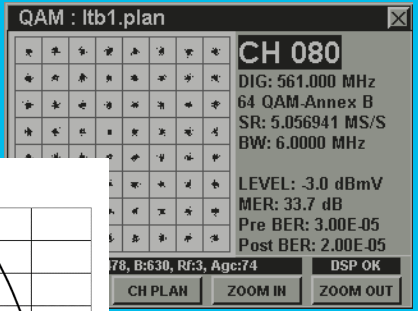
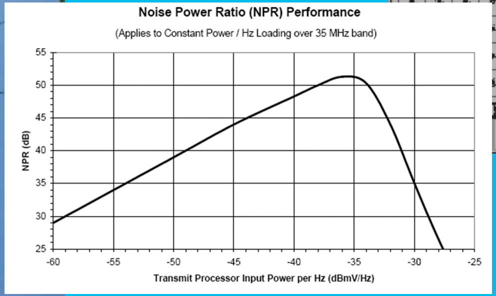
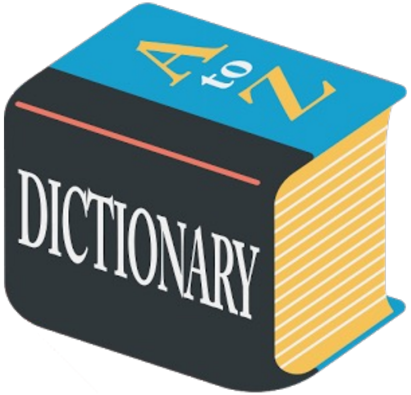
Putting the decibel to work



Ron Hranac

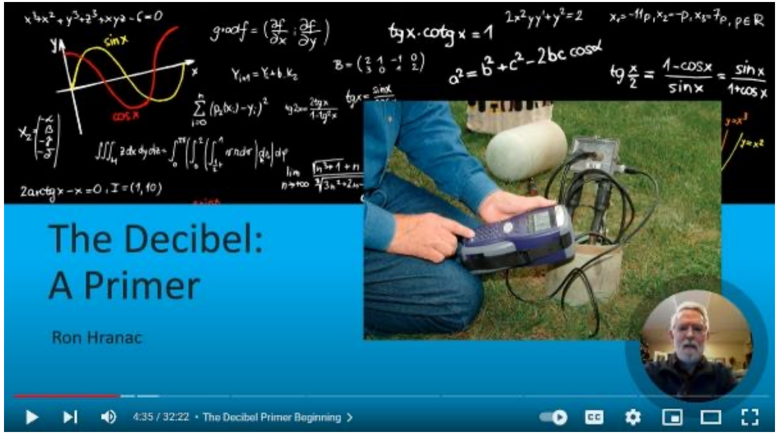


Defining the decibel



decibel (dB): A logarithmic-based expression of the ratio between two values of a physical quantity, typically power or intensity. The decibel provides an efficient way to express ratios which span one or more powers of the logarithmic base, most commonly 10. Mathematically, the ratio of two power levels P_1 and P_2 in decibels is $dB = 10\log_{10}(P_1/P_2)$.

For an overview of the decibel, see the video here: https://youtu.be/jOVa4xJSLiA



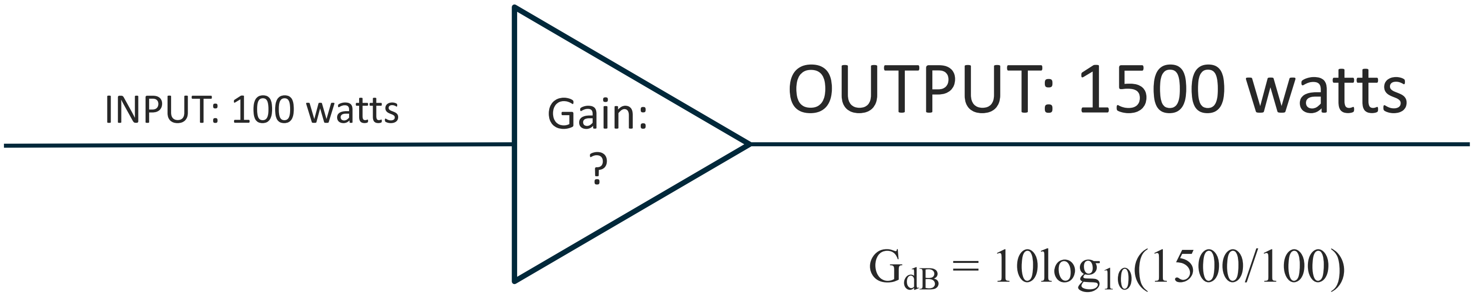
Using the decibel

dB	dBmV*
✓ gain	✓ signal level (RF power)
✓ loss (attenuation)	X
✓ signal-to-noise ratio (SNR)	X
✓ carrier-to-noise ratio (CNR)	X
✓ modulation error ratio (MER)	X
✓ return loss	X
✓ noise power ratio (NPR)	X
✓ carrier-to-distortion ratio (e.g., composite triple beat, composite second order, common path distortion)	X

*Note: Other examples of absolute values include decibel microvolt (dBµV), decibel milliwatt (dBm), decibel watt (dBW), decibel volt (dBV), and decibel microvolt per meter (dBµV/m)

Gain

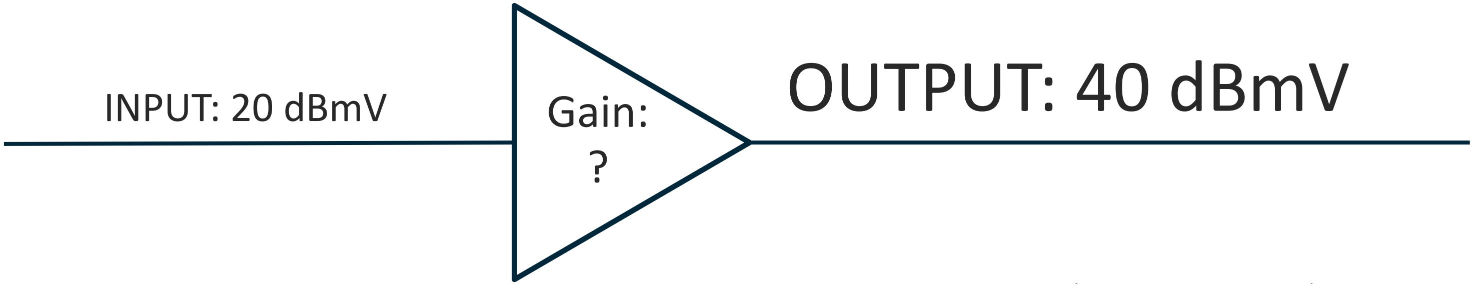
gain: An increase in the power of a signal or signals, usually measured in decibels. Expressed mathematically, $G_{dB} = 10\log_{10}(P_{out}/P_{in})$, where G_{dB} is gain in decibels, P_{out} is output power in watts, P_{in} is input power in watts, and $P_{out} > P_{in}$. When signal power is stated in dBmV, $G_{dB} = P_{out}(\text{dBmV}) – P_{in}(\text{dBmV})$.



$G_{dB} = 10\log_{10}(1500/100)$
$G_{dB} = 10 * \log_{10}(15)$
$G_{dB} = 10 * 1.18$
Gain = 11.76 dB

Gain (cont'd)

gain: An increase in the power of a signal or signals, usually measured in decibels. Expressed mathematically, $G_{dB} = 10\log_{10}(P_{out}/P_{in})$, where G_{dB} is gain in decibels, P_{out} is output power in watts, P_{in} is input power in watts, and $P_{out} > P_{in}$. When signal power is stated in dBmV, $G_{dB} = P_{out}(\text{dBmV}) – P_{in}(\text{dBmV})$.

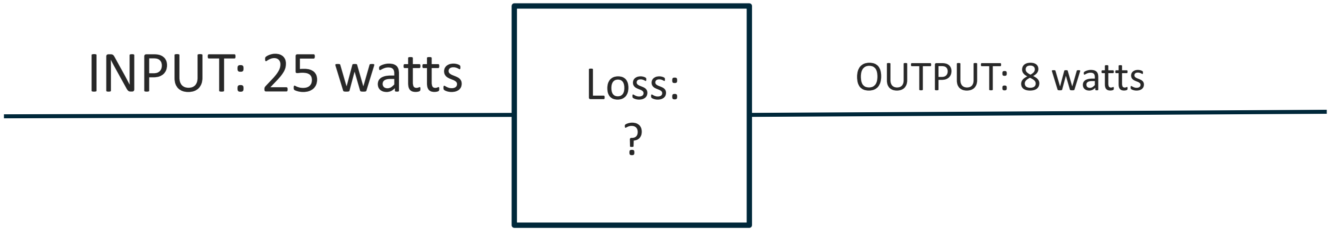


$G_{dB} = 40\ \text{dBmV} – 20\ \text{dBmV}$

Gain = 20 dB

Loss (attenuation)

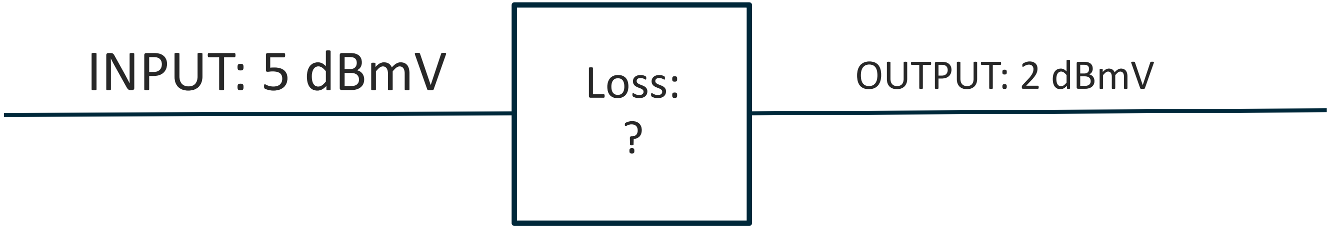
loss: A decrease in the power of a signal or signals, usually measured in decibels. Expressed mathematically, $L_{dB} = 10\log_{10}(P_{in}/P_{out})$, where L_{dB} is loss in decibels, P_{in} is input power in watts, P_{out} is output power in watts, and $P_{out} < P_{in}$. When signal power is stated in dBmV, $L_{dB} = P_{in}(\text{dBmV}) – P_{out}(\text{dBmV})$.



$L_{dB} = 10\log_{10}(25/8)$
$L_{dB} = 10 * \log_{10}(3.13)$
$L_{dB} = 10 * 0.49$
Loss = 4.95 dB

Loss (attenuation)

loss: A decrease in the power of a signal or signals, usually measured in decibels. Expressed mathematically, $L_{dB} = 10\log_{10}(P_{in}/P_{out})$, where L_{dB} is loss in decibels, P_{in} is input power in watts, P_{out} is output power in watts, and $P_{out} < P_{in}$. When signal power is stated in dBmV, $L_{dB} = P_{in}(\text{dBmV}) - P_{out}(\text{dBmV})$.

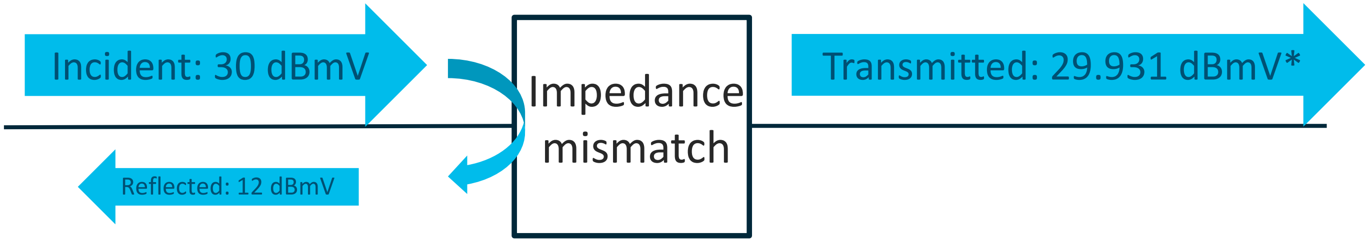


L_{dB} = 5 dBmV – 2 dBmV

Loss = 3 dB

Return loss

return loss: The ratio, in decibels, of the power incident upon an impedance discontinuity to the power reflected from the impedance discontinuity. Note: When $P_{reflected} < P_{incident}$ return loss is a positive number.

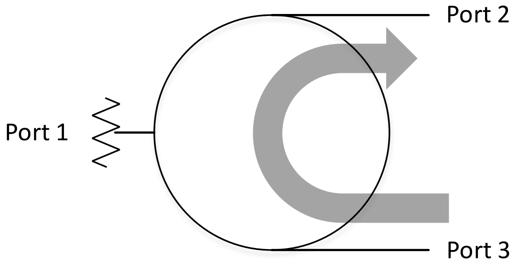


R_{dB} = 30 dBmV – 12 dBmV
Return loss = 18 dB

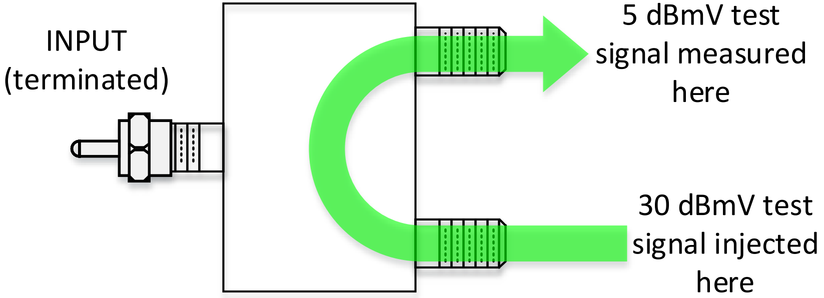
*Note: What is called *mismatch loss* is 0.069 dB in this example.

Isolation

isolation: The difference, in decibels, between the RF power injected into one port of a device and another port of the same device. One common measure is output port-to-output port isolation on a passive device such as a splitter or tap. Note: During an isolation measurement, unused ports are terminated.



Isolation

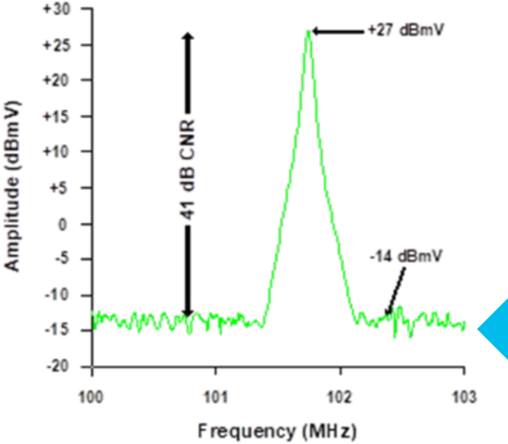


$$\text{Isolation}_{\text{dB}} = 30 \text{ dBmV} - 5 \text{ dBmV}$$
$$\text{Isolation} = 25 \text{ dB}$$

Carrier-to-noise ratio

Before measuring CNR, make sure the displayed noise floor is the system's noise, not the test equipment's noise.

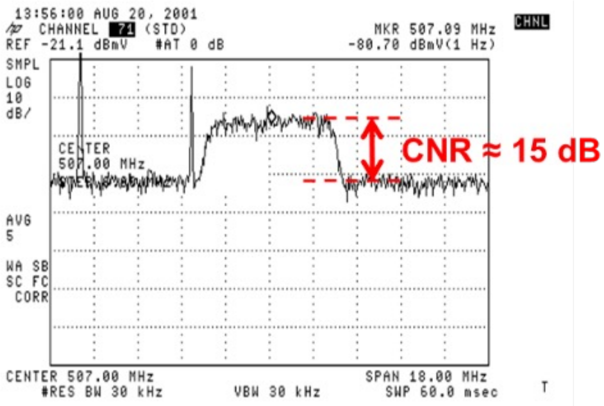
carrier-to-noise ratio (CNR): The ratio of carrier o… …nal noise power in a specified bandwidth, as measure… …alyzer or similar equipment. Note that "noise" can also ref… …ise, such as relative intensity noise, shot noise, etc., but does not re…r to transient noise.



The noise floor measurement may have to be corrected to a specified bandwidth (e.g., 4 MHz for NTSC analog visual CNR measurements). For instance, if the spectrum analyzer's resolution bandwidth (RBW) is 300 kHz, the noise power correction for 4 MHz is $10\log_{10}(4{,}000{,}000/300{,}000) = 11.25$ dB. That is, 11.25 dB must be added to the 300 kHz RBW noise measurement. In this example, -14 dBmV + 11.25 dB = -2.75 dBmV, making the corrected CNR = 29.75 dB rather than the indicated 41 dB.

Carrier-to-noise ratio (cont’d)

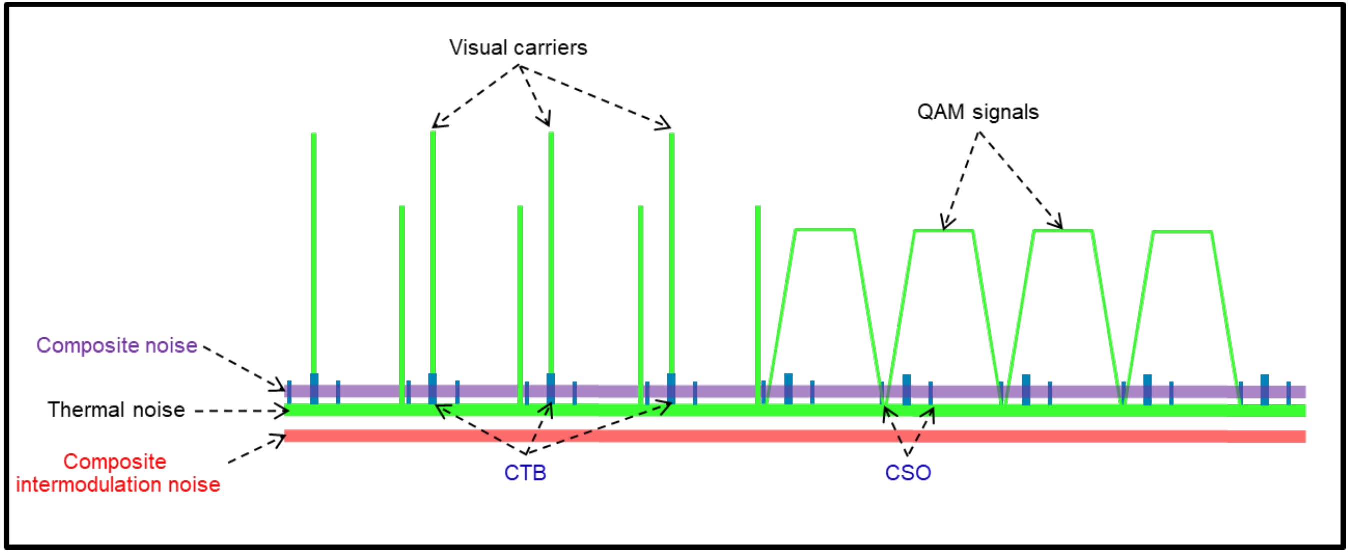
carrier-to-noise ratio (CNR): The ratio of carrier or signal power to the thermal noise power in a specified bandwidth, as measured on an RF spectrum analyzer or similar equipment. Note that “noise” can also refer other types of noise, such as relative intensity noise, shot noise, etc., but does not refer to transient noise.



For SC-QAM CNR measurements, a noise floor correction is not necessary. (Just make sure the displayed noise is not test equipment noise.)

Carrier-to-distortion ratio

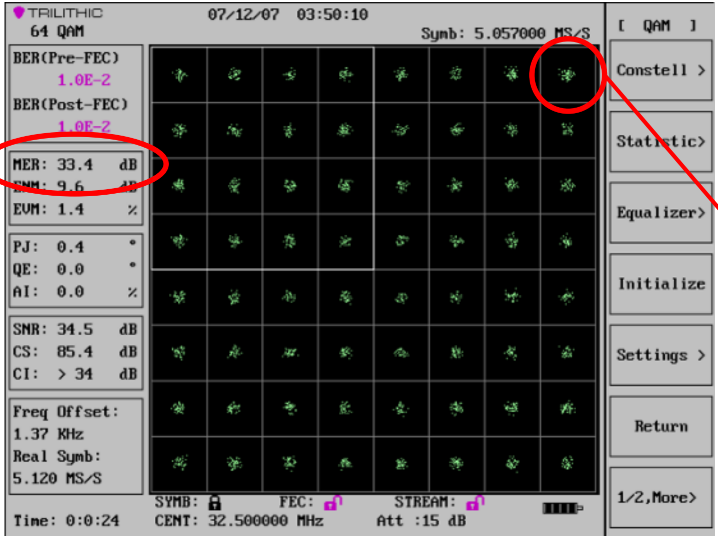
The ratio of carrier or signal power to the distortion in a cable network. Examples of distortions of interest include composite second order (CSO), composite triple beat (CTB), and composite noise (CN).



Receive modulation error ratio

modulation error ratio (MER): The ratio of average signal constellation power to average constellation error power, stated in decibels.
receive modulation error ratio (RxMER): The MER as measured in a digital receiver after demodulation, with or without adaptive equalization.

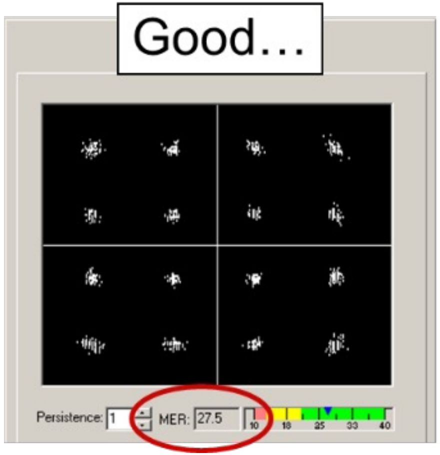
The RxMER in this example is 33.4 dB

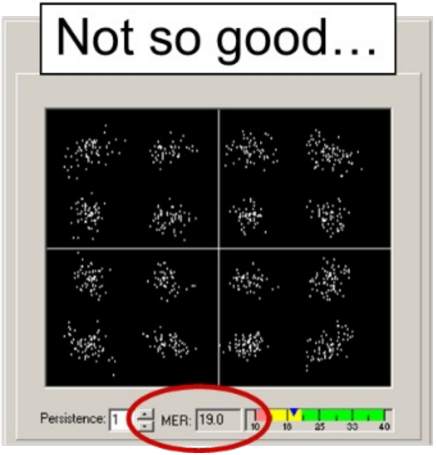


Think of RxMER as a measure of the spreading of a constellation's symbol points. The more spread out they are, the lower the RxMER, and the closer together the points are, the higher the RxMER.

Receive modulation error ratio (cont'd)

modulation error ratio (MER): The ratio of average signal constellation power to average constellation error power, stated in decibels.
receive modulation error ratio (RxMER): The MER as measured in a digital receiver after demodulation, with or without adaptive equalization.



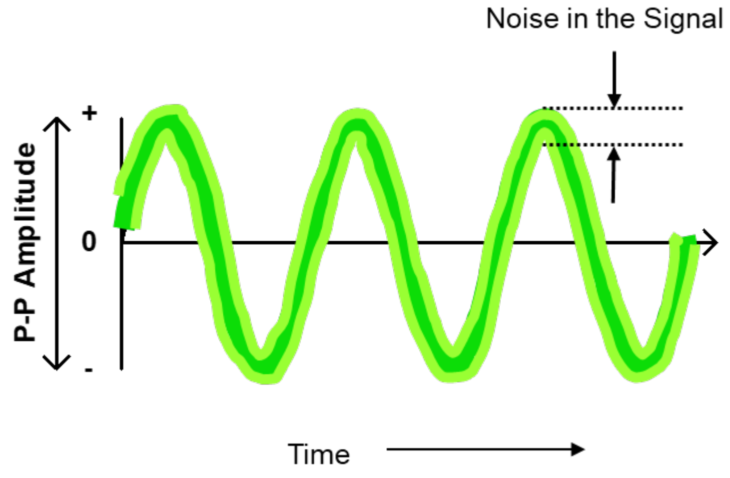


Signal-to-noise ratio

signal-to-noise ratio (SNR): 1) A general measurement of the ratio of signal power to noise power. 2) In a specific context, a measurement of the ratio of signal power to noise power made at baseband before modulation or after detection or demodulation.

In cable industry vernacular, SNR has long been accepted to be a pre-modulation or post-detection measurement, that is, one made on a baseband signal such as video or audio.

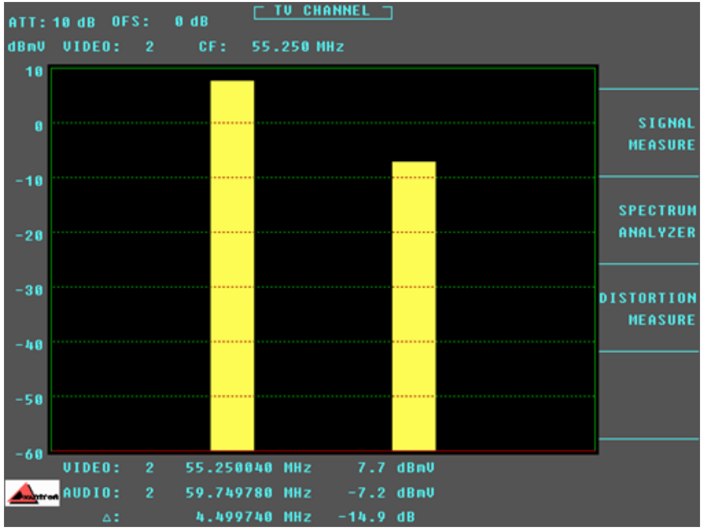
For example, analog baseband video SNR in dB = $20\log_{10}(L_{nominal}/N_{rms})$, where $L_{nominal}$ has a value of 714 millivolts peak-to-peak (100 IRE units) for NTSC or 700 mV p-p for PAL. These luminance values exclude sync.



Signal level

signal level: The amplitude of a signal, specifically the RF power of that signal. Signal level in cable networks is expressed in dBmV (not dB). The decibel millivolt (dBmV) is a unit of power expressed in terms of voltage.

- In the case of an analog TV channel's visual carrier, signal level is the carrier's *peak envelope power*
- The signal level of an SC-QAM signal is its *average power*, also called digital channel power or digital signal power. (The signal level of a downstream OFDM signal is the average power per 6 MHz. The signal level of an upstream OFDMA signal is the average power per 1.6 MHz, although some prefer to normalize that power to 6.4 MHz.)



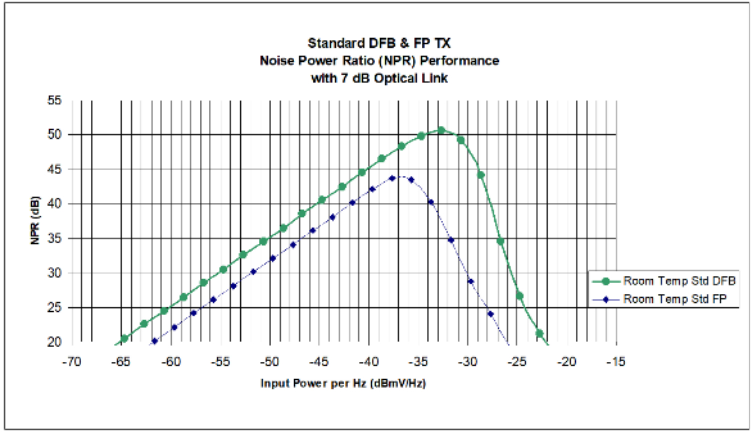
A few other applications of the decibel

ubr7246#show cable modem phy

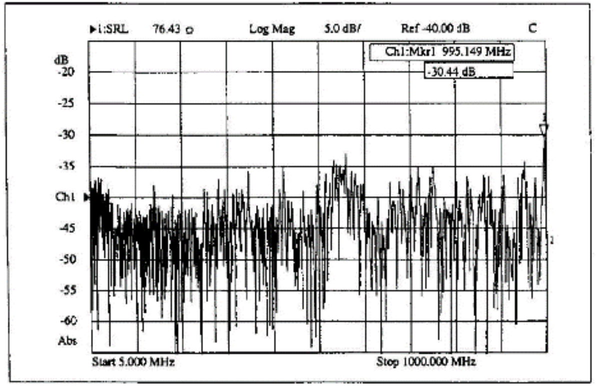
MAC Address	I/F	Sid	USPwr (dBmV)	**USSNR (dB)**	Timing	MicrReflec	DSPwr	DSSNR	Mode
0002.8a8c.0000	C6/0/U0	9	46.07	**35.42**	[illegible]	[illegible]	[illegible]	[illegible]	tdma
000b.06a0.0000	C6/0/U0	10	48.07	**36.12**	2037	46	0.05	41.00	atdma

Yes, it says "USSNR," but it's actually upstream RxMER.

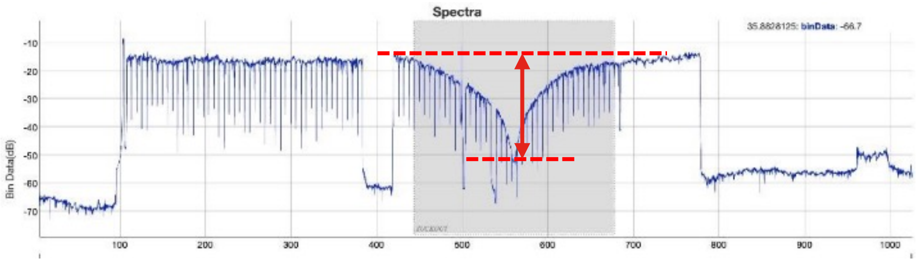
Noise power ratio (NPR)



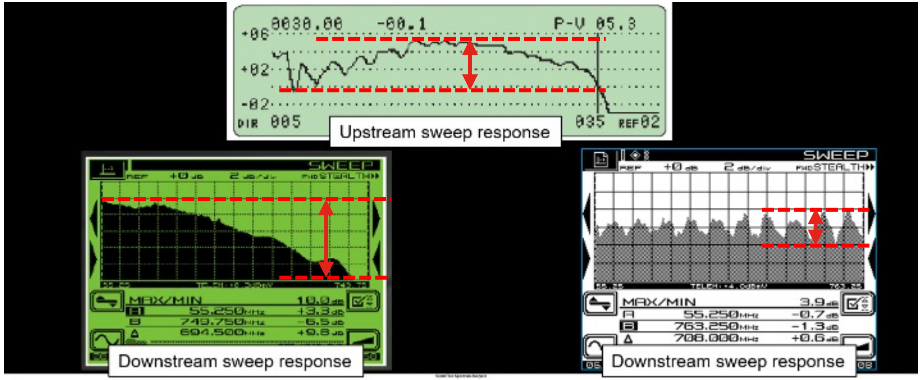
Coaxial cable structural return loss (SRL)



A few other applications of the decibel



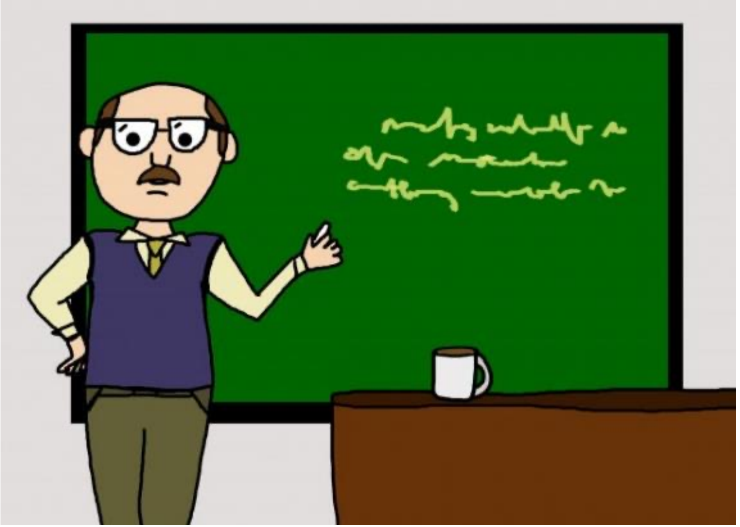
Frequency response is measured in dB peak-to-peak or peak-to-valley.



Some decibel shortcuts

Change in decibels	**Change to power**
1 dB increase or decrease	Power increases or decreases by 1.26x
3 dB (actually 3.01 dB) increase or decrease	Power increases or decreases by 2x
6 dB (actually 6.02 dB) increase or decrease	Power increases or decreases by 4x
10 dB increase or decrease	Power increases or decreases by 10x
20 dB increase or decrease	Power increases or decreases by 100x
30 dB increase or decrease	Power increases or decreases by 1000x
60 dB increase or decrease	Power increases or decreases by 1,000,000x

Summary



- Decibels express the logarithmic ratio of two power levels: $dB = 10\log_{10}(P_1/P_2)$
- The decibel is used in a variety of cable network measurements: gain, loss (attenuation), return loss, isolation, carrier-to-noise ratio, carrier-to-distortion ratio, RxMER, signal-to-noise ratio, noise power ratio, structural return loss, and even signal level (dBmV).

Keep in mind the correct usage of the decibel:

“The signal level at the modem input increased by 2 dB, going from +3 dBmV to +5 dBmV.”
“The RF signal level at the input to a modem is -2 dBmV, or the RF signal level at a line extender output is +48 dBmV.”
“The specified cable modem input level range is 0 dBmV, ± 15 dB.”
“The CNR is 35 dB.”