How to measure carrier-to-noise

Complying with FCC standards

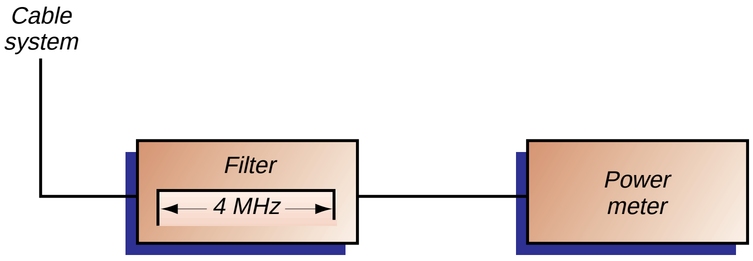

Figure 1: *Ideal world setup*

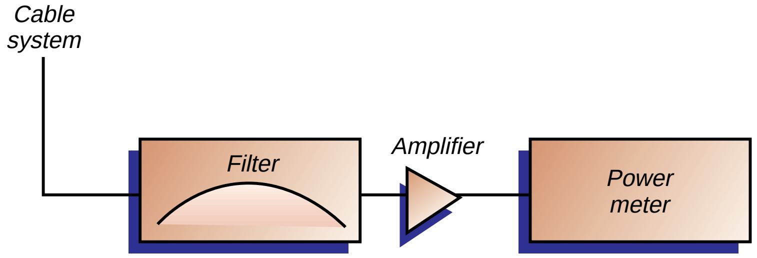

Figure 2: *Real world setup*

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New FCC technical standards, the increasing use of fiber and higher quality expectations of subscribers have all created a demand for better carrier-to-noise measurements. Obtaining repeatable results when measuring noise requires a detailed knowledge of how the instrument being used measures noise, its limitations and necessary corrections. To help take the mystery out of this measurement, five correction factors are introduced to help describe a practical measurement method.

Section I.D. of the NCTA Recommended Practices covers the visual carrier-to-noise ratio (CNR) measurement in detail. This article will expand on two of the concepts described in that section: the noise correction factors and measuring noise in-service.

The carrier-to-noise test requires two measurements–carrier level and noise level. Much has been written on measuring carrier level, which is the signal power during synchronizing pulses. This article will concentrate on the more difficult measurement of noise.

FCC rules

Currently, the FCC requires that the ratio of the visual carrier level to system noise be at least 40 dB. As of June 30, 1995, this ratio increases to at least 43 dB. The rules define system noise as noise measured in the range from the visual carrier frequency to 4 MHz above it [CFR 47; Parts 76.5(w) & 76.605(a)(7)].

When measuring noise, a number of corrections to the initial instrument readout are usually necessary. To understand what they are and why they are used, let's look at five of the most important of these.

Noise-equivalent bandwidth

To measure CNR in an ideal world, we would use a perfectly rectangular, 4 MHz wide filter covering the desired frequency range with its output connected to a power meter (see Figure 1).

Unfortunately, our ideal world scenario is not possible for a number of reasons. These reasons give rise to the correction factors that are necessary in practice.

The first problem we encounter is that perfectly rectangular filters do not exist. So we must introduce the concept of "noise-equivalent bandwidth." This is the bandwidth that the filter would have if it were perfectly rectangular, while passing the same amount of noise as the imperfect filter. Since filters are often specified as their bandwidth 3 dB or 6 dB down on either side of center frequency, our first correction factor is to change the specified bandwidth to a noise-equivalent bandwidth. A typical value is -0.52 dB for filters specified at their 3 dB points. This means that, in this case, the noise equivalent bandwidth is slightly wider than a specified 3 dB bandwidth.

Correction to 4 MHz bandwidth

We now know that specifying a filter by its noise-equivalent bandwidth gives an effectively perfect rectangular filter. However, it still isn't likely to be what we want, i.e., exactly 4 MHz wide. So our second correction factor changes our real world filter bandwidth (whatever it is) to 4 MHz.

Noise figure

Now that we have dealt with the filter in Figure 1, let's consider the power meter. Again, the ideal world setup doesn't work. This is because power meters cannot directly measure the low levels of noise we need to measure; therefore, we have to add an amplifier to bring the noise level up to what the meter can measure. But the amplifier adds its own noise, which must be accounted for (see Figure 2).

Thus, noise figure is our third correction factor.

Why don't we normally measure CNR with the Figure 2 setup? There are several reasons:

1. Knowing the filter's noise-equivalent bandwidth is critical to the measurement, but the bandwidths of tunable filters vary as a percentage of center frequency, so their noise equivalent bandwidths will also change with tuning. Using calibrated filters is possible, but not very convenient, and they are not commonly available to the cable TV technician.

2. Measuring in an exactly 4 MHz wide bandwidth has the advantage that it incorporates any ripple or

slope in the noise level and exactly meets the FCC rule for summing over the system noise range. However, it will also include any distortion products, extraneous signals or the unmodulated carrier, if present. This might lead to an erroneously high result. In practice, noise measurements are done in narrower bandwidths, typically 30 kHz to 300 kHz, with the results mathematically corrected to what the noise power would have been if actually measured in a 4 MHz bandwidth, as in Figure 1.

3. Power meters are not commonly available to cable TV technicians.

Using a spectrum analyzer

Spectrum analyzers are available to cable TV technicians and are very convenient to use for this purpose. When not sweeping (zero span), a spectrum analyzer is a fixed tuned, frequency selective voltmeter (see Figure 3.) When it is sweeping, it's simply displaying the results of a series of zero span measurements made over a range of frequencies. When an analyzer displays power, it is calculated from that measured voltage.

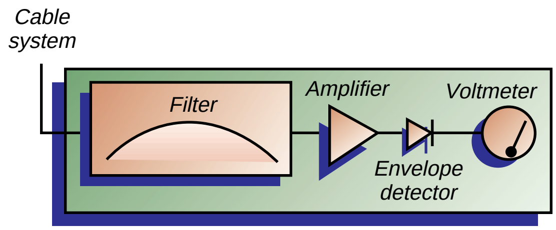


Figure 3: *Spectrum analyzer*

In Figure 3 we have transformed the ideal, but impractical setup of Figure 1 into a real world, practical measurement setup through the use of the three above-mentioned correction factors.

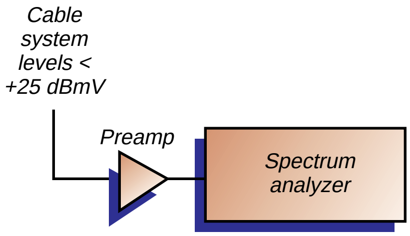


Figure 4: *Spectrum analyzer with preamp*

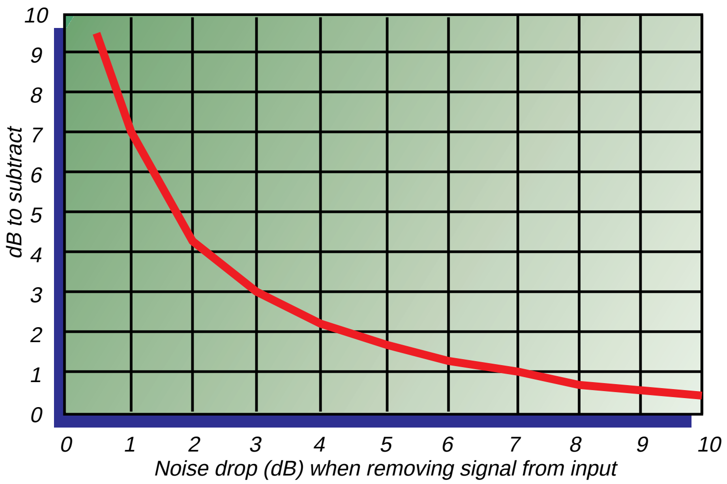
Logarithmic detection of noise

The fourth correction factor to be introduced is a result of using the measurement unit "dB."

A spectrum analyzer is a voltmeter which, when displaying results in units of dB(m, mV, etc.), is actually measuring a voltage that has been converted into a logarithmic value. This allows very widely differing levels, such as carrier and noise, to be viewed on the same display. Otherwise noise, for example, when on screen with a carrier, would be too small to see.

However, measuring noise in dB reports a value 2.5 dB too low. So our fourth correction factor is to add 2.5 dB to our measured noise level.

Figure 5: *Noise-near-noise correction*



Preamp noise contribution

The setup in Figure 3 performs well when measuring CNR in high level parts of the distribution system, such as at line extender outputs. However, when measuring CNR at lower levels such as at drops, the amplifier noise figure correction is not adequate. To boost the noise to be measured into the measuring range of the spectrum analyzer, a preamplifier is used.

We have now added yet another uncertainty to the measurement and must add another noise figure correction factor. Our list of corrections with typical values for a spectrum analyzer now looks like:

1. Noise-eq-BW: -0.52 dB
2. 30 kHz to 4 MHz: +21.25 dB
3. Analyzer noise figure: (use Figure 5)
4. Log detect noise: +2.5 dB
5. Preamp noise figure: (use Figure 6).

Now that we know the correction factors involved, let's do a sample measurement using the following conditions:

Carrier level at preamp output: +13 dBmV
Uncorrected CNR: 73 dB
Noise drop when disconnecting cable from analyzer input: 9 dB
(use Figure 5 to get 0.6 dB)
Preamp Gain: 10 dB
Preamp Noise Figure: 7 dB.

Using the above information, we calculate CNR at the output of the preamp:

73 - (-0.52 +21.25 +2.5 -0.6) =
50.37 dB CNR at preamp output

where:

73 = uncorrected CNR
0.52 = filter noise-equivalent bandwidth
21.25 = 30 kHz to 4 MHz
2.5 = log detect noise
0.6 = analyzer noise figure.

Now, to correct for the noise contribution of the preamp, we subtract the CNR just found above from the carrier level at the input of the preamp, which is the output carrier level minus the gain:

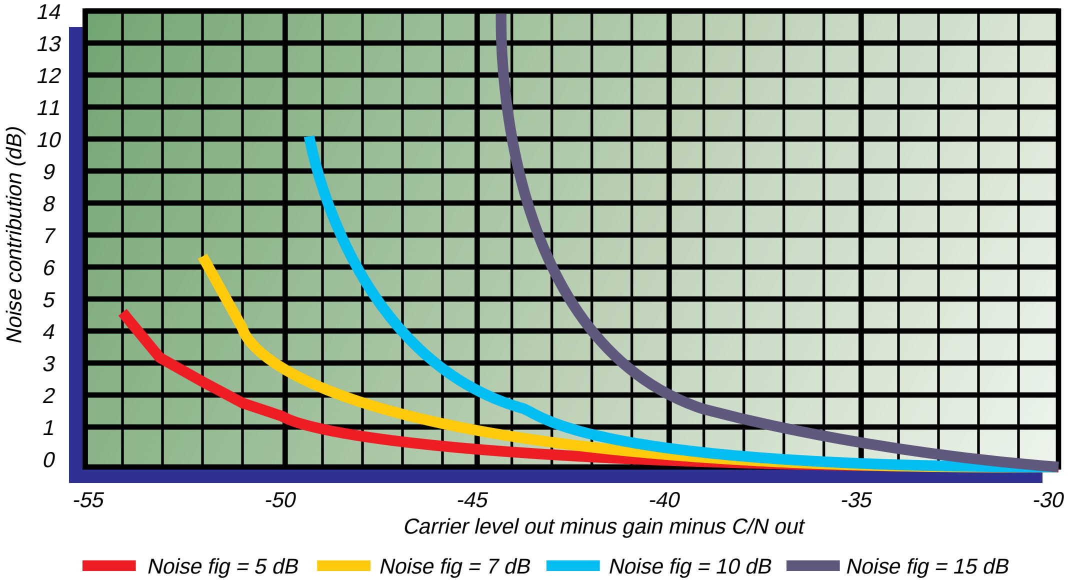
+13 - 10 - 50.37 = -47.37

Find -47.37 on the x-axis of Figure 6 to find the noise correction value of 1.3 dB on the curve for a noise figure of 7 dB. This means the preamp is adding 1.3 dB of noise at its output, so we should add thus:

50.37 + 1.3 = 51.67 dB CNR

This value, 51.67 dB CNR, is now the value we would have measured with the ideal Figure 1 setup, if it were possible.

Figure 6: *Preamp noise contribution*



Smart instruments and set-tops

Newer instruments can automate many of the above tasks. Indeed, one spectrum analyzer measures carrier-to-noise, showing exactly how it calculated the result, and what correction factors it used.

Measuring CNR involving convertors is a subject that deserves more attention, but goes well beyond the scope of this article. This subject is covered in the NCTA Recommended Practices CNR Section I.D. in its "Discussion." Also, issues involving baseband convertors are reviewed in Appendix D.

Another subject worthy of more attention but beyond the scope of this article is that of measuring individual noise contributing components such as headend active devices, trunk and distribution amplifiers, and convertors, then summing their individual contributions for a net CNR result. As with convertors, this subject is addressed in the "Discussion" section of the NCTA Recommended Practices CNR Section I.D.

Measuring CNR in-service

Traditionally, CNR is tested by measuring the carrier level, then removing video modulation and measuring the underlying noise level. Disadvantages of this technique are that at least two people are required, which increases labor expense, and service interruptions are required, which cause customer dissatisfaction. For these reasons, cable operators have asked test equipment vendors for tests that can be done in-service.

In response, several companies have developed in-service carrier-to-noise tests which measure noise during a selected line or lines in the vertical interval. These tests are not only non-disruptive to service, but they also actually measure the carrier-to-noise of the picture as would be viewed by the subscriber (as long as the line being measured has not been disassociated from the picture lines by video path switching).

This advantage, however, can also be a disadvantage to the cable operator. This occurs when the video feed to the cable operator is excessively noisy. Here, the in-service CNR test result may not meet FCC limits, but the operator may still be legal, because the cable TV system-contributed noise without the video feed noise may be within the FCC limit. One way to find out is to revert to removing the video modulation. Another option for satellite or local origination channels is to place a video line stripper at the headend, then measure the noise on the stripped line. An option for off-air channels is to measure the absolute noise level of the in-service signal at the input of the first active device after the antenna, and subtract that from the noise measured at the system test point.

In addition to the FCC rules mentioned above, the FCC says, "system noise . . . power indications . . . are taken in successive increments of frequency equal to the bandwidth . . . summing the power indications to obtain the total noise power present over a 4 MHz band . . . If it is established that the noise level is constant [flat] within this bandwidth, a single measurement may be taken which is corrected by an appropriate factor . . ." [CFR 47; Part 76.609(e)].

In the traditional noise measurement with video modulation off, the noise floor is assumed to be (and usually is) "constant" or flat, and the noise is measured at a single point, which is then corrected to 4 MHz. In-service noise measurement very often means that the noise floor is not constant, as mentioned in the rules above. This is because video channels often have various kinds of filtering and frequency dependent processing. Indeed, modulators, processors and convertors themselves can add much to the unflatness of the channel. The rules account for this by requiring that the noise be integrated or "summed" over the 4 MHz bandwidth when the noise floor is not flat.

What follows are a few measurement results using a spectrum analyzer capable of doing the test both with modulation off and in-service in order to compare the two methods. The spectrum analyzer measured in-service by summing the noise over 85 percent of the 4 MHz range in order to eliminate the effect of the carrier, which is always present. This 85 percent range is automatically corrected to 4 MHz. For the modulation off-test, a single point was measured.

In theory, the results with video modulation "on" should be the same or worse than with video modulation "off." Numerous measurements have confirmed this, and in this case, ranged from equal results to a worst case of 6.8 dB for the in-service measurement. A typical channel can be expected to measure approximately 2 dB to 4 dB worse.

Figure 7 shows essentially the same results between the video off and in-service measurements. This equivalency has also been seen when measuring a line which has been stripped at the headend, and on channels which are digitally delivered to the headend. This channel had local character generation with video leaking into the vertical interval which was excluded from the noise summation.

Figure 8 is typical, showing a 2.3 dB difference; however, even the worst in-service result at 47.2 dB CNR is clearly acceptable.

Figure 9 is an example of the worst noise contribution of video signal noise that is likely to be seen. This could be due to a noisy active device anywhere in the signal path before the modulator.

Test results confirm that in-service carrier-to-noise testing can be used to satisfy FCC proof tests, if the combination of video program noise and cable TV system noise is within FCC limits. In-service test results will be equal to, but no better than, the video off-test, and can be several dB worse. When the in-service CNR result is not within FCC limits, the alternatives are to test in the traditional way by turning modulation off, stripping the test line at the headend, or in the case of off-air signals, subtract the in-service noise from the incoming signal.

Another consideration for satellite channels is that the noise could be coming from the LNB and/or the satellite receiver/descrambler. Currently, I don't know of a convenient way to test these components for CNR, other than device substitution.

If the noise is truly on the programmer-supplied video, another option is to ask the video feed provider for a cleaner signal, since the poor in-service CNR signal is what the subscriber will ultimately see.

Conclusion

Getting repeatable results when measuring carrier-to-noise over a wide dynamic range requires attention to a number of details. Modern instrumentation can do much of the work while increasing measurement accuracy, reducing errors and measuring in-service.

e 1: Ideal world setup

References

1. "Spectrum Analysis Basics," Application Note 150, Hewlett-Packard Company, 1989.

2. Lin, Wen Tsung and Tim Homiller, "Noise Measurements For A CATV System-C/N, S/N, Phase Noise," 1989 NCTA Technical Papers, p. 179.

3. Schwartz, Mischa, "Information Transmission, Modulation and Noise," Second Edition, McGraw-Hill, 1970.

4. "Visual Carrier-To-Noise." Recommended Practices (National Cable Television Assn. 2nd ed. October 1993), sec. I.D.

5. Code of Federal Regulations, Title 47, Chapter I, Part 76, "Cable Television Service."

6. Bullinger, Rex, "Wide Dynamic Range Carrier-To-Noise Testing," 1993 NCTA Technical Papers, p. 330.

Figure 7a(red)/7b(blue)

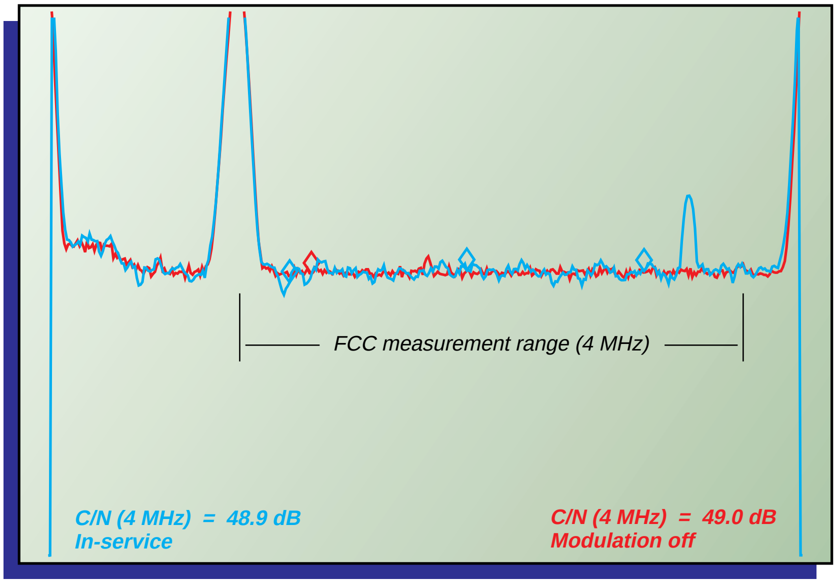


Figure 8a(red)/8b(blue)

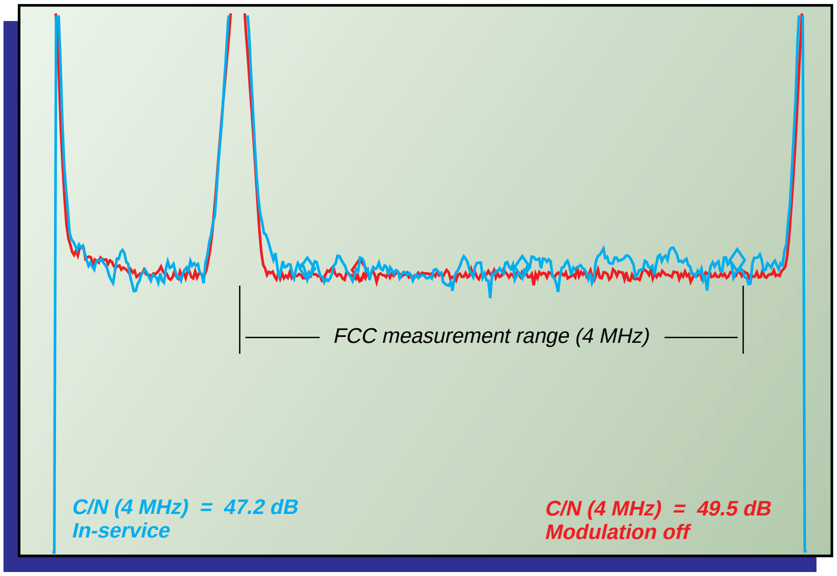


Figure 9a(red)/9b(blue)