

Antennas – A Brief Tutorial

Antennas are simply lengths of conductive metal that radiate radio signals into the air. Most common antennas are designed to be one-quarter, sometimes one-half, the wavelength of the radio signal they are to transmit/receive. Wavelength is calculated with the formula: $\text{Wavelength (meters)} = 300/\text{frequency (MHz)}$. For example, Phoenix Contact wireless modules use frequencies ranging from 902-928MHz, so based on this formula, the wavelength of our radio signals are approximately one-third of a meter, or one-foot. Keeping in mind then that antennas are generally one-quarter wavelength of the radio signal, our basic antennas for the 900MHz are typically no more than 3 inches in height.

ANTENNA TYPES

There are wide varieties of antennas used for the transmission of radio signals in the world today. The basic antenna is known as an “omni-directional.” Omni antennas radiate their RF energy in all directions, essentially outwards in a three-dimensional spherical pattern. Omni antennas usually resemble vertical rods but can come in other shapes as well. Some have horizontal rods of the same length placed at their base to increase their performance/distance. These are called “ground planes.”

Other antenna types include the “dipole”, where a section of wire, one-half the wavelength, is positioned either horizontally or vertically in the air to transmit signals. Dipoles emit their signals in more of a two-dimensional semi-circular or “doughnut” pattern, the key being both the transmitter and receiver’s antennas must be aligned the same (horizontally or vertically). Dipoles do not require a ground-plane are considered “bi-directional,” in that their signals travel in two opposite directions, depending on how the antenna is oriented.

The more focused (uni-directional) type of antenna is called a “Yagi.” A Yagi antenna is basically a standard one-half wavelength antenna, but with additional “elements” placed in front of it to focus the energy for transmission in one direction. The “reflector” and “director” elements are just similar-sized resonators spaced appropriately to increase the strength and narrow the direction of the signal prior to transmission. Again, the key to successfully using Yagi antennas is the correct orientation and alignment of the transmitting/receiving antennas.

ANTENNA GAIN

Antenna "gain" is a word that seems to strike fear in the hearts and minds of uninitiated radio users everywhere. It is often the word used to refer to some sort of mysterious signal amplifier, yet never really understood. However, one antenna with a “higher” gain does not amplify the signal more than another with “less” gain, as most people think. An antenna with greater gain simply focuses the energy of the signal differently.

To get a handle on "gain," let's talk about it in terms using a megaphone. When you want to get your message across a noisy stadium you can do two things with that megaphone to get the result: 1) you can shout into it as loudly as possible, and 2) you can direct the focused end of the megaphone toward the listener. The same two actions can be applied to sending a radio signal farther. First you can increase the transmit power (to a limit of 1 Watt for spread spectrum radios, FCC Part 15), and second you can "aim" the power that's radiating from the antenna toward the receiver. Aiming the power is the "gain." Taking this one step further, if someone in the stadium also had a megaphone and really wanted to hear what you had to say they could put their megaphone to their ear and aim the open end toward you, thereby focusing in on what's being transmitted from your location. Likewise, a receiving radio gets "gain" by focusing the direction of the "listening" antenna toward the source. In other words, gain is simply how you focus the radiated energy at the transmitter and how you focus the ear of the receiver.

Now, how does gain apply to the two types of antennas (omni and yagi) most commonly used in spread spectrum industrial radio installations? In very simple terms, omni antennas radiate transmit power (the

signal) in all directions (360 degrees) and listen for incoming messages from all directions. Yagi (directional) antennas focus their radiated transmit power in one direction and also listen for incoming signals with a more focused ear. Yagi antennas, therefore, tend to send a signal farther than omni antennas with the same gain. Yagis are the megaphones in the antenna world.

For the majority of MCR-RAD applications, the standard 1/4 wave whip unity-gain antennas purchased along with the equipment work just fine. However, sometimes you need to send the signal further and to do so, you must play within the rules laid out by the FCC in Part 15 of their guidelines. The two rules of most interest to the spread spectrum radio user are: 1) the maximum transmit power of the spread spectrum radio is 1 Watt, and 2) the maximum gain of a spread spectrum system must not exceed 6dB.

WHAT DOES “dB” STAND FOR?

Here's the technical definition. “dBm” (often referred to simply as “dB”) is the Power Ratio of the radio relative to 1mW. For example, a 1mW power level is referred to as 0dB. Likewise, a 1000mW, or 1W, power level can be referred to as 30dB. A 1/1000mW power level is -30dB, and the threshold sensitivity of an MCR-RAD, which exceeds 1/10000000000mW, can be more easily expressed as -110dB. As you can see, a MCR-RAD receiver doesn't need to capture very much energy from its transmitter in order to maintain a solid lock and secure data.

Now let's make this easier. Since many folks who use the MCR-RADs are unfamiliar with radio theory and are simply looking for an easy-to-use cable and conduit replacement, we reassure them it is simply sufficient to know that 6dB of antenna gain (remember that "gain" has to do with focusing the energy radiated from the antenna) more or less doubles the distance a signal will travel with no obstructions. For example, if a "no gain" (0dB) 1/4 wave omni antenna sends a 1 Watt MCR-wireless device signal 4 miles in perfect line-of-sight conditions, a 6dB gain antenna should send the signal 8 miles. In other words, we say "Don't worry about the specifics of dB measurement, it's not necessary to be a radio expert."

How do antennas increase the distance like that? Simply put, omni antennas that radiate energy in a sphere with no gain "squish the sphere into a *donut* shape" as the gain is increased. The more you "squish the sphere," the larger the radius of the *donut* becomes. Less energy sent vertically means more energy sent out in a horizontal direction. In a similar fashion, a directional yagi antenna takes the energy about to be radiated and focuses it in one direction. Using an analogy, the higher the gain a yagi antenna has the more narrowly its energy is focused, so that its "beam" changes from a *street lamp* to a *lighthouse* to a *laser* as the gain is increased. You can see why aiming becomes important with a high gain yagi.

dB LOSES AND CABLING

Now, back to the FCC rules. At first glance, it may appear that if you were using a 1 Watt MCR-wireless devices you would never need an antenna that exceeds a 6dB rating, but this isn't quite true. The 6dB applies to the system and the system includes cables and connectors as well as the antenna. But what do the cables and connectors have to do with it? Cables and connectors have a "dB loss" rating. For example, RG58 cable loses 16dB per 100', RG213 loses 7.6dB per 100' and LMR400 cable loses 3.9dB per 100'. Connectors also have loss ratings, although they are minimal. So if you have an application where you need to add quite a bit of cable in order to get out of a building, or up a tower, these losses have to be taken into account.

Here's an example. Let's say you have an MCR-RAD at a water tank, nine miles away from your control room. You know you'll need to get as much gain as possible to send the signal so you decide on a 6dB directional yagi antenna, thinking this is the maximum antenna gain you're allowed. But let's say you've decided to put the yagi antenna near the top of a tower close to the tank so that you can clear a stand of trees and a few houses. The antenna will be 60 feet in the air and the rest of the cable run adds another 40 feet. You decide on LMR400 cable with a few connectors. Based on the cable losses quoted above, this means that the total system loss will be approximately -4dB. Add this to the antenna gain of +6dB and your system now has a total gain of only 2dB. Will this get the signal nine miles? Probably not. So in this

case, you would need to purchase a 10dB directional yagi so that once all the losses (-4dB) are factored in you still end up with the maximum gain allowed (6dB) and required.