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WHAT'S YOUR CNR?

By RON HRANAC

"How many of you have measured the carrier-to-noise ratio (CNR) of downstream digitally modulated signals on your system?"

When I ask that question at SCTE seminars, rarely do more than a couple attendees raise their hands. Most of the time, no one does. When I ask about analog TV channel CNR, many seminar attendees indicate they have measured that. The assumption is if the analog TV channel CNR is OK, then it's probably OK on the digital channels. But is it?

Maybe, maybe not

The Federal Communications Commission requires that we measure analog TV channel CNR when doing proof-of-performance tests. The FCC's minimum CNR is 43 dB, which, in my opinion, is nowhere near good enough in today's competitive environment. Indeed, most cable operators have company specs for end-of-line CNR somewhere in the mid to high 40s, typically 46 to 49 dB.

This might be a good time to define CNR. Simply put, it's the difference, in dB, between the amplitude of a signal - generally an RF carrier of some sort - and the amplitude of a cable system's noise floor. The system noise measurement part of CNR is almost always defined in a specific bandwidth. For instance, §76.609(e) of the FCC's Rules state that system noise is the "total noise power present over a 4 MHz band centered within the cable television channel."

Why measure system noise in a 4 MHz bandwidth? That 4 MHz bandwidth is sometimes called modulation bandwidth and is roughly equal to the bandwidth of the baseband video that modulates an analog TV channel's visual carrier. Let's look at an example. (Warning: math ahead.)

Which bandwidth?

Say you measure an analog TV channel's visual carrier, and find it to be +30 dBmV. With the spectrum analyzer's resolution bandwidth (RBW) control set to 100 kHz, the system noise is found to be -30 dBmV. Assume that spectrum analyzer detector correction factors have been taken into consideration, if applicable. What's the CNR? At first glance you might be inclined to think it's 60 dB, but that's not the correct answer. Recall that the FCC wants system noise to be measured in a 4 MHz bandwidth. We just measured it in the spectrum analyzer's RBW, which in this example is only 100 kHz. That means we have to apply a correction factor to the system noise measurement to get a value equivalent to a 4 MHz measurement. Here's how we figure the correction factor that must be added to the spectrum analyzer's noise measurement:

CF_{dB} = 10log(modulation bandwidth/measurement RBW)
   = 10log(4,000,000/100,000)
   = 10 x log(40)
   = 10 x 1.6021
   = 16.02 dB

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The corrected system noise is -30 dBmV + 16.02 dB = -13.98 dBmV. That makes the CNR 43.98 dB.

Before I get too far along in this discussion, it's important to note that when you measure system noise, you need to make sure you're actually measuring the cable system's noise floor and not the test equipment's internal noise floor. The easiest way to find out is to temporarily disconnect the spectrum analyzer's RF input. The displayed noise on the analyzer should drop at least 10 dB. If it doesn't, you're measuring mostly test equipment noise, not system noise. If this is the case, find a hotter test point with more signal.

Digital

What about the CNR of the digitally modulated signals on your system? Let's say you measure the digital channel power of a downstream 64-QAM (quadrature amplitude modulation) cable modem signal and find it to be +20 dBmV. The system noise is still -30 dBmV, once again measured with the spectrum analyzer's RBW set to 100 kHz. What's the CNR? It's not 50 dB. As before, we have to correct the system noise measurement to a value equivalent to the signal's modulation bandwidth. But what's the modulation bandwidth for a digitally modulated signal? Is it the same 4 MHz we used for our analog TV channels? Is it the channel's 6 MHz occupied bandwidth?

Nope. It's equal to the digitally modulated signal's symbol rate.

A DOCSIS downstream 64-QAM signal's symbol rate is 5.056941 Msym/sec (megasymbols per second), so its modulation bandwidth is 5.056941 MHz (the modulation bandwidth for 256-QAM is 5.360537 MHz). With this information, we can figure out the correction factor to add to the spectrum analyzer's noise measurement:

$$CFdB = 10\log(5{,}056{,}941/100{,}000)$$
$$= 10 \times \log(50.5694)$$
$$= 10 \times 1.7039$$
$$= 17.04 \text{ dB}$$

The corrected system noise is -30 dBmV + 17.04 dB = -12.96 dBmV. That makes the CNR 32.96 dB.

Wait a minute! When we calculated the analog TV channel CNR, it was 43.98 dB. Why is the 64-QAM signal's CNR more than 10 dB lower than the analog TV channel's? After all, the 64-QAM signal's digital channel power is 10 dB less than the analog TV channel's visual carrier level. Shouldn't the CNR also be 10 dB less? The answer is no, and the reason is that the system noise measurement bandwidth is different for the two signals.

We used 4 MHz for the analog TV channel, and 5.06 MHz for the 64-QAM signal. There is more system noise with the digitally modulated signal because of the somewhat greater noise power bandwidth.

One more problem: The DOCSIS Radio Frequency Interface Specification's assumed RF channel transmission characteristics says 35 dB is the minimum CNR for downstream digitally modulated signals, and our example came up with ~33 dB. Not good. If we run our 64-QAM signals at -10 dBc relative to analog TV channel levels, the CNR of our analog TV channels will have to be at least 46 dB to have approximately 35 dB CNR on the cable modem signal.

Good news

Now for some good news. There is an easier way to measure digitally modulated signal CNR than the example described here. Assuming the spectrum analyzer is displaying system noise (as mentioned previously, temporarily disconnect the analyzer's RF input and make sure the noise drops at least 10 dB), the CNR is the difference between the amplitude of the displayed system noise and the amplitude of the digitally modulated signal's haystack. No correction factors necessary. In most cases you probably can eyeball the

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analyzer screen to see the difference between the top of the haystack and the noise floor, and figure out the CNR to within a couple dB.

If you're wondering why this shortcut works - and why modulation bandwidth equals symbol rate for digitally modulated signals - take a look at the two part article "Digital Transmission: Carrier-to-Noise Ratio, Signal-to-Noise Ratio, and Modulation Error Ratio" in the June and July 2007 issues of Communications Technology: www.cable360.net/ct/operations/testing/23792.html and www.cable360.net/ct/operations/bestpractices/24367.html.

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