WHITE PAPER

# CARRIER-TO-NOISE RATIO IN CABLE NETWORKS


**Executive Summary**

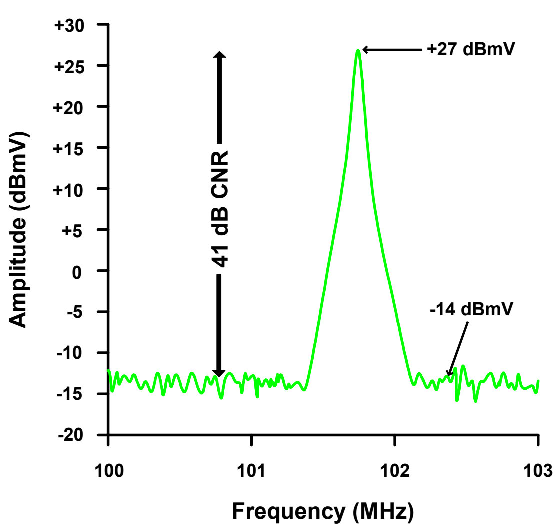
**Cable operators routinely measure carrier-to-noise ratio (CNR) as one means of characterizing the health of their cable networks. Government regulations require that cable networks meet certain minimum standards for analog television signal CNR. Also, the DOCSIS® Radio Frequency Interface Specification includes in its assumed RF channel transmission characteristics a minimum CNR parameter for data signals. But just what *is* CNR? This white paper provides a comprehensive tutorial on the subject.**


## THE CONCEPT OF CNR

CNR is in cable industry vernacular a pre-detection measurement—that is, a measurement performed in the frequency domain. By definition, CNR is the difference, in decibels, between the amplitude of an RF signal and the amplitude of noise present in the transmission path of the RF signal. The RF signal may be unmodulated (also called continuous wave, or CW) or modulated. The noise may be one or a combination of several types: thermal noise; shot noise and relative intensity noise (RIN) in optical fiber links; and, in cable systems carrying a mix of analog TV channels and digitally modulated carriers, non-thermal noise such as composite and intermodulation noise. This paper focuses on thermal noise generated by passive and active devices through which the RF signal is transmitted. The amplitude of thermal noise—also known as additive white Gaussian noise, or AWGN—is usually specified over a certain bandwidth, called noise power bandwidth.

Figure 1 is an example of a typical spectrum analyzer display when making a CNR measurement.

**Figure 1.** CNR Is a Frequency Domain Measurement



Many of today's signal level meters, spectrum analyzers, and quadrature amplitude modulation (QAM) analyzers support the measurement of both analog TV channels and 64- and 256-QAM digitally modulated carriers. TV channel signal level or amplitude generally refers to the visual carrier amplitude, which is defined as the root mean square (rms) value of the instantaneous synchronizing peak. Digitally modulated carrier amplitude is a measure of the signal's average power. The signal level, or amplitude, of a TV channel or digitally modulated carrier is the "C" in CNR.

Analog TV channel visual carrier amplitude and digitally modulated carrier average power are commonly measured using decibel millivolt (dBmV), a unit of power expressed in terms of voltage.

*dBmV = 20log(signal amplitude in millivolts/1 millivolt)* Equation [1]

But what about the "N" in CNR? That is the thermal noise rms amplitude.

### THERMAL NOISE

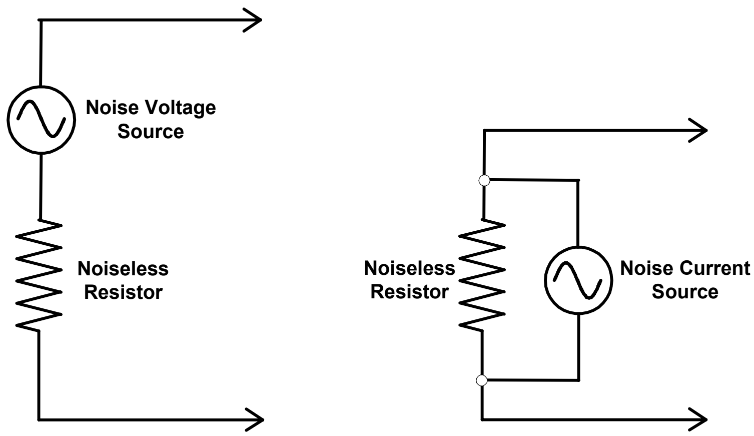
According to *Fundamentals of RF and Microwave Noise Figure Measurement*[1], thermal noise is "the fluctuating voltage across a resistance due to the random motion of free charge caused by thermal agitation." The HP application note goes on to say "The probability distribution of the voltage is Gaussian with mean square voltage…"

$$e_n^2 = 4kT \int_{f_1}^{f_2} R(f)p(f)df$$ Equation [2]

The equivalent circuit model for a noisy resistor can be represented as a noise voltage source in series with a noiseless resistor, or as a noise current source in parallel with a noiseless resistor. Figure 2 illustrates these models.

[1] *Fundamentals of RF and Microwave Noise Figure Measurement*, Application Note 57-1, Hewlett-Packard, July 1983

**Figure 2.** Equivalent Circuit Model for a Noisy Resistor




These equivalent circuit models are mentioned here because in the world of electronic amplifier design, the concepts of input referred noise voltage and input referred noise current are important. The optimum source resistance necessary to minimize the noise figure of an electronic amplifier is the ratio of input referred noise voltage to input referred noise current—in general. This statement is true for low-frequency amplifiers, where input referred noise voltage and input referred noise current are uncorrelated. In higher-frequency RF-type amplifiers, the input referred noise voltage and input referred noise current have finite correlation such that the optimum input impedance becomes a complex value. That is, the phase angle becomes important.

The previously mentioned *Fundamentals of RF and Microwave Noise Figure Measurement* states that the "power delivered by a thermal source into an impedance matched load is *kTB* watts," where

$kTB$ Equation [3]

$k$ = Boltzmann's Constant ($1.38*10^{-23}$ joules/kelvin)

$T$ = Temperature in kelvin (K)

$B$ = Bandwidth

At a reference source temperature[2] of 290 K, the 1 Hz bandwidth thermal noise power delivered to any load impedance from a matched source impedance is $4.002*10^{-21}$ watt or –203.98 dBW. This shows that available thermal noise power into a matched load is directly proportional to bandwidth. For example, if the bandwidth doubles from 1 to 2 Hz, the available thermal noise power increases by 3.01 dB to $8.004*10^{-21}$ watt or –200.97 dBW.

[2] The IRE (predecessor to IEEE) adopted 290 K as the standard temperature for determining noise figure. The temperature 290 K (16.8º C or 62.3º F) is close to the average temperature "seen" by receive antennas pointed at transmit antennas across the atmosphere toward the horizon.

#### Converting Thermal-Noise Power to dBmV

To get thermal noise power into the world of the more familiar dBmV, we start with a variation of Equation [2]. From that, we can derive the following formula for calculating the open-circuit noise voltage from a resistance or impedance:

$$e_n = \sqrt{4kTBR} \qquad \text{Equation [4]}$$

where

$k$ = Boltzmann's Constant ($1.38*10^{-23}$ joules/kelvin)

$T$ = Temperature in kelvin (K)

$B$ = Bandwidth in Hz

$R$ = Resistance (or impedance) in ohms

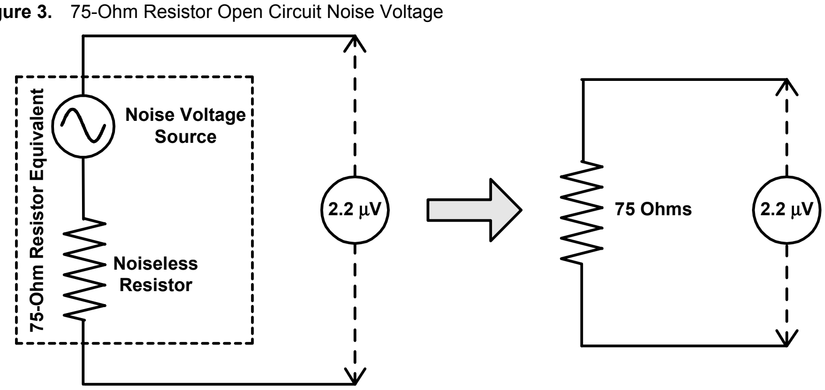
Equation [4] allows us to calculate the open-circuit noise voltage over a 4 MHz bandwidth (the noise power bandwidth used for analog National Television System Committee [NTSC] television channel CNR measurements) generated by a 75-ohm resistor at room temperature (68° F, or 293.15 K). Figure 3 shows the open-circuit noise voltage of a 75-ohm resistor equivalent circuit model and a standalone 75-ohm resistor.

$$e_n = \sqrt{4*(1.38*10^{-23})*293.15*4{,}000{,}000*75}$$

$e_n = 2.2033075*10^{-6}$

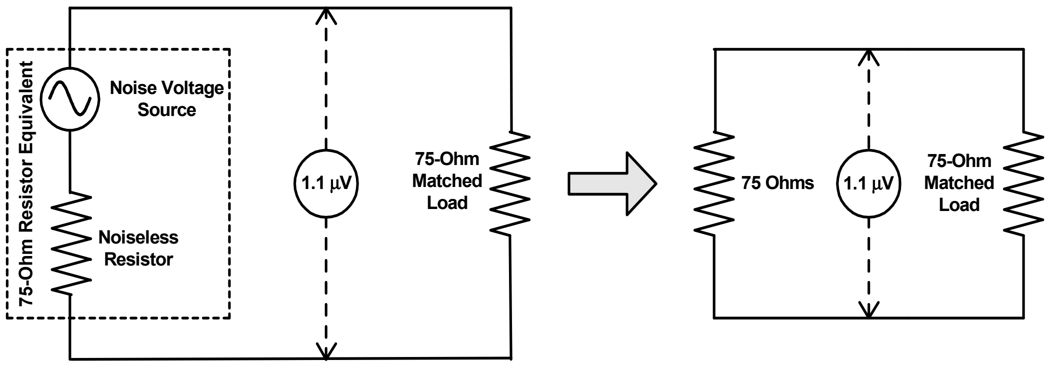
$e_n$ = 2.2033075 microvolts (µV)

**Figure 3.** 75-Ohm Resistor Open Circuit Noise Voltage



When this 75-ohm impedance noise source is terminated by an equal value resistance—say, connected to the input of a 75-ohm impedance amplifier—the thermal noise is $e_n/2$ or 1.10165375 microvolts. This is shown in Figure 4.

**Figure 4.** 75-Ohm Resistor Terminated Noise Voltage




The formula to convert microvolts to dBmV follows:

$dBmV$ = 20log(microvolts/1000) Equation [5]

$dBmV$ = 20*log(1.10165375/1000)

$dBmV$ = 20*log(0.001101653755)

$dBmV$ = 20*(–2.95795)

$dBmV$ = –59.16

That is, 1.1 microvolts = –59.16 dBmV

Now consider Equation [3]. If we plug some now familiar values into that equation, we can validate the previous calculations:

kTB

$(1.38*10^{-23})*293.15*4,000,000$

$1.62*10^{-14}$ watt or –137.91 dBW

To convert dBW to dBmV in a 75-ohm system, add 78.75 to the value in dBW: –137.91 dBW + 78.75 = –59.16 dBmV.

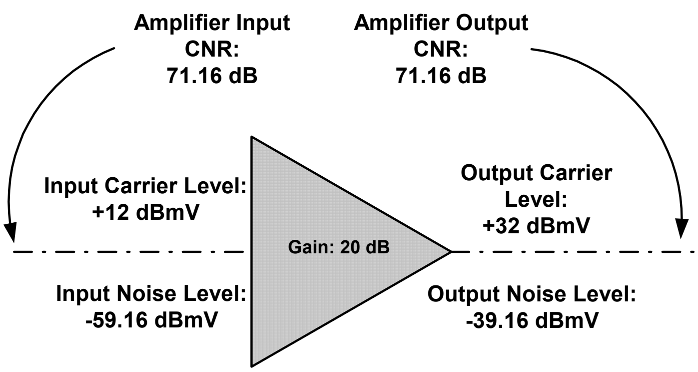
If we use a reference source temperature of 290 K rather than room temperature (293.15 K), the answer is –59.21 dBmV, although most cable network CNR calculations assume room temperature.

***Noise Figure***

If a 75-ohm resistor at room temperature is capable of generating measurable noise power (–59.16 dBmV in a 4 MHz bandwidth), imagine the noise that is generated by active devices such as amplifiers. Indeed, real-world amplifiers do generate noise, which must be accounted for when calculating or measuring CNR.

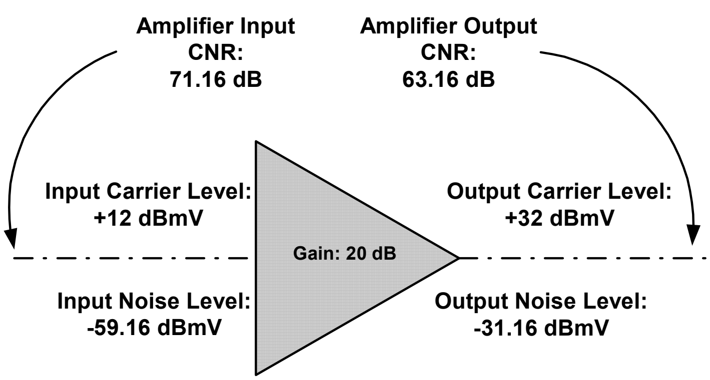
If we had a perfect amplifier, the RF carrier and noise output levels would be greater—by the amplifier's gain in decibels—than the input carrier and noise levels. For example, a 20 dB gain amplifier with +12 dBmV RF carrier input level would have an output carrier level of +12 dBmV + 20 dB = +32 dBmV. If the input noise level at that same amplifier were –59.16 dBmV, the output noise level would be –59.16 + 20 dB = –39.16 dBmV. In addition, the CNR at the amplifier input and output would be equal: 71.16 dB in this example. Figure 5 illustrates this.

**Figure 5.** Ideal Amplifier




A real-world amplifier behaves more like what is shown in Figure 6.

**Figure 6.** Real-World Amplifier



As expected, the output RF carrier level is 20 dB greater than the input RF carrier level. However, the output noise level is 28 dB greater than the input noise level. Furthermore, the output CNR is 8 dB worse than the input CNR. How can this be? Is the amplifier amplifying noise more than it does the RF carrier? No—the CNR degradation is related to the noise figure of the amplifier.

*Fundamentals of RF and Microwave Noise Figure Measurement* defines noise figure as the "…degradation in signal-to-noise ratio as the signal passes through the [device under test]." The most commonly accepted definition originated in the 1940s[3], which stated that the noise figure (F) of a network is the ratio of the signal-to-noise power ratio at the input to the signal-to-noise power ratio at the output: $F = (S_i/N_i)/(S_o/N_o)$.

In the previous example, the amplifier output CNR is 8 dB worse than the input CNR, so the amplifier noise figure is 8 dB. The noise figure of an amplifier is independent of input and output levels. Amplifier manufacturers try to reduce the noise figure by optimizing impedance levels and circuit design, and choosing low-noise transistors or hybrids. Typical cable TV amplifier noise figures are in the 7 to 10 dB range.

### NOISE POWER BANDWIDTH

As previously mentioned, the noise power bandwidth for analog NTSC television channels is 4 MHz. When calculating or measuring the CNR of a digitally modulated carrier, the noise power bandwidth should be equal to the symbol rate[4]. For example, the symbol rate of a 6 MHz bandwidth downstream 64-QAM digitally modulated carrier is 5.056941 million symbols per second (Msym/sec), so the noise power bandwidth is 5.056941 MHz. This value, expressed in Hz (5,056,941 Hz), is substituted for *B* in Equation [4] to calculate the thermal noise level. Tables 1 and 2 summarize noise power bandwidth and thermal noise level for several common digitally modulated carrier bandwidths used in DOCSIS and Euro-DOCSIS® networks.

**Table 1 Noise Power Bandwidth—Symbol Rate Bandwidth**

| Channel RF Bandwidth | Symbol Rate[5] | Noise Power Bandwidth | Thermal Noise Level at 68°F (75-ohm impedance) | |
|---|---|---|---|---|
| 6 MHz | 5.056941 Msym/sec | 5,056,941 Hz | 1.24 microvolts | –58.14 dBmV |
| 6 MHz | 5.360537 Msym/sec | 5,360,537 Hz | 1.28 microvolts | –57.89 dBmV |
| 8 MHz | 6.952 Msym/sec | 6,952,000 Hz | 1.45 microvolts | –56.76 dBmV |
| 200 kHz | 160 ksym/sec | 160,000 Hz | 0.22 microvolt | –73.14 dBmV |
| 400 kHz | 320 ksym/sec | 320,000 Hz | 0.31 microvolt | –70.13 dBmV |
| 800 kHz | 640 ksym/sec | 640,000 Hz | 0.44 microvolt | –67.12 dBmV |
| 1.6 MHz | 1,280 ksym/sec | 1,280,000 Hz | 0.62 microvolt | –64.11 dBmV |
| 3.2 MHz | 2,560 ksym/sec | 2,560,000 Hz | 0.88 microvolt | –61.10 dBmV |
| 6.4 MHz | 5,120 ksym/sec | 5,120,000 Hz | 1.25 microvolts | –58.09 dBmV |

[3] Friis, H.T., *Noise Figures of Radio Receivers*, Proceedings of the IRE, July 1944, pages 419–422
[4] Some prefer to use the full RF channel bandwidth rather than the symbol rate bandwidth for digitally modulated carrier noise power bandwidth. Symbol rate bandwidth is preferred, though, because it is equal to the noise power bandwidth –3 dB points.
[5] DOCSIS 2.0 uses modulation rate in kHz rather than symbol rate for upstream digitally modulated carriers.

**Table 2 Noise Power Bandwidth—Full RF Channel Bandwidth**

| Channel RF Bandwidth | Symbol Rate | Noise Power Bandwidth | Thermal Noise Level at 68°F (75-ohm impedance) | |
|---|---|---|---|---|
| 6 MHz | 5.056941 and 5.360537 Msym/sec | 6 MHz | 1.35 microvolts | –57.40 dBmV |
| 8 MHz | 6.952 Msym/sec | 8 MHz | 1.56 microvolts | –56.15 dBmV |
| 200 kHz | 160 ksym/sec | 200,000 Hz | 0.25 microvolt | –72.17 dBmV |
| 400 kHz | 320 ksym/sec | 400,000 Hz | 0.35 microvolt | –69.16 dBmV |
| 800 kHz | 640 ksym/sec | 800,000 Hz | 0.49 microvolt | –66.15 dBmV |
| 1.6 MHz | 1,280 ksym/sec | 1,600,000 Hz | 0.70 microvolt | –63.14 dBmV |
| 3.2 MHz | 2,560 ksym/sec | 3,200,000 Hz | 0.99 microvolt | –60.13 dBmV |
| 6.4 MHz | 5,160 ksym/sec | 6,400,000 Hz | 1.39 microvolt | –57.12 dBmV |

**CNR**

The CNR of an individual cable TV amplifier can be calculated with the formula:

$$C/N_i = N_t - NF + I \qquad \text{Equation [6]}$$

In this equation:

$C/N_i$ is the CNR of an individual amplifier.

$N_t$ is the thermal noise level from Equation [5] (expressed as a positive number so that the answer will come out positive). Note that for the following example, analog NTSC television channels are assumed, so 59.16 is used.

NF is the amplifier noise figure in dB.

I is the amplifier RF input level in dBmV.

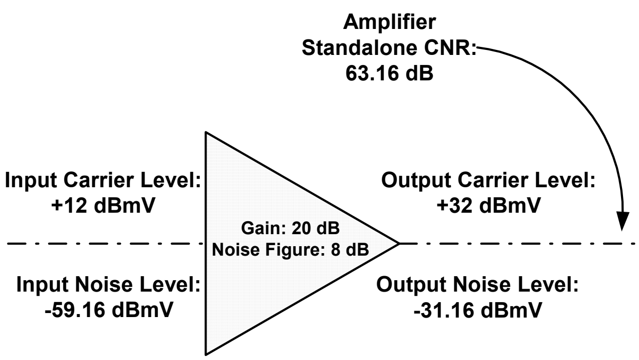
For example, the standalone CNR of an amplifier with 8 dB noise figure and +12 dBmV input is

$C/N_i = 59.16 - 8 + 12$

$C/N_i = 63.16$ dB

Figure 7 provides an example of the standalone CNR of a cable amplifier.

**Figure 7.** Amplifier CNR




### PERFORMANCE TARGETS

Federal Communications Commission regulations require that the analog NTSC TV channel CNR in U.S. cable systems be no less than 43 dB at the subscriber terminal. Good engineering practice suggests that the worst-case CNR should be better than the FCC minimum—most modern cable networks are designed to provide end-of-line CNR in the mid to upper 40s.

The assumed channel transmission characteristics in the DOCSIS *Radio Frequency Interface Specification* include the following minimum CNRs for digitally modulated carriers, regardless of modulation format:

Downstream: 35 dB

Upstream: 25 dB

### POWER ADDITION

Calculating downstream CNR in a cable network is generally done by first calculating the CNR of each type of standalone amplifier used in the network, and then calculating the CNR of the longest cascade of amplifiers in the network. The cascaded amplifier CNR is then combined with the headend and fiber link CNR using power addition. This exercise yields the overall CNR from headend to the network end-of-line.

A cascade of identical cable TV amplifiers has a combined CNR of

$C/N_t = C/N_i - 10\log(N)$ Equation [7]

For instance, a cascade of six identical amplifiers (shown in Figure 8), each with a standalone CNR of 63.16 dB, has a combined end-of-line CNR of

$C/N_t = 63.16 - 10*\log(6)$

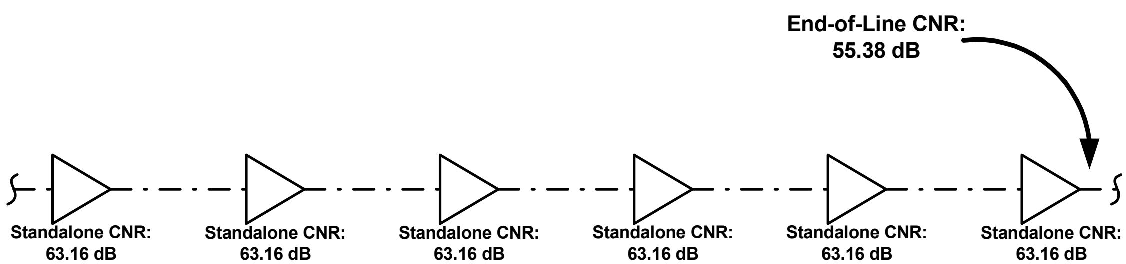
$C/N_t = 63.16 - 10*0.7782$

$C/N_t = 63.16 - 7.78$

$C/N_t = 55.38$ dB

**Note:** We can get even more accurate with a cascaded CNR calculation by accounting for the thermal noise contribution of the coaxial cable between each amplifier, although the overall impact is small. In addition, coaxial cable has frequency-dependent attenuation, which may affect CNR. Most cable distribution network cascade CNR calculations do not consider the effects of the cable—only the active devices.

**Figure 8.** Amplifier Cascade CNR




The following power addition formula can be used for combining individual CNRs:

$$C/N_{total} = -10*\log\left[10^{\frac{-C/N_1}{10}} + 10^{\frac{-C/N_2}{10}} + 10^{\frac{-C/N_3}{10}} ... + 10^{\frac{-C/N_n}{10}}\right]$$ Equation [8]

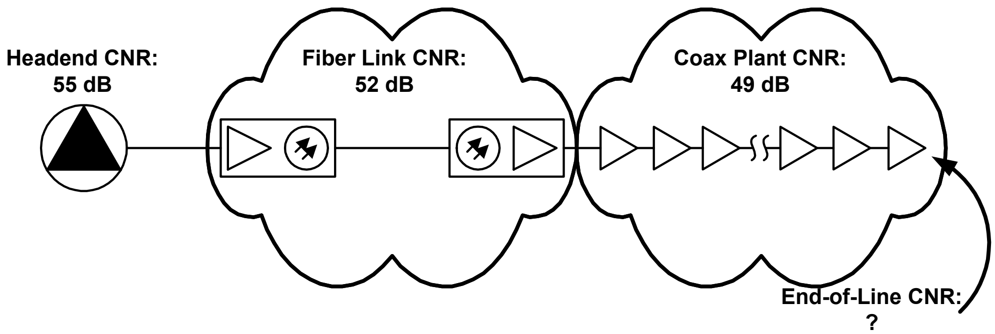
Using this formula, we can calculate the downstream end-of-line CNR for a cable network when the CNRs of individual components or elements are known. In addition, we can use Equation [8] to combine unlike CNRs. For instance, if we know the headend, fiber link, and coax plant CNRs, we can combine them using Equation [8] to calculate the end-of-line CNR. Assume the headend, fiber link, and coax plant have the following standalone CNRs, as shown in Figure 9:

Headend CNR: 55 dB

Fiber link CNR: 52 dB

Coax plant CNR: 49 dB

**Figure 9.** Cable Network End-of-Line CNR




$$C/N_{total} = -10 * \log\left[10^{\frac{-55}{10}} + 10^{\frac{-52}{10}} + 10^{\frac{-49}{10}}\right]$$

$$C/N_{total} = -10 * \log\left[10^{-5.50} + 10^{-5.20} + 10^{-4.90}\right]$$

$$C/N_{total} = -10 * \log[0.00000316227766 + 0.00000630957344 + 0.00001258925254]$$

$$C/N_{total} = -10 * \log[0.0000220611052229]$$

$$C/N_{total} = -10 * -4.66$$

$$C/N_{total} = 46.56$$

If the headend CNR is increased from 55 dB to, say, 60 dB, the end-of-line CNR improves slightly from 46.56 dB to 47.01 dB. Indeed, excluding the headend CNR contribution from the calculation—that is, calculating the combined CNR for only the fiber link and coaxial plant—results in an insignificant change to the results, increasing the end-of-line CNR to 47.24 dB:

$$C/N_{total} = -10 * \log\left[10^{\frac{-52}{10}} + 10^{\frac{-49}{10}}\right]$$

$$C/N_{total} = -10 * \log\left[10^{-5.20} + 10^{-4.90}\right]$$

$$C/N_{total} = -10 * \log\left[0.00000630957344 + 0.00001258925254\right]$$

$$C/N_{total} = -10 * \log\left[0.0000188988275627\right]$$

$$C/N_{total} = -10 * -4.72$$

$$C/N_{total} = 47.24$$

But what if we want to calculate the CNR of one of the contributing elements, say, the coaxial plant, when only the fiber-link and end-of-line CNRs are known? This is possible, but it requires a slight juggling of the power addition formula (subtraction is used inside the formula brackets rather than addition). Note that the headend CNR has been excluded.

$$C/N_{coaxplant} = -10 * \log\left[10^{\frac{-C/N_{EOL}}{10}} - 10^{\frac{-C/N_{fiber}}{10}}\right] \qquad \text{Equation [9]}$$

$$C/N_{coaxplant} = -10 * \log\left[10^{\frac{-47.24}{10}} - 10^{\frac{-52}{10}}\right]$$

$$C/N_{coaxplant} = -10 * \log\left[10^{-4.724} - 10^{-5.20}\right]$$

$$C/N_{coaxplant} = -10 * \log\left[0.000018879913491 - 0.00000630957344\right]$$

$$C/N_{coaxplant} = -10 * \log\left[0.0000125703400462\right]$$

$$C/N_{coaxplant} = -10 * -4.90$$

$$C/N_{coaxplant} = 49$$

From this, the coax plant CNR contribution is 49 dB, which agrees with the value used in the earlier example. To calculate the fiber link CNR when only the coax plant and end-of-line CNRs are known, we use the following variation of the formula:

$$C / N_{fiber} = -10 * \log\left[10^{\frac{-C/N_{EOL}}{10}} - 10^{\frac{-C/N_{coaxplant}}{10}}\right] \qquad \text{Equation [10]}$$

$$C / N_{fiber} = -10 * \log\left[10^{\frac{-47.24}{10}} - 10^{\frac{-49}{10}}\right]$$

$$C / N_{fiber} = -10 * \log\left[10^{-4.724} - 10^{-4.90}\right]$$

$$C / N_{fiber} = -10 * \log[0.000018879913491 - 0.0000125892541179]$$

$$C / N_{fiber} = -10 * \log[0.0000062906593731]$$

$$C / N_{fiber} = -10 * -5.20$$

$$C / N_{fiber} = 52$$

#### UPSTREAM CNR

The upstream CNR of a cable network is calculated somewhat differently than the downstream CNR. In the forward path, the network branches out from a common point—say, a node. The worst-case downstream CNR is almost always through the longest individual cascade of amplifiers. In the reverse path, the network combines at a common point—the node, hub site, or headend. This results in a reverse funneling effect for system noise and impairments. Instead of calculating the CNR for a given cascade of amplifiers, the upstream CNR accounts for all the reverse amplifiers that are connected to a common point.

If a network design is such that 50 amplifiers are connected to a node, the downstream CNR is the end-of-line value through the longest single cascade of amplifiers, which may be only 6 or 8 (not the entire 50). But going the other direction, noise from all 50 amplifiers combines back at the node, so upstream CNR must account for that. Assuming all 50 reverse amplifiers are identical, we first calculate the CNR of a standalone amplifier using Equation [6]. For example, if the noise figure of each reverse amplifier is 10 dB and the RF input level is +18 dBmV, the CNR of one amplifier is 67.16 dB.

$$C/N_i = N_t - NF + I$$

$$C/N_i = 59.16 - 10 + 18$$

$$C/N_i = 67.16$$

The combined CNR at the upstream input of the node for 50 identical reverse amplifiers can be found using Equation [7], where *N* is the total number of reverse amplifiers rather than the longest cascade of amplifiers.

$C/N_t = C/N_i - 10log(N)$

$C/N_t = 67.16 - 10log(50)$

$C/N_t = 67.16 - 10*log(50)$

$C/N_t = 67.16 - 10*1.70$

$C/N_t = 67.16 - 16.99$

$C/N_t = 50.17$

Equation [8] is used to combine the total upstream amplifier CNR (50.17 dB in this example) with the upstream fiber link CNR. If the standalone CNR of the fiber link is 39 dB, the combined CNR at the headend is 38.68 dB.

$$C/N_{total} = -10*\log\left[10^{\frac{-C/N_1}{10}} + 10^{\frac{-C/N_2}{10}}\right]$$

$$C/N_{total} = -10*\log\left[10^{\frac{-50.17}{10}} + 10^{\frac{-39}{10}}\right]$$

$$C/N_{total} = -10*\log\left[10^{-5.02} + 10^{-3.90}\right]$$

$$C/N_{total} = -10*\log[0.0000096161 + 0.0001258925]$$

$$C/N_{total} = -10*\log[0.0001355087]$$

$$C/N_{total} = -10*-3.87$$

$$C/N_{total} = 38.68$$

The power addition formula (Equation [8]) also can be used to calculate the combined CNR at the upstream input port to a cable modem termination system (CMTS). Assume the following CNRs from four upstream fiber links (including the respective node and coax plant ):

Upstream output from fiber receiver A: 35 dB

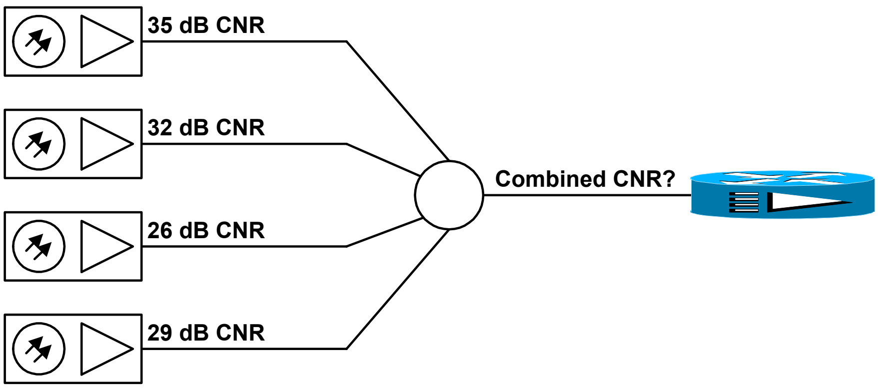
Upstream output from fiber receiver B: 32 dB

Upstream output from fiber receiver C: 26 dB

Upstream output from fiber receiver D: 29 dB

Figure 10 illustrates this example.

**Figure 10.** Combining CNRs at CMTS Upstream Input




$$C/N_{total} = -10 * \log\left[10^{\frac{-C/N_1}{10}} + 10^{\frac{-C/N_2}{10}} + 10^{\frac{-C/N_3}{10}} \ldots + 10^{\frac{-C/N_n}{10}}\right]$$

$$C/N_{total} = -10 * \log\left[10^{\frac{-35}{10}} + 10^{\frac{-32}{10}} + 10^{\frac{-26}{10}} + 10^{\frac{-29}{10}}\right]$$

$$C/N_{total} = -10 * \log\left[10^{-3.5} + 10^{-3.2} + 10^{-2.6} + 10^{-2.9}\right]$$

$$C/N_{total} = -10 * \log[0.000316227766017 + 0.00063095734448 + 0.00251188643151 + 0.00125892541179]$$

$$C/N_{total} = -10 * \log[0.0047179969538]$$

$$C/N_{total} = -10 * -2.33$$

$$C/N_{total} = 23.26$$

In this example, four-to-one combining results in a CNR at the CMTS input that does not meet the DOCSIS assumed upstream channel transmission characteristic minimum of 25 dB. We could either migrate to two-to-one combining (combining the 35 dB and 26 dB upstream values yields 25.49 dB CNR, whereas combining the 32 dB and 29 dB upstream values yields 27.24 dB CNR), or troubleshoot the plant to correct—if possible—the two lower CNRs[6].

## SUMMARY

CNR is generally accepted to be a pre-detection measurement—that is, one made at RF. When we carried only analog TV channels on our networks, CNR was understood to be the difference, in decibels, between the amplitude of the visual carrier of a TV channel and the rms amplitude of system noise in some specified bandwidth. Today's cable networks carry a variety of signals in addition to traditional analog channels, including digitally modulated carriers that use high-order modulation formats such as 64- and 256-QAM. Understanding

[6] In modern cable networks, upstream thermal noise is seldom a limiting factor. Impairments such as burst or impulse noise, ingress, and common path distortion are more likely to affect upstream performance.

CNR, how it degrades through a cascade of devices, and how it affects all the signals carried on a cable network are critical parts of ensuring reliable network operation.

CNR is a powerful tool for characterizing the health of an RF transmission medium or standalone device. Cable operators have long used CNR as a measure of network performance, along with other parameters such as carrier-to-composite triple beat (CTB), carrier-to-composite second order (CSO), and carrier-to-cross modulation (XMOD) ratios, hum modulation, and broadband sweep response. CNR by itself does not necessarily describe the quality of signals carried on a cable network, although CNR does have an impact on signal quality. Maintaining CNR at or above certain performance thresholds is one way to minimize that impact.

**References**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DOCSIS 1.1 Radio Frequency Interface Specification—
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