio only had an SSB bandwidth. Older radios (Drake, Collins) had no switchable preamp. Compare them to a modern radio with Preamp ON or Preamp #1 ON.)

Noise Floor is similar to the Sensitivity measurement on SSB which is given in microvolts (µV). (see the definition below) Due to the wider bandwidth used when receiving SSB, the signal vs. the noise at the specified Sensitivity level sounds about the same by ear.

To measure Noise Floor, a signal generator is fed into the receiver and the output at the speaker is read on a true-RMS voltmeter.[1] The generator level is adjusted so the difference between readings when the signal is in or out of the passband is 3 dB. In other words, so that the signal is 3 dB stronger than the receiver noise.

Practically, a measurement of the receiver's noise floor is only significant on the higher frequency HF bands. This is due to the higher level of external band noise (atmospheric and man-made) on the low bands, assuming you are receiving on your transmit antenna. If you are using a Beverage or a low-gain loop, then noise floor could be an issue on any band.

A Noise Floor value of -135 dBm is more than adequate on 15 meters in a quiet rural location. A lower noise floor (-138 dBm) might be useful on 10 meters in a quiet location. Serious 6 meter DXers often use an external low-noise preamp to get the noise floor down to or a few dBm lower than -140 dBm. If you are in the city, hardly any of this matters due to all the local noise. (On 15 – 6 meters, hardline would be important to reduce the feed line loss to make the best use of the lower Noise Floor performance.)

AGC Threshold

AGC Threshold is the signal level below which the AGC system is not active and the receiver gain is maximized. Again, this is mainly of significance at 14 MHz and up, since the S meter often shows AGC action (an up-scale reading above S0) due to noise on the lower-frequency bands.

If the band noise is high enough to cause AGC action and the S meter reads up-scale by several S units, signals below the AGC threshold will not be readable. Some newer radios let you set the AGC threshold, though it may not settable by band which would be helpful. For modern radios with a switchable preamp, I prefer an AGC Threshold of 2.5 µV with the preamp OFF and 1 µV with the preamp ON.

Blocking

Blocking occurs when the radio is just beginning to overload and is observed as a reduction in gain due to a signal outside the passband. It is measured as the range between the Noise Floor and the signal level that causes a 1 dB reduction in gain at some spacing from the desired signal. Sherwood uses 100 kHz signal spacing.[3] The measured level for Blocking is usually about 30 dB greater than the Dynamic Range of the radio (described below). If a receiver has a good Dynamic Range, then it will have a good blocking level. 130 dB is a good Blocking value.

With direct sampling radios, blocking is technically not the correct term. An A-to-D converter has an absolute overload point at which the signal voltage exceeds the maximum value that can be digitized. This is unlike a 1 or 3 dB gain compression point where the gain of the receiver begins to reduce gradually. Note: Instantaneous overload from many strong signals adding together may cause a receiver's overload indicator to flicker, but may not have a sustained audible effect.

Sensitivity

This figure of merit has been around since at least the 1940s. I measure it in µV at a 10 dB S+N/N ratio, usually with a 2.4 kHz SSB filter bandwidth. To measure Sensitivity, a signal generator is fed into the receiver and the output at the speaker is read on a true-RMS voltmeter.[1] The generator level is adjusted so the difference between readings when the signal is in or out of the passband is 10 dB. In other words, so that the signal is 10 dB stronger than the receiver noise.

Phase Noise

Old radios (Collins, Drake, Hammarlund, National) used an analog VFO or PTO (Permeability Tuned Oscillator) and crystal oscillators for tuning and mixing. Noise in the local oscillator (LO) chain was minimal. When synthesized radios came along in the 1970s, phase jitter in synthesizer added significant noise sidebands to the LO signal. This noise mixes with strong signals outside the passband of the receiver and add noise on top of a weak signal you are trying to copy.

Phase noise is measured in a narrow bandwidth at specific offsets from the carrier (or oscillator) frequency. Most values are given in dBc / Hz, meaning dB with respect to the carrier signal's amplitude measured in a 1 Hz bandwidth. (www.radioelectronics.com/info/t_and_m/spectrum_analyser/measuring-phase-noise-measurements.php)

This can be a significant problem, such as: You have a neighboring ham close by, during Field Day when there are multiple transmitters at the same site, and certainly in a multi-multi contest station. You would like the measured Phase Noise value to be lower than -130 dBc / Hz at 10 kHz. Non-synthesized radios (Drake, Collins, etc.) have so little noise the measurements could be made closer-in, between 2 and 5 kHz offset from the carrier signal.

Note: Very few legacy superheterodyne receivers have low phase noise, though most direct sampling receivers have low phase noise. The ARRL has clearly emphasized low phase noise (RMDR) since 2013. (RMDR = Reciprocal Mixing Dynamic Range)

Front End Selectivity

This refers to the type of filter in the receiver's front end.[4] Front end selectivity is less of an issue today as almost every receiver has a half-octave filter in the front end. For legacy receivers, the R-390A had the best mechanical front end (preselector) with the Drake and Collins somewhat behind. The R-390A preselector tracked the tuning knob, while you had to peak the Drake and Collins by hand. A very few receivers today have an preselector that follows the main tuning dial.

Note: Direct sampling receivers are more prone to overload from very strong signals within a given band since they have no roofing filter as in down-conversion receivers. Some direct sampling receivers have a tracking preselector that helps to some extent in environments like Field Day or having another ham near your QTH.

Filter Ultimate (Attenuation or Rejection)

Signal leakage around the receiver filters was an issue in superheterodyne receivers. Either the filter didn't have enough poles, or there was leakage around the filter (a.k.a. - *filter blow-by*). 70 dB was a typical value for the ultimate amount of attenuation a filter could provide.

As receivers improved, dual-conversion became common, with a crystal filter at an IF in the range of 5 to 10 MHz, then another filter at 455 kHz. Even if each filter only provided 70 dB attenuation, by the time the out-of-passband signal was attenuated twice, filter leakage was a non-issue: 2×70 dB = 140 dB.

Synthesizers with phase noise replaced VFO/PTO/crystal oscillators. Now the problem became that of close-in phase noise limiting the rejection of the filter. Instead of hearing signal leakage on the edge of the filter, one hears noise from the LO, called *reciprocal mixing.*

I make a Filter Ultimate measurement a few filter bandwidths away from the passband. On CW that would be a couple kHz and on SSB that would be 4 to 6 kHz. Most of the legacy superheterodyne receivers near the top of the list are phase-noise limited. Most of the older radios near the bottom of the list are leakage limited, if one makes a generalization.

Note: New direct sampling receivers generally have both excellent phase noise and filter rejection. On SSB transmitted splatter from a station a few kHz away is typically the reception limit, not filter performance.

Dynamic Range

In 1975 the League had started testing noise floor and dynamic range, new concepts for most amateurs. I started testing radios in 1976 because the ARRL rated the Drake R-4C very highly, but in a CW contest it was terrible: the receiver was easy to overload in a CW pile-up, so I tried to figure out what was wrong with their testing. When a receiver is overloaded, it starts generating spurious signals on its own from the distortion created by the overload.

Dynamic Range is the difference in dB between the noise floor and the level of input signals at which two strong test signals create distortion or spurious signals in the receiver that are equal in strength to the noise floor. The receiver thus can handle that range of signals before the strong signals just start to overload the receiver. *Spurious Free Dyanmic Range* (SFDR) measures how well the receiver can handle strong undesired signals at the same time as a weak desired signal, without overload creating spurious signals.

The League originally measured Dynamic Range using 20 kHz test signal spacing, which was reasonable at the time. But as multi-conversion receivers became the norm, this test was inadequate: The Drake example was a case in point. When the two test signals are 20 kHz apart, the overload distortion products are 20 kHz above and below the pair of test signals. In other words, the League was testing as if the QRM was always going to be 20 and 40 kHz away! In reality the QRM is likely going to be close by because the strong signals that create the QRM are likely to be close by.

In 1977 I published an article in *Ham Radio* (magazine) discussing this subject.[2] I tested the offending R-4C at 2 kHz in addition to 20 kHz. In that case the 20 kHz dynamic range was over 80 dB, but the 2 kHz dynamic range was less than 60 dB.

The roofing filter of the R-4C is 8 kHz wide, and in a CW contest, there were many signals inside that 8 kHz filter, overloading the receiver. I installed a 600 Hz roofing filter in the R-4C, and the problem went away. When testing the Sherwood-modified R-4C at 2 kHz spacing, the dynamic range was over 80 dB, just like it was with the 20 kHz test.

Most receivers in the 70s and 80s had gone to up-conversion for two reasons. This got rid of the need for a preselector and it allowed general coverage reception without a gap at the first IF frequency. In an up-conversion receiver, the first IF was always above 28 MHz, and often above 50 MHz. The first IF filters were at least 15 kHz wide, and that created the problem. Almost all of these receivers had a dynamic range around 70 dB. That was barely adequate for SSB and inadequate for CW.

In 2003 the Ten-Tec Orion came along, and it went back to a 9 MHz first IF (instead of 40 to 70 MHz), and offered a narrow CW roofing filter like I had added to the Drake. It was the first commercial receiver to perform better than the Sherwood-modified R-4C with a roofing filter. Later the Elecraft K3 came to market, and now Yaesu and Kenwood have what is now called "down-conversion" receivers with a low-frequency first IF.

For more than 40 years I have been testing radios, and I decided to sort the table on my website by close-in dynamic range at 2 kHz spacing. This was the "acid test" for CW contest and DX pileup operation.

What do you need in the way of close-in Dynamic Range? You want at least 70 dB for SSB and at least 80 dB for CW. A 10 dB cushion would be nice so that requires 80 dB for SSB and 90 dB for CW. Today there are approximately 20 radios meeting that specification.

Note: Several transceivers have multiple listings on my website. In some cases, like the K3 which has been available for over 10 years, the performance has improved over that decade. There are several "second samples" of radios tested over the past 1 to 5 years. Direct sampling receivers have more variation from sample to sample than legacy superheterodyne receivers.

Notes:

[1] Since receiver noise has such a low crest factor, I have found that one can make reasonable measurements with an average reading meter like the HP 400E or the 400EL. The same comment applies to the Sensitivity measurements. Parallel measurements with an HP 3400A RMS meter and an HP 400EL average reading meter found both meters gave the same results.

[2] "Present-Day Receivers - Some Problems and Cures," *ham radio*, December 1977, page 10

[3] I measure at 100 kHz spacing because for years before RMDR was defined, phase noise typically dominated at 20 kHz. I also measure at the 3 dB compression point, while the ARRL uses 1 dB. I measure the blocking of a 1 µV signal since that is below AGC threshold on modern transceivers with the preamp OFF. When one measures an S5 signal as the signal being blocked, the AGC of the receiver will compensate for the gain compression until it runs out of AGC range. With the typical RMDR of synthesized radios, noise being measured by the RMS meter will read higher instead of the audio going down 1 dB. As a result, I had to use a spectrum analyzer such as an HP 3585A or an HP 3561A. It was virtually impossible to measure a 1 dB compression point that was being buried in noise from poor RMDR. Thus, I use a 3 dB compression point instead of 1 dB. As the state-of-the-art has improved for RMDR, it is likely easier to measure the 1

dB compression point today, noting that for direct sampling radios, that measurement is not meaningful.

[4] The type of filter is further specified by the letter preceding the description:

- A+ tracking preselector like in an R-390A
- A tracking preselector like in an IC-7800, IC-7851, IC-7610, or TS-990S.
- A- bandpass with unusually high selectivity. Flex 6600, for example, but in this case with high insertion loss, thus the poor noise floor without a lot of preamp gain.
- B typical bandpass or half-octave front end
- C would be a mediocre bandpass filter or preselector
- D would be a very limited front end, like the Flex 6300 which is only a HPF at 1.7 MHz and a LPF at 55 MHz, or octave bandpass.