Application Note

AEROFLEX
A passion for performance.

Understanding Phase Noise Specifications for Radio Test Applications

by Mike Hermel



The phase noise specification of an RF signal generator is important for several measurements in the receiver. We will focus on receiver selectivity, adjacent channel measurements, and on-channel measurement such as In-Phase (AM) or Quadrature Phase (FM) errors and how they are all affected by phase noise. Each of these tests has a different related frequency offset that is critical for the test to be performed correctly. We will show from a simple point-of-view, why the different frequency offsets are critical for each test.

Why is phase noise important for measuring receiver selectivity?

As an example, let's say that the channel bandwidth is specified at the 6 dBc point, and the bandwidth of the IF filter is 25 kHz. This bandwidth can be adjusted for other radio applications used in today's radio systems, but the concept is the same. Selectivity would be an easy test if we only had to measure the 6 dB points; however, the difficult part of the selectivity measurement is obtaining an accurate reading measuring the 60 dBc points. For this example, we will use 40 kHz to be the 60 dBc points in determining the proper operation of the IF receiver.

The reason for the difficulty in making this measurement is directly related to the phase noise of the generator. You can see in Figure 1 (Traditional Generator Plot), the noise level of the generator from 20 kHz (Marker 4) to 40 kHz is substantially lower than from 0 to 20 kHz. Since the selectivity test measures the rejection on the edge of the IF filter, we need to integrate the generator noise across the entire transfer function of the filter, including the filter edges. The integration results need to be below -60 dBc in reference to the carrier in order to accurately measure the 60 dBc point of the filter. The math to calculate the contributed noise in this bandwidth is extensive, and beyond the scope of this paper; however, we must realize that the additive power is not flat across the band and lower frequency phase noise will add more error to the measurement. This is apparent in Figure 1 where we can see that the noise level at 1-3 kHz (Marker 2) offset is 20 - 30 dB higher than at 20 kHz offset. Granted the phase noise of the generator will be reduced (attenuated) by the side of the filter, but in this example, the filter would pass everything above a 7.5 kHz offset from the center frequency. (40 kHz less 25 kHz divided by 2, since we are looking at the low side of the filter). Even the noise at 10 kHz (Marker 3) is still 10 dB higher than the noise at 20 kHz offset. This phase noise will dominate the calculation and add a huge amount of noise to the measurement.

The phase noise at 10 kHz and below will be a huge contributor to errors in finding the corresponding frequency during the 60 dBc selectivity measurement. We determined from our tests that the phase noise of the signal generator needs to be at or lower than -110 dBc/Hz at 10 kHz offset to accurately measure the 60 dBc selectivity of the receiver.

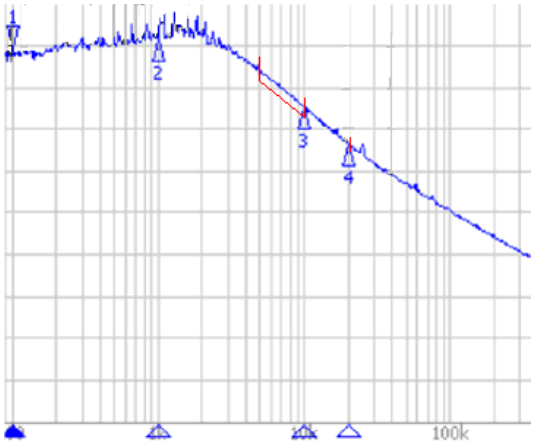


Figure 1: Traditional Generator Plot

How does phase noise affect adjacent channel rejection ratio (ACRR) measurements?

For many years, the FCC channel spacing between adjacent carriers was 25 kHz for most radio systems. Each of these carriers has a defined amount of bandwidth to pass the desired signal through its receiver. That same adjacent channel receiver also passes the same bandwidth of noise from the generator. This led the industry to standardize on 20 kHz offset from the carrier for phase noise specification. Over the last couple decades, the FCC has reduced the channel spacing down to 12.5 kHz, 8.33 kHz, 6.25 kHz, and even 5 kHz for narrowband operation. This requires a smaller frequency offset specification as the channel spacing gets narrower.

For this adjacent channel discussion, let's use 8.33 kHz channel spacing and AM modulation. We will define the modulation and noise bandwidth of the receiver to be +/- 3.33 kHz. We would have a pass band for our adjacent channel interferer at an offset frequency of (8.33 - 3.33 = 5 kHz) to (8.33 + 3.33 = 11.66 kHz). The first graph (Figure 1) shows a typical response for a generator that has a 20 kHz offset specification for phase noise. We have placed a red mark band for the adjacent channel pass-band. You can see that the adjacent channel pass-band is 10 - 20 dB higher noise level than the 20 kHz level at Marker 4.

The critical frequency offset point for measuring phase noise in adjacent channel is determined by the channel spacing and bandwidth. In the above example of 8.33 kHz channel spacing, the phase noise is critical at 5 kHz offset and would be even more critical at lower offset frequencies in narrower channel spacing cases.

How does phase noise affect the on-channel signal?

In narrow channel transceivers, the close-in phase noise is dominant for the on-channel measurements. This is true for AM, FM, and complex modulation for digital protocols. Each modulation protocol has a measurement that shows the performance of the signal on-channel. In the case of analog systems, it is measured using hum & noise, and in digital systems, it is measured using Error Vector Magnitude (EVM) or FSK error. In each instance, the measurement is adversely affected by phase noise. The primary frequency offset for phase noise that affects the on-channel measurement falls inside its pass-band. If we again use our 8.33 kHz channel with +/-3.33 kHz bandwidth, we would be concerned about the 100 Hz - 3.33 kHz region in Figure 1.

Again, you notice that at 100 Hz - 3.33 kHz (Marker 2) the level is 25 - 30 dB above the reference at 20 kHz (Marker 4). When the phase noise in this frequency range is integrated, it will be substantially higher amount of noise than if you used the 20 kHz reference number.

Therefore, in this narrowband example, the generator needs to be specified for phase noise at the 1 kHz offset frequency, not the typical 20 kHz offset. At this offset we have determined that the phase noise must be at or below -100 dBc/Hz with 1 kHz offset from carrier in order to not affect the measurement.

What would be a good choice for the phase noise on a generator?

The signal generator should have phase noise specified (Figure 2: New Generator Plot) at 1 kHz (Marker 1) and 10 kHz (Marker 2) offset. All the tests mentioned above have concerns with the phase noise at different offset frequencies, but they all fall into the region at or below 10 kHz. There will be much better results from the previous tests by using a generator with lower phase noise in the 1 kHz and 10 kHz region.

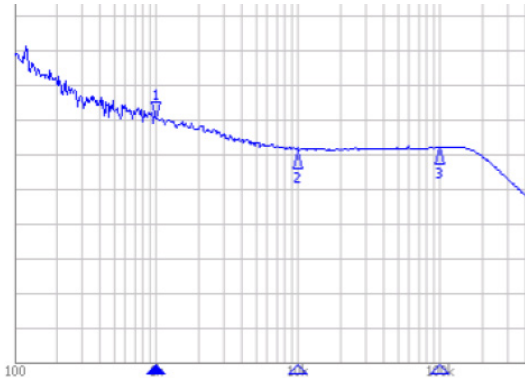


Figure 2: New Generator Plot

Conclusion

The selectivity response, adjacent channel measurement, and the on-channel modulation tests are all affected by the phase noise performance at or below 10 kHz offset frequency. Therefore, the phase noise at 1 kHz offset and 10 kHz offset should be defined on any generator and are specified on the new Aeroflex 3920B generator.

CHINA Beijing
Tel: [+86] (10) 6539 1166
Fax: [+86] (10) 6539 1778

CHINA Shanghai
Tel: [+86] 21 2028 3588
Fax: [+86] 21 2028 3558

CHINA Shenzhen
Tel: [+86] (755) 3301 9358
Fax: [+86] (755) 3301 9356

FRANCE
Tel: [+33] 1 60 79 96 00
Fax: [+33] 1 60 77 69 22

GERMANY
Tel: [+49] 89 99641 0
Fax: [+49] 89 99641 160

HONG KONG
Tel: [+852] 2832 7988
Fax: [+852] 2834 5364

INDIA
Tel: [+91] 80 [4] 115 4501
Fax: [+91] 80 [4] 115 4502

JAPAN
Tel: [+81] (3) 3500 5591
Fax: [+81] (3) 3500 5592

KOREA
Tel: [+82] (2) 3424 2719
Fax: [+82] (2) 3424 8620

SCANDINAVIA
Tel: [+45] 9614 0045
Fax: [+45] 9614 0047

SINGAPORE
Tel: [+65] 6873 0991
Fax: [+65] 6873 0992

TAIWAN
Tel: [+886] 2 2698 8058
Fax: [+886] 2 2698 8050

UK Stevenage
Tel: [+44] (0) 1438 742200
Fax: [+44] (0) 1438 727601
Freephone: 0800 282388

USA
Tel: [+1] (316) 522 4981
Fax: [+1] (316) 522 1360
Toll Free: 800 835 2352

AEROFLEX
A passion for performance.

As we are always seeking to improve our products, the information in this document gives only a general indication of the product capacity, performance and suitability, none of which shall form part of any contract. We reserve the right to make design changes without notice. All trademarks are acknowledged. Parent company Aeroflex, Inc. ©Aeroflex 2012.

www.aeroflex.com

info-test@aeroflex.com

Our passion for performance is defined by three attributes represented by the icons pictured above: solution-minded, performance-driven and customer-focused.

Part No. 46900/826, Issue 1, 11/13