# Terms Explained for the Sherwood Table of Receiver Performance

Starting left to right

**Noise Floor:**

Noise floor measures how weak of a signal you can hear. Practically it is only of significance on the upper HF bands and 6 meters due to the higher level of band noise on the lower bands. This assumes you are listening on your transmit antenna. If you are using a Beverage or a low gain loop, then it could be an issue on any band.

The noise floor is measured with a 500 Hz CW filter bandwidth, assuming the radio has a CW filter. There is a note on the measurement 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. A noise floor 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 -140 dBm or a few dBm lower. 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 feedline loss to make the best use of the noise floor.)

Noise floor is quoted in dBm (power). Consider it a similar measurement to Sensitivity on SSB, which I quote in microvolts (uV). Noise floor is a 3 dB S+N/N ratio, usually measured at 500 Hz bandwidth. Sensitivity is a 10 dB S+N/N ratio, usually measured with a 2.4 kHz bandwidth for SSB. Due to the wider bandwidth on SSB, the signal vs. the noise sounds about the same by ear.

**AGC threshold:**

The threshold is the signal level below which the receiver gain is running wide open. Again this is mainly of significance on 20 meters and up since the S meter often reads up scale on noise on the lower bands. If band noise reads up-scale a few S units, a signal is never going to be below the AGC threshold. Some newer radios let you set the AGC threshold, though it may not be memorized by band, which would be helpful. For modern radios with a switchable preamp, I prefer a threshold of 2.5 uV with the Preamp OFF and 1 uV with the Preamp ON.

Note: SDR radios such as Apache, Elecraft and Flex have 6 dB for an S unit. Most Japanese radios have 3 dB for an S unit. 6 dB per S unit allows the meter to read on scale for much wider range of signals. In other words the signal range between S0 and S9 is either 27 dB for 3 dB per S unit or 54 dB for 6 dB per S unit. In general signal readings above S9 are accurate.

## Blocking:

Blocking occurs when the radio is just beginning to overload from a signal outside the passband. It is usually about 30 dB above the Dynamic Range of the radio (to be described below). If a radio has a good dynamic range, then it will have a good blocking number. 130 dB is a good number. With direct sampling radios, blocking is technically not the correct term. An ADC (analog to digital converter) has an absolute overload point in voltage (not power), unlike a 1 or 3 dB gain compression point of a preamp or gain stage. Note: Instantaneous overload from many strong signals may cause the overload indicator flicker, but may not have an audible side effect.

## Sensitivity:

This figure of merit has been around since at least the 1940s. I quote it in uV, as mentioned above so comparisons can be made over decades of radio designs. To measure it, a signal generator is fed into the radio, and the output at the speaker is read on an RMS volt meter. The generator level is adjusted so the difference from when the signal is tuned in vs. when the signal is out of the passband equals 10 dB. In other words, the signal is 10 dB stronger than the receiver noise. Likewise, when one measures noise floor in CW mode, when the signal is tuned in it goes up 3 dB.

## Phase Noise:

Old radios (Collins, Drake, Hammarlund, National) used a VFO or PTO and crystal oscillators to tune the bands. Any noise in the local oscillator (LO) chain was minimal. When synthesized radios came along in the 70s, the LO had noise on it. It is caused by phase jitter in the circuit, and puts significant noise sidebands on the LO. This can mix with a strong signal outside the passband of the radio and put noise on top of the weak signal you are trying to copy.

This is a significant problem in some cases: 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 number to be better that 130 dBc / Hz at 10 kHz. A non-synthesized radio, such as a Drake or Collins, has so little local oscillator noise the measurements were made closer-in between 2 and 5 kHz.

Note: Very few 20 to 30 year old synthesized superhet radios have low phase noise, while most direct sampling radios have low phase noise. The ARRL has clearly emphasized low phase noise (RMDR) since 2013. (RMDR = Reciprocal Mixing Dynamic Range) To convert my LO Noise (dBc/Hz) column data to RMDR subtract 27 dB for a 500-Hz bandwidth.

## Front End Selectivity:

This is less of an issue today as many radios have a half-octave filter in the front end. The R-390A had the best mechanical front end (preselector) ever made, 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. Some high end superhet radios today have a preselector that follows the main tuning dial.

Note: Direct sampling radios are more prone to overload from very strong signals (S9+60) within the front-end L/C filter. They have no roofing filters since there is no IF. Note: Some IF sampling radios from Yaesu have roofing filters followed by an ADC around 9 MHz. Some direct sampling radios have a tracking preselector that helps to some extent in environments like Field Day or if another ham is very near your QTH.

## Filter Ultimate:

In the old days filter leakage was an issue. Either the filter didn't have many poles, or there was leakage around the filter (filter blow-by). 70 dB was a typical number. As radios improved, it became common to have dual conversion, with a crystal filter at 5 to 10 MHz, and 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.

Then along came synthesized radios with phase noise. Now the problem became the close-in phase noise limiting the rejection of the filter. Instead of hearing signal leakage on the edge of the filter, one would hear noise from the LO, called reciprocal mixing.

I measure filter ultimate a few filter bandwidths away from the passband. On CW that could be at 1 kHz, and on SSB that could be 4 kHz. Most of the legacy superhet radios 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 radios 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:

Now we get to the nitty gritty. I started testing radios in 1976 because the ARRL rated the Drake R-4C very good, but in a CW contest it was terrible. The radio overloaded in a CW pile-up, so I decided to figure out what was wrong with their testing. In 1975 the League had started testing for noise floor and dynamic range, new terms for most amateurs. Spurious Free Dyanmic Range measures how the radio can handle strong undesired signals at the same time as weak desired signals without generation additional interference in the radio.

Dynamic range is defined as the level in dB when two strong test signals make distortion in the radio equal to the noise floor. The radio thus can handle that range of signals before the strong signals just start to overload the radio.

The League originally only tested the dynamic range at 20-kHz test spacing, which was reasonable at the time. But as multi-conversion radios 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 each side of 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.

In 1977 I published an article in "ham radio magazine" discussing this subject. 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 can be many signals inside that 8-kHz filter causing overload. I installed a 600 Hz roofing filter in the R-4C first IF, and the problem went away. When testing the Sherwood modified R-4C at 2 kHz, the dynamic range was over 80 dB, just like it was with the 20-kHz test.

Most radios in the 70s and 80s had gone to up-conversion for two reasons. This got rid of the necessity of a mechanical preselector, and it allowed general coverage without a dead spot equal to the first IF frequency. In the up-conversion radio, the first IF was always above 10 meters, and often above 6 meters. First IF filters were at least 15 kHz wide, and there was the problem. The Drake 8-kHz first IF was bad enough, and now almost all the radios for 20+ years had a first IF what was at least 15-kHz wide. Almost all of them had a close-in dynamic range around 70 dB. That was barely adequate for SSB and inadequate for CW.

For 50 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 & RTTY contest / DX pile up operation.

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

What do you need in the way of close-in dynamic range? Of the top 25 individual models on my website, the values range from 110 dB to 87 dB. Right in the middle is a 100 dB radio that was unheard of 20 years ago. Any of these choices work well in most RF environments for DXing and contesting, let alone daily operating.

Note: Several transceivers have multiple listening on my website. In some cases for example the K3 and K3S was available for over 10 years. The performance improved over that decade. There are several "second samples" of radios tested over the past 1 to 5 years. Direct sampling radios have more variation from sample to sample than legacy superhet radios. If comparing direct sampling radios look to see if there are two data sets for the same model. Dynamic Range data scatter between random samples of the radio is generally less than 6 dB

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