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# Phase Noise in Communications Receivers

by Steve Ratzlaff

Oscillators are an essential part of any communications receiver. An ideal oscillator would have all its energy centered on the fundamental frequency, but in the real world, such is not the case. Oscillators have energy on either side of the fundamental frequency; these undesired noise sidebands are oscillator phase noise, and are usually strongest close to the oscillator's fundamental frequency. If this phase noise is excessive, receiver performance can be adversely affected under some conditions.

In the "old" days of vacuum tube receivers, oscillator phase noise was rarely mentioned since vacuum tube oscillators generally had low phase noise (quiet oscillators) and didn't degrade receiver performance. It has only been in recent times, with the introduction of the synthesized receiver, that phase noise problems have been an area of concern.

In a receiver, a desired signal from the antenna is mixed with a local oscillator signal to produce an intermediate frequency which is then filtered, amplified and detected. For example, a DX signal on 1476 kHz might be mixed with a local oscillator signal of 1931 kHz to produce an IF signal at 455 kHz (1931-1476 = 455). The problem a receiver with a noisy oscillator would experience is known as "reciprocal mixing", when undesired out-of-band signals mix with oscillator phase noise to produce in-band noise that degrades receiver sensitivity and dynamic range. In our example above, the local oscillator, tuned to 1931 kHz, might be producing noise sidebands at 1935 kHz, which will then mix with an undesired signal or noise on 1480 kHz to produce 455 kHz (1935-1480 = 455), so the 1480 signal will interfere directly with the 1476 signal in the IF filter. So the noise level or interference level of the receiver rises, depending on how far away in frequency the out-of-band signals are. The closer you tune to the undesired signals, the louder the noise level becomes, until the undesired signals become the dominant signal in the output.

A receiver's overall phase noise performance is dependent on both the oscillator phase noise and any filters used in the receiver before the mixer. As a result, receiver phase noise performance is very much affected by the frequency offset from the desired frequency. A communications receiver's phase noise might be specified at offsets of 100 Hz, 1 kHz, 10 kHz, and 100 kHz.

It is important to remember that transmitters use oscillators too, and therefore are subject to the same potential phase noise problems as receivers. Phase noise on a transmitted signal from nearby causes the same effects as phase noise generated in a receiver. The oscillator with poorest phase noise limits the performance of the system.

Oscillator phase noise is generally specified as the noise on one side of the fundamental signal, that is the Single Sideband (SSB) phase noise. It is measured in units of dBc/Hz (this means the power in decibels of the noise relative to the power of the carrier, measured in a one Hertz bandwidth). As mentioned above, an offset frequency from the fundamental carrier is used. An offset of 1 kHz means that the phase noise is measured 1 kHz from the carrier. Usually phase noise is plotted on a logarithmic scale graph, from which you can determine the phase noise at any offset desired, up to the maximum on the graph (usually 1 MHz or so).

Actually measuring phase noise of an oscillator generally involves expensive equipment that only a design laboratory might be able to justify purchasing. On the other hand, experimenters can construct equipment capable of measuring overall receiver phase noise. This information is contained in the 1989 ARRL Handbook (pp. 10-18 through 10-24; originally appeared in QST in March and April 1988), and I highly recommend it if you're interested in determining your receiver's overall phase noise performance, or if you're wanting to find out more about phase noise problems in depth.

I've been fortunate in having access to lab-grade equipment to test receivers . Over the past several years I have collected performance data on various brands of HF communications equipment, including blocking and reciprocal mixing performance. Some receivers have been multi-kilobuck units , while others have been lower-priced general-coverage receivers and