Antennas (a brief overview)

dBi

The FCC Part 15 regulations limit the antenna system gain for a 1 Watt unlicensed radio system to 6dBi.
This is based on an "isotropic" antenna model or "theoretical" antenna that radiates equally well in all directions. Such an antenna does not exist in the real world, but for purposes of determining the amount of antenna system gain permissible under Part 15 of this theoretical model is used.

The importance of understanding "theoretical" antennas versus "real" antennas has to do with the fact that the FCC views antenna gain in terms of dBi while the antenna manufacturers typically rate antenna gain in terms of dBd, which relates to a real world antenna known as a half-wave dipole. This difference in starting points influences "the math" a company like Phoenix uses when correctly determining the gain/loss of an antenna, cable and connector system it supplies.

How is "the math" influenced? Without going into a long technical discussion, simply stated, the difference between dBd and dBi is expressed by the value 2.15. An antenna with a gain of 3dBd is viewed by the FCC as having a gain of 3 + 2.15 = 5.15dBi.

Since most end-users seldom use or understand dBd, dBi, or dBm (not discussed here), but instead use the general "catch phrase" dB when referring to the gain/loss of antenna system components, we recommend that they are aware of the fact that Phoenix Contact uses the following standard formula when determining Gain/Loss of an antenna system connected to a 1 Watt Phoenix FHSS radio.

Antenna gain (dB) - cable/connector losses (dB) + 2.15 = System Gain/Loss in dBi (not to exceed 6dBi)

Gain

In simple terms, gain can be thought of as the yardstick for determining how far a radio/cable/antenna system will transmit a signal by "focusing" the radiated energy produced by that radio. The simplest antenna - a 0dBi Omni - can be visualized as radiating signals in a sphere. To add "gain" to such an antenna, the radiation pattern of the energy can be shaped/focused, and in the case of an Omni directional antenna one thing that can be done is to flatten, or squish, the sphere. By turning the sphere into a donut, less energy is allowed to radiate vertically and more energy is diverted horizontally. An Omni antenna with its energy focused in this fashion will radiate energy further on a horizontal plane. Nothing is added to the system - only the radiation pattern is changed.

Loss

Loss is the yardstick, often given in "dB," for measuring the resistance of all the things that reduce the strength of a signal as it travels to the antenna. Cables, connectors, surge protectors, etc. all absorb energy from the signal as it passes through them. LMR400 cable, for example, has a loss of 3.9dB per 100 feet. When calculating antenna gain and cable loss, be sure to add 2.15 to the final value in order to convert the total dB gain/loss to dBi.

Gain/Loss Example

An antenna with 6dB gain will be mounted on a mast and require 100 feet of LMR400 cable. Using the formula given above, this would be calculated as 6dB - 3.9dB + 2.15 = 4.25dBi. Since this is within the 6dBi limit, it would be acceptable under FCC Part 15 to implement this system.

Types of Antennas

Omni directional antennas radiate and receive signals in all directions. They usually resemble vertical rods but can come in other shapes as well. Some have horizontal rods at their base to form a ground plane for increased performance. Because Omni antennas focus their gain over a wide area, they are typically used at MASTER radios that need to send and receive information to and from many surrounding radios, and with radio systems separated by short distances or residing in obstructed locations where the signals are bouncing around structures and buildings.

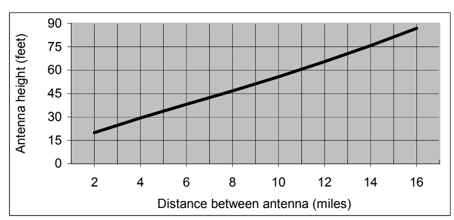
Yagi antennas are uni-directional, meaning they have their energy focused tightly enough to only transmit and receive signals in the direction they are pointed. Yagi antennas are useful when you want to increase signal strength in one direction and send the signal farther than you could with an Omni antenna. They are typically used in outdoor installations to cover long distances from point to point.

Antenna Height

For maximum transmission effectiveness, several factors must be taken into account. Obviously, distances between antennas are important, as radio signals dissipate as they travel. The Fresnel Zone, or the space occupied by the propagating radio signal, changes shape as i t travels across the earth and must be relatively clear of obstacles. For distances greater than 7 miles (11km), the curvature of the earth can adversely affect the radio link because it enters into the Fresnel zone. As a result, the overall formula for calculating approximate total antenna heights is:

$$H=13.7\sqrt{D+\frac{D^2}{8}}$$

Where:
H = antenna height in feet
D = distance between radios in miles



To simplify this, refer to the table at the right to find the suitable minimum height of the antennas at each end of the link.

Mounting

No matter what type of radio you are using, to maximize the signal strength getting to the receiver, mounting the radios with in Line-of-Sight of each other is the best option. That much said, 902 to 928MHz signals (used by Phoenix Contact) have characteristics that lend themselves well to bouncing and reflecting off of objects. This enables them to perform well in industrial environments where Line-of-Sight cannot be achieved. To take full advantage of bouncing and reflecting signals in an obstructed environment, Omni directional antennas should be used and mounted in areas where they can radiate and capture signals coming from the maximum number of reflective surfaces. For examle, in a refinery, mounting an Omni directional antenna outside the control room on a catwalk open to the superstructure of the facility, rather than burying it inside the control room, will greatly enhance the performance of the radio link.

When using Yagi antennas at remote sites to communicate back to a central MASTER with an Omni antenna, be sure to aim the Yagi's directly at the Omni and mount the elements of the Yagi antennas vertically - like the Omni. This will ensure maximum signal strength within the system.

If two Yagi antennas are used in a point to point application, their elements need to be aligned the same, either vertically or horizontally. Some system designers prefer to mount the Yagi elements horizontally as they feel this helps reduce interference from other radio systems in the area (which are typically vertically polarized).

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