# Maximizing Range

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**Application Note**

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Website: www.digi.com
Email: rf-experts@digi.com

# Abstract

This document introduces the basics of a wireless communications system and explains how to maximize range when commissioning a system. It explains how to install radios, antennas and cables in a way to maximize the reliability of communication.

# RF Communication Systems

Communication systems have several components that should be looked at in each system.

- Transmitting Element
- Receiving device
- The environment through which communication is occurring
- Antennas or other focusing elements

**Figure 1. Basic Communication System**


## Transmitter and Receiver

The transmitter's role in wireless communications is to feed a signal to an antenna for transmission. A radio transmitter encodes data into RF waves with a certain signal strength (power output) to project the signal to a receiver.

The receiver receives and decodes data that comes through the receiving antenna. The receiver performs the task of accepting and decoding designated RF signals while rejecting unwanted ones.

RF communication can be compared to simple audio communication; the vocal cords transmit sound waves that may be received by the eardrum. Megaphones can focus and direct the sounds waves to make communication more efficient.

## Environment

The space between the transmitter and receiver is the system's environment. Physical obstructions and noise (interference) can enter into the environment and limit the system's ability to get information from one place to another. Range-reducing elements are commonly introduced into simple wireless communications systems in the form of walls, other people talking, wind, etc.

## Visual vs. RF Line-of-Sight

Attaining RF Line-of-Sight (LOS) between the sending and receiving antennas is essential in achieving long range in wireless communication systems. There are two types of LOS that are generally used to describe an environment:

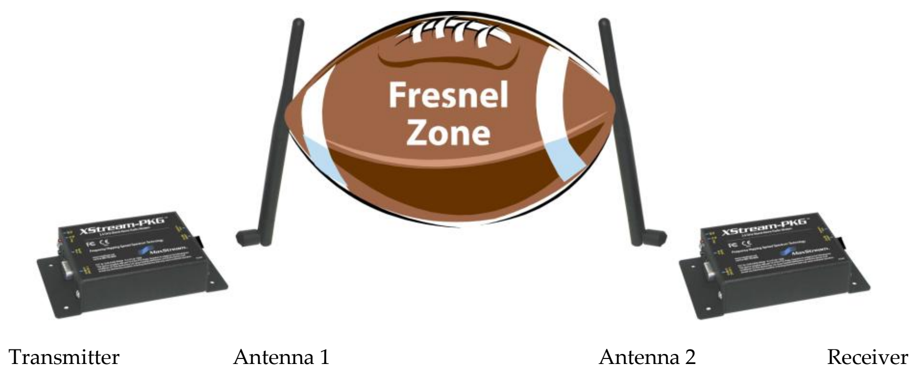
**Visual LOS** is the ability to see from one site to the other. It requires only a straight linear path between two points.

**RF LOS** requires not only visual LOS, but also a football-shaped path free of obstacles for data to optimally travel from one point to another.

## Fresnel Zone

The Fresnel Zone can be thought of as a football-shaped tunnel between two sites that provides a path for RF signals.

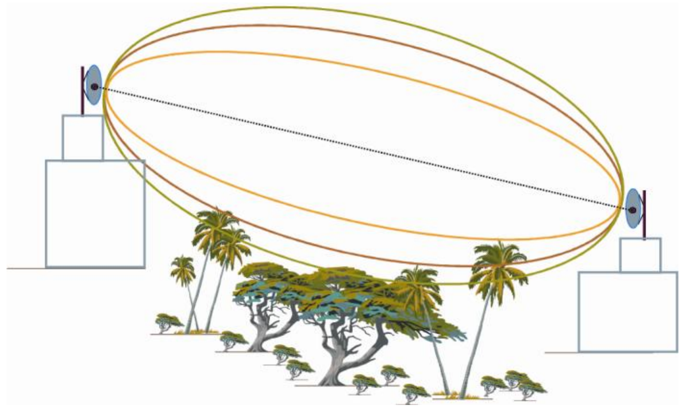
**Figure 2. Shape of the Fresnel Zone**




In order to achieve the greatest range, the football-shaped path in which radio waves travel must be free of obstructions. Buildings, trees or any other obstacles in the path will decrease the communication range. If the antennas are mounted just barely off the ground, over half of the Fresnel zone ends up being obstructed by the earth resulting in significant reduction in range. To avoid this problem, the antennas should be mounted high enough off of the ground so that the earth does not interfere with the central diameter of the Fresnel zone.

It is also important to understand that the environment may change over time due to growing vegetation, building construction, etc. If obstacles exist between two points, the antennas can be raised on one end or on both ends to clear the Fresnel zone of obstructions.

**Figure 3. Physical Obstructions overcome by antenna height**



How far above the ground and other obstacles the antennas need to be is determined by the diameter of the Fresnel zone. The diameter of the Fresnel zone depends upon the frequency and distances between the two radios. Various data points were inserted into Fresnel zone formulas to provide some points of reference. The following table provides approximate Fresnel zone diameters at 1000 feet, 1 mile, 5 mile and 10 mile ranges:

**Table 1. Fresnel Zone Diameters**

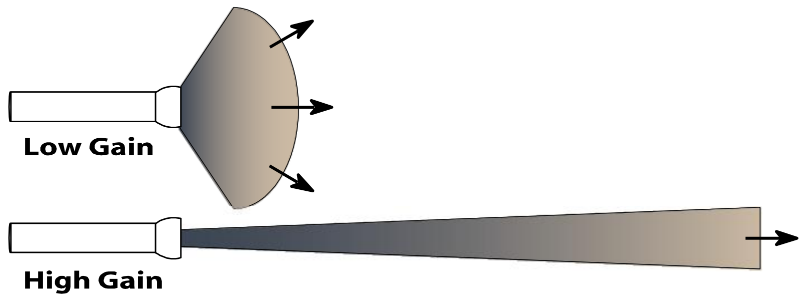
| Range Distance | Required Fresnel Zone Diameter (900 MHz Radios) | Required Fresnel Zone Diameter (2.4 GHz Radios) |
|---|---|---|
| **1000 ft. (300 m)** | 16 ft. (7 m) | 11 ft. (5.4 m) |
| **1 Mile (1.6 km)** | 32 ft. (12 m) | 21 ft. (8.4 m) |
| **5 Miles (8 km)** | 68 ft. (23 m) | 43 ft. (15.2 m) |
| **10 Miles (16 km)** | 95 ft. (31 m) | 59 ft. (20.2 m) |

In order to have ground clearance, the combined antenna height should be equal to the diameter of the Fresnel zone.

## Antennas

Antennas are devices that focus energy in a particular direction similar to the way the megaphone focuses voice energy. Antennas can provide different radiation patterns depending on the design and application. How much the energy is focused in a given direction is referred to as *Antenna Gain.* A flashlight can help illustrate the principle. Some flashlights allow the user to adjust the beam of light that comes out by twisting the lens. The lens can either focus or spread the beam of light. When the lens is used to spread or diffuse the beam of light, the beam of light travels a shorter distance than when the lens is twisted in a direction that tightens the beam of light.

**Figure 4. High and Low Beams**



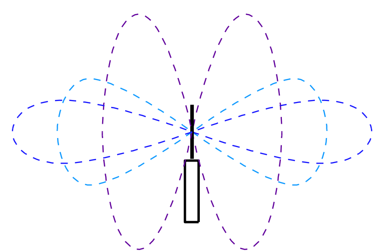

## Increase Antenna Gain

Transmitting and receiving antennas are used to focus and direct radio waves in specific directions. Antennas are another component that can be adjusted to increase the distance data can travel in a wireless communication system. Antenna gain is an important variable that can be adjusted in order to increase range. Antenna gain describes the amount of focus the antenna is able to apply to the system by directing the energy. The more focus the antenna can apply, the more range the system will yield. High gain antennas can achieve greater range than low gain antennas, though they cover less area.

**Omni-directional** antennas focus energy evenly in a doughnut-shape around the antenna [see the "Low Gain" flashlight example on page 1].

Gain vs. Vertical Beam Width (VBW)

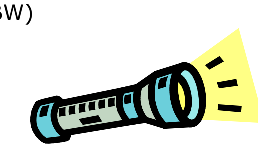
- 2.1 dBi (0 dBd) = 75º VBW
- 5.1 dBi (3 dBd) = 33º VBW
- 8.1 dBi (6 dBd) = 17º VBW



**Directional Antennas** focus energy more in one direction [see the "High Gain" flashlight example on page 1].

Gain vs. Vertical Beam Width (VBW)

- 8.1 dBi (6 dBd) = 70º
- 11.1 dBi (9 dBd) = 55º
- 15.1 dBi (13 dBd) = 35º



Notice how, like the flashlight, beam width is decreased as gain is increased.

### Mounting Considerations

When mounting an antenna, care should be taken to make sure it is as far away from metal objects as possible. If nearby metal gets too close to an antenna, it has the potential to interfere with the way the antenna radiates and may cause some undesirable results.

In some cases, a cable must be used to connect an antenna to a transmitter or receiver. All RF cables add some loss to the system. For any given cable, the longer the cable the more signal will be lost over that cable. Because of this the length of the cable should be kept as short as possible. Often a longer serial cable can be used to minimize the length of the antenna cable.

# Installing an RF System

Before installing a system a range test should be performed with two standalone units or a development kit. The X-CTU test software can allow a simple range test with one computer and one radio in loopback mode. Performing a range test will give an initial indication of the expected performance. If the loopback test indicates that additional range may be required, ask the following questions about the installation.

**Do I have clear RF line-of-site?**

If the Fresnel zone is not clear of the ground or other obstructions, often the best way to improve range is to raise the antennas higher off the ground. This not only gets the ground out of the Fresnel zone, but usually helps transmit over vegetation or other obstacles.

**What frequency am I using?**

Digi offers radios in both the 900 MHz and 2.4 GHz bands. The 900 MHz waves penetrate objects and travel better than their 2.4 GHz counterparts. If you are in the US, Canada, or Australia you will be better off range-wise using the 900 MHz radios. The 2.4 GHz radios must be used in European countries and where the ETSI standard is required.

**Can I use a directional antenna?**

Directional antennas will have better gain than the omni-directional antennas. While the omni-directional gain antennas can improve performance in line-of-site applications, the performance in non line-of-site situations is very similar to a dipole. If you need to maximize range, using a yagi or other gain antenna may be the best solution.

**Is the antenna mounted properly?**

Using long antenna cables or having the antenna right next to metal can reduce performance. Antenna cables add loss to a system. Using a shorter antenna cable can help keep the losses to a minimum. Often, a longer serial data cable can be used in conjunction with a shorter coax cable to keep antennas in a desired location. The radiating portion of the antenna should not touch other metal objects or be mounted right next to them. This can cause the antenna to operate inefficiently. It is best to give at least several inches of separation between the antenna and other metal structures or objects.