Reciprocal Mixing Test Procedure

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A Reciprocal Mixing Dynamic Range (RMDR) test evaluates a receiver's phase noise, or phase noise plus AM noise, which is called *composite noise*. For evaluating amateur equipment, we are interested in both kinds of noise, and the normal test procedure will measure both types of noise. (Some dedicated phase noise measuring equipment will only measure phase noise and ignore AM noise.)

Equipment to test RMDR has the same requirements as testing for intermodulation dynamic range. For third-order dynamic range (DR3) measurements, two very-low-noise signal generators (oscillators) are required. For RMDR, only one generator is required. Very high generator-to-generator isolation is required for DR3, on the order of 120 dB. No such issue exists for RMDR, as only one generator is used.

Until recently, most synthesized amateur transceivers were RMDR-limited rather than DR3-limited, at least at the close spacing of 2 kHz. Some are even RMDR-limited at 20 kHz, as can be observed on my website (www.sherweng.com/table.html). Any radio with an "f" footnote in the two Dynamic Range columns is RMDR-limited.

Measuring Noise Floor

To measure RMDR, one first must measure the Noise Floor of the receiver. The RMDR value will be referenced to the receiver Noise Floor. This is the same way in which DR3 is referenced to the receiver Noise Floor.

As with DR3 measurements, the audio from the receiver (transceiver) is fed to an analog true-RMS voltmeter with a dB scale. Examples of appropriate voltmeters include:

HP 3400A, HP 3400B, Ballantine 323, HP 339A, Sound Technology 1710A, etc.

From a practical standpoint, an average-reading meter can be used in place of the true-RMS meter, such as an HP 400E or 400EL.

It is desirable to be able to hear the audio signal and have the meter connected at the same time. I use an Icom SP-20 speaker that has an output jack along with input jacks. The analog meter is attached to the output jack.

Let's walk through a noise floor measurement:

One can measure RMDR using any filter bandwidth, but normally it is done in a 500 Hz bandwidth, just like when measuring third-order dynamic range (DR3).

A signal is fed into the receiver and the audio level is measured on the analog meter using the dB scale. Since noise floor is being measured, this test level should not be moving the receiver's S meter, as the AGC threshold is far above receiver Noise Floor. In most cases the Noise Floor will be below -120 dBm, though with some direct sampling receivers the value may be as high as -110 dBm with the preamp turned OFF.

The level of the test signal is reduced until the difference on the analog meter is 3 dB between having no signal tuned in and having the test signal tuned in. It doesn't matter which dB value on the meter is used as the reference, -3 dB, -6 dB, etc. All that matters is when the signal is tuned in, the reading goes up 3 dB.

As a reality check, it would be ideal to have a known low-noise crystal oscillator to compare to the signal generator or synthesizer being used, particularly with the highest performance radios on the market today. In my lab I have a Wenzel 7.000000 MHz crystal oscillator to compare to my HP 8642A synthesizers. An HP 8640B is not likely to have low enough phase noise, at least at close in spacing of a few kHz. Most synthesized signal generators will not be clean enough to make measurements on the transceivers listed below:

> Elecraft K3S, Icom IC-7851, Flex 6000 series, Apache ANAN 7000DLE and 8000DLE, Icom IC-7610 and IC-7300.

One note of caution as to Noise Floor measurement: If receiver Noise Floor is lower than -130 dBm, and certainly lower than -135 dBm, leakage from the oscillator or generator may be an issue. It may be difficult in such cases to make a measurement, for example, on 10.0 MHz using a piece of test equipment that has a 10 MHz frequency reference. Leakage of the 10 MHz reference may make a Noise Floor measurement difficult if not impossible.

When I make a measurement of a Noise Floor below -135 dBm, I use a 10 dB inline attenuator on the output of my HP synthesizers. (8662A or 8642A)

RMDR Measurement

It is suggested that an RMDR measurement be made on the low end of an amateur band to keep the data taken inside the ham band. Example: Set the test signal to 14.0 MHz and make measurements at higher frequencies within the 20 meter band.

Once we have a valid Noise floor measurement, the next step is to tune above the test signal at specified offsets. Since receiver filter leakage can be a problem at very close spacings, I usually test at the following offsets:

2.5 kHz, 5 kHz, 10 kHz, 15 kHz, 20kHz, 30 kHz, 50 kHz, 100 kHz, etc.

Many legacy superheterodyne receivers can be tested as far as 500 kHz from the test signal, while direct sampling radios will likely be driven into A-to-D converter overload before 100 kHz is reached. Most direct sampling radios have an overload indicator except Flex.

Start with a standard offset of 10 kHz as your first measurement. Use the analog voltmeter reference you used for measuring Noise Floor. Let's assume you used -3 dB on a scale that extends at least 1 to 3 dB above 0 dB on the meter face. Increase the test signal until noise raises the voltmeter reading from the -3 dB reference to 0 dB. There will be some fluctuation in the meter reading on the order of +/- 0.5 dB.

Example: Noise Floor is measured at -130 dBm. At 10 kHz offset let's assume the signal level that raised the voltmeter to 0 dB (a 3 dB increase) was -30 dBm. That would mean the RMDR was the difference between -130 dBm and -30 dBm, or 100 dB.

Now you can go back and make measurements at any spacing.

Converting LO Noise Measurements to RMDR

On my website there is no column labeled RMDR, as this is a relatively new term coined by the ARRL and my measurement data goes back over 40 years. You can calculate RMDR from the column titled "LO noise spacing dBc/Hz". Take this value and subtract 27 dB if you are making a measurement in a 500 Hz bandwidth. The next column lists the test spacing, which for most measurements is 10 kHz. A few modern high-performance radios will list 10 kHz and 50 kHz, and a few legacy radios before synthesizers will list an offset of a few kHz. A really old legacy radio would likely block at 10 kHz if trying to make an RMDR measurement.