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OUR OLD FRIEND CNR

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When you think of downstream carrier-to-noise ratio (CNR or C/N), what comes to mind? This sounds like an "it depends" question, so let's establish a couple ground rules before getting too far along in the discussion.

First, CNR is a post-modulation or pre-detection measurement made in the RF domain. Second, I'm going to defer to the excellent reference Modern Cable Television Technology, 2nd Ed. for some of the basic math behind CNR: "Carrier-to-noise ratio (C/N) is defined as follows: C/N (dB) = 10log(c/n), where c and n are the scalar power levels of the carrier and noise respectively." Third, the noise is additive white Gaussian noise (AWGN) or thermal noise, not ingress, impulse noise or other interference.

OK, with the ground rules spelled out, what is meant when talking about the CNR of an analog TV channel? Part of the answer almost always assumes that the analog TV channel visual carrier's CNR is what we're after.

The cable industry long has used the decibel millivolt (dBmV) to express power in terms of voltage. The latter gives us a slightly different formula for carrier-to-noise ratio: CNR(dB) = CdBmV – NdBmV, where CdBmV and NdBmV are the carrier and noise powers in dBmV, respectively. Here, we're interested in the visual carrier's peak envelope power (PEP) and the average power of the noise. Consider the following example:

Assume that an analog TV channel's visual carrier PEP is 0.00013333 watt (133.33 microwatts), and the noise power is 0.00000001333 watt (13.33 nanowatts). Using the first formula, the CNR is 10log(0.00013333 watt/0.00000001333 watt) = 40 dB. If we use dBmV for the two power levels (0.000133333 watt = 40 dBmV and 0.00000001333 watt = 0 dBmV), the CNR is 40 dBmV – 0 dBmV = 40 dB.

So far, so good.

The part that's missing is the noise power bandwidth (also called modulation bandwidth) that, for analog NTSC television channels, is specified in the FCC rules as 4 megahertz. The assumption here is that the baseband video that normally modulates the visual carrier has a nominal bandwidth of about 4 megahertz, although in practice it varies somewhat from this value, depending upon video content.

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If you've ever wanted to see the bandwidth of baseband video, connect an analog baseband video source to the RF input of a spectrum analyzer. Adjust the analyzer's horizontal span to 1 megahertz per division, the vertical scale to 10 dB per division, and set the center frequency to 5 megahertz. Tweak the input attenuator and reference level controls as necessary to display the noise floor and signal. You should see on the left half of the display what looks similar to an analog TV channel, except without an aural carrier. There is no visual carrier, either, although what might be mistaken for one on the far left of the screen is the analyzer's zero-hertz feed-through (think local oscillator). Note that the baseband video occupies a bandwidth of 4 or 5 megahertz, give or take.

What's all of this baseband video bandwidth stuff got to do with a CNR measurement? After all, didn't I say we're dealing with a RF measurement? Yes, but the noise power part of a CNR measurement must be corrected to a bandwidth equivalent to the modulation bandwidth, which is the FCC-specified 4 megahertz for NTSC analog TV channels. This simply means if you measure the noise power using test equipment that is set to a measurement bandwidth other than 4 megahertz, the result must be corrected to 4 megahertz.

Here's an example: Let's say you measure the system's noise floor power with a spectrum analyzer that has its resolution bandwidth (RBW) control set to 100 kHz, and get something like –10 dBmV. That's the noise power in a 100 kHz bandwidth, which must be corrected to 4 megahertz. The correction factor to add to the measured value can be calculated with the formula 10log(modulation bandwidth/measurement bandwidth) or, in this example, 10log(4,000,000 Hz/100,000 Hz) = 16.02 dB. It's not critical that the numerator and denominator be in hertz as shown here; just use the same units for each. The corrected noise measurement is –10 dBmV + 16.02 dB = +6.02 dBmV. (Note: I've left out any applicable spectrum-analyzer detector correction factors that might be required. Check the test equipment's instruction manual.)

All of this sounds a whole lot more difficult than it really is. Just make sure the spectrum analyzer's displayed noise floor is the cable network's noise floor, not the test equipment's noise floor. Most newer spectrum analyzers and similar gear incorporate automated CNR measurements, further simplifying the process and minimizing operator error.

So far, we've taken a look at analog-TV-channel CNR. What about the CNR of those noise-like quadrature amplitude modulation (QAM) signals? One certainly can measure a QAM signal's digital channel power – that is, its average power integrated over the occupied bandwidth – to get the "C" in CNR. But what noise power bandwidth do we use for the "N?" Once again, it's the modulation bandwidth, but not the 4-megahertz value used for analog TV channels.

With digitally modulated signals, the modulation bandwidth is equal to the symbol rate. So, for a 6-megahertz bandwidth downstream 64-QAM signal, the noise power bandwidth is 5.056941 megahertz; for 256-QAM, it's 5.360537 megahertz. These numbers come from the two constellations' 5.056941 megasymbols per second (Msym/sec) and 5.360537 Msym/sec symbol rates.

Believe it or not, a QAM signal's CNR is easier to measure than an analog TV channel's CNR. Using a spectrum analyzer, the CNR is the height of the haystack in decibels above the noise floor – no correction factors necessary. As before, make sure the displayed noise floor is the system noise floor and not the test-equipment noise floor. If you want a deep dive into why all of this is true, take a gander at the white paper Digital Transmission: Carrier-to-Noise, Signal-to-Noise, and Modulation Error Ratio by Broadcom's Bruce Currivan and yours truly, available online at http://www.cisco.com/en/US/prod/collateral/video/ps8806/ps5684/ps2209/prod_white_paper0900aecd805738f5.html.

Here's a fun example to noodle on: Assume an analog TV channel's visual carrier PEP is +15 dBmV and the CNR is 48 dB. An adjacent 256-QAM signal's digital channel power is 6 dB lower than the analog TV channel's PEP, or +9 dBmV. What would you expect the QAM signal's CNR to be? If you said 42 dB, refill your coffee cup and read along.

Because the analog TV channel's CNR is 48 dB, the noise floor power NNTSC for the analog channel is +15 dBmV – 48 dB = –33 dBmV (4 megahertz noise power bandwidth).

To sort out the 256-QAM signal's CNR, we first have to calculate what the noise-floor amplitude is for that QAM signal, based on a noise power bandwidth equal to its symbol rate. The latter is the previously mentioned 5.360537 megahertz. From this, we can calculate the noise floor power N256-QAM for the QAM signal using the formula N256-QAM = NNTSC + [10log(5.36 megahertz /4 megahertz)] = –31.73 dBmV. The 256-QAM signal's CNR is +9 dBmV – (–31.73 dBmV) = 40.73 dB.

The CNR of the 256-QAM signal is degraded by more than the 6 dB difference in signal levels because of the QAM signal's somewhat greater 5.36-megahertz noise power bandwidth compared to the analog TV channel's 4-megahertz noise power bandwidths.

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