8000 Lee Highway
Falls Church, VA 22042
703-205-0600
www.ydi.com

Understanding Decibels and Their Use in Radio Systems

By Michael F. Young
President and CTO
YDI Wireless

Background
This article discusses the basic unit of measurement used in radio signals: the decibel or dB. It is named after Alexander Graham Bell - that is why the “B” is capitalized. There are several variations of the dB used in radio. This paper contains some definitions and explanations of dBs, plus other related terms and concepts that you might find useful in implementing your wireless systems.

dB (Decibel)
The difference (or ratio) between two signal levels. Used to describe the effect of system devices on signal strength. For example, a cable has 6 dB signal loss or an amplifier has 15 dB of gain. This is useful since signal strengths vary logarithmically, not linearly. Since the dB scale is a logarithmic measure, it produces in simple numbers for large-scale variations in signals. It is very useful because system gains and losses can be calculated by adding and subtracting whole numbers.

Every time you double (or halve) the power level, you add (or subtract) 3 dB to the power level. This corresponds to a 50% gain or reduction. 10 dB gain/loss corresponds to a ten-fold increase/decrease in signal level. A 20 dB gain/loss corresponds to a hundred-fold increase/decrease in signal level. In other words, a device (like a cable) that has 20 dB loss through it will lose 99% of its signal by the time it gets to the other side. Thus, big variations in signal levels are easily handled with simple digits.

dBm (dB milliWatt)
A signal strength or power level. 0 dBm is defined as 1 mW (milliWatt) of power into a terminating load such as an antenna or power meter. Small signals are negative numbers (e.g. -83 dBm).

For example, typical 802.11b WLAN cards have +15 dBm (32mW) of output power. They also spec a -83 dBm RX sensitivity (minimum RX signal level required for 11Mbps reception).

Another example, 125 mW is 21 dBm and 250 mW is 24 dBm.

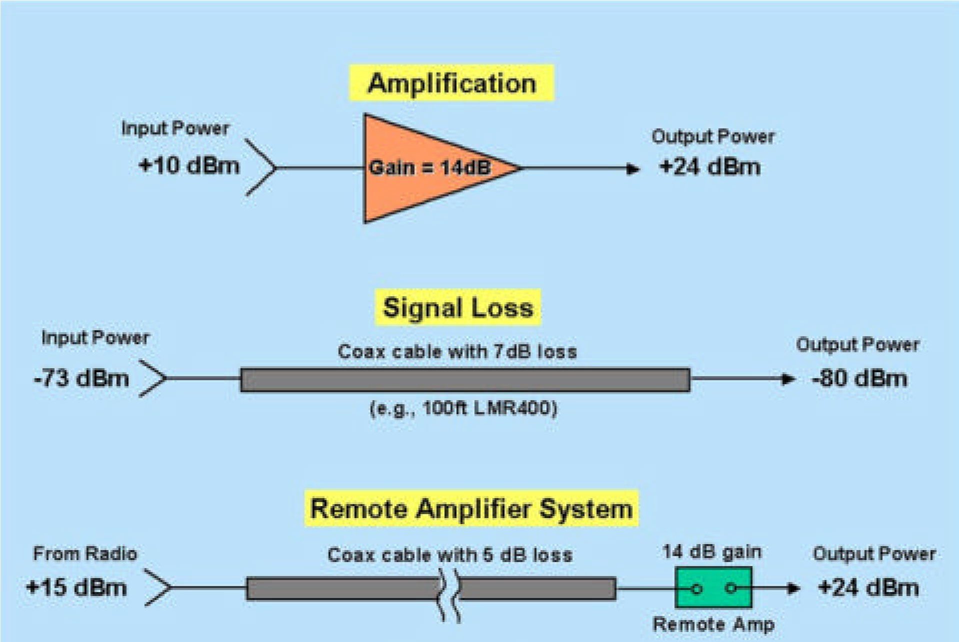

Figure 1

dBd (dB dipole)
The gain an antenna has over a dipole antenna at the same frequency. A dipole antenna is the smallest, least gain practical antenna that can be made. The term dBd (or sometimes just called dB) generally is used to describe antenna gain for antennas that operate under 1GHz (1000Mhz). The reason why the gain of many antennas, especially VHF/UHF antennas, is measured in dBd is because antenna manufacturers calibrate their equipment using a simple dipole antenna as the standard. Then they replace it with the antenna they are testing. The difference in gain (in dB) is reference to the signal from the dipole.

dBi (dB isotropic)
The gain a given antenna has over a theoretical isotropic (point source) antenna. Unfortunately, an isotropic antenna cannot be made in the real world, but it is useful for calculating theoretical fade and System Operating Margins. The gain of Microwave antennas (above 1 GHz) is generally given in dBi. A dipole antenna has 2.14 dB gain over a 0 dBi isotropic antenna. So if an antenna gain is given in dBd, not dBi, add 2.15 to it to get the dBi rating, For example, it an omni antenna has 5 dBd gain, it would have 5 + 2.15 = 7.15 dBi gain.

NOTE: If an antenna gain is just specified in dB from a manufacturer, be sure to ask if it is dBi or dBd. If they cannot tell you or do not know the difference, then you should consider buying from another vendor!

EIRP (Effective Isotopic Radiated Power)
Effective Isotropic Radiated Power is defined as the effective power found in the main lobe of a transmitter antenna relative to an Isotropic radiator which has 0 dB of gain. It is equal to the sum of the antenna gain (in dBi) plus the power (in dBm) into that antenna. For example, if a 12 dBi gain antenna is fed with 15 dBm of power has an Effective Radiated Power (ERP) of:

12 dBi + 15dBm = 27 dBm (500 mW).

With an amp that has 24 dBm (250mW) output - max allowed by the FCC into a 12 dBi omni:

12 dBi + 24dBm = 36 dBm (4 Watts)
- which, BTW, is the same as 1W (+30 dBm) into a 6 dBi omni:

6 dBi + 30 dBm = 36 dBm (4 Watts)

But it is much better to have a higher gain omni antenna since, while the ERP is the same, a higher gain antenna has the gain on receive as well. This is where you really need it since most of your clients will not be equipped with amplifiers.

NOTE: The ERP is found in the main lobe only. If you are using a high-gain omni-directional antenna, the radiation pattern is very flat and narrow (like a pancake). If the antenna is too high, the main lobe will actually shoot over the heads of your customers. But oftentimes need great height to clear obstacle from the WIPOP antenna to your customers! A solution is to use down-tilt sector antennas. They have more gain than omni-antennas and the main lobe can be focused into the desired coverage area. Doing this also defines a "cell" that will prevent radio coverage all the way to the horizon. This has the benefit of not only minimizing interference at the WIPOP from distant signals, but also will enable you to re-use the frequency at another cell several miles away.

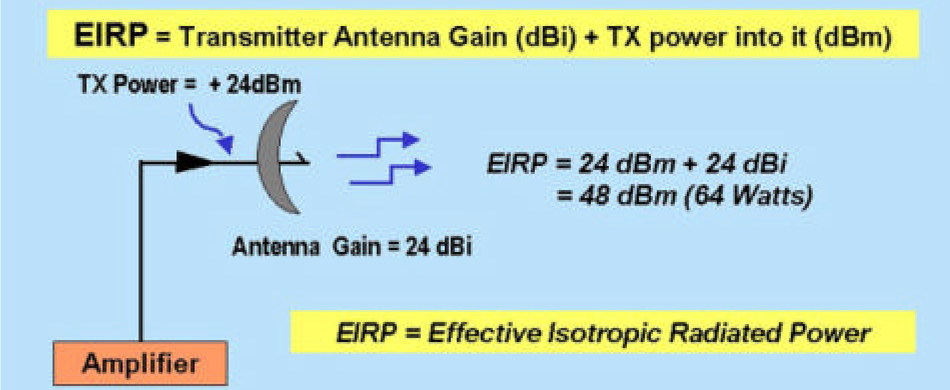

Figure 2

FSL (Free Space Loss)
Free Space Loss is defined as the loss that a radio signal experiences when traveling through free space. The formula at 2.4 GHz is:

FSL = 104.2 + 20 log D Where: **D** = Distance in miles

Example: At 5 miles FSL is 118 dB

RULE OF THUMB: Every time you double (or halve) the distance from the transmitter to the receiver, the signal level is lowered (or increased) by 6dB.

System Operating Margin (SOM)

System Operating Margin (also referred to as Fade Margin) is defined as the difference between the received signal level (in dBm) and the receiver sensitivity (in dBm) needed for error free reception. For example, if the received signal level is -71 dBm and the receiver sensitivity is -83dBm (typical for a 11Mbps WLAN), then the SOM is:

-71dBm - (-83 dBm) = 12 dB SOM

This should work if there is not bad interference. YDI recommends 10 dB SOM or more. 20 dB is excellent.

NOTE: If your WIPOP (Wireless Internet Point of Presence) is amplified and your customer's WLAN card or AP is not, then the SOM needs to be calculated from the remote site back to the WIPOP. This is because the remote site has the weakest TX signal in the system.

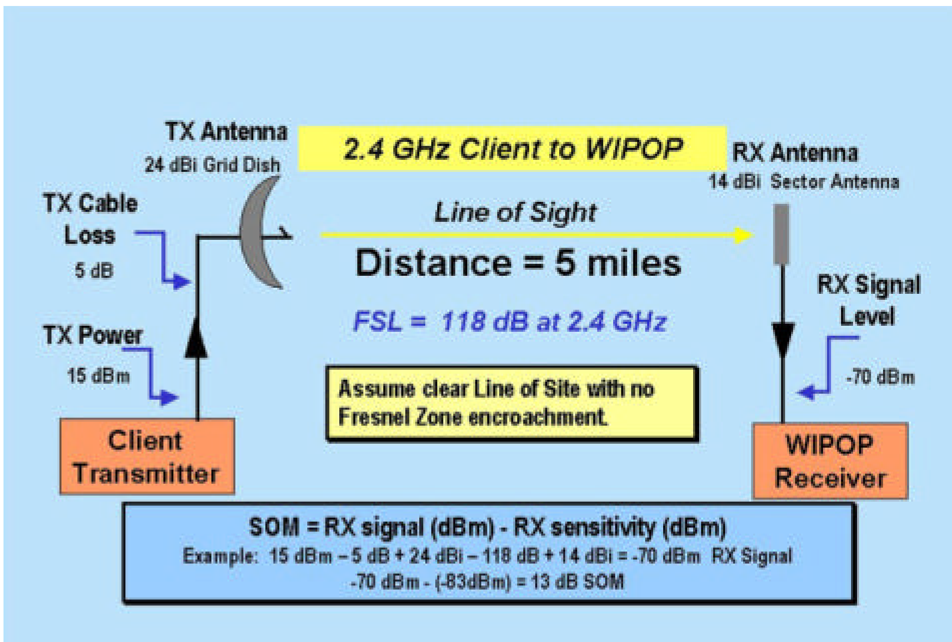

Figure 3

For a good Calculation Page, visit: http://www.ydi.com/calc.asp

Other White Papers on these topica can be found at:

http://www.ydi.com/deployinfo/white-papers.php