

AirTegrity Network Planning Guide

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Feedback

At AirTegrity Wireless, Inc., our goal is to create in-depth technical documentation of the highest quality and value. Each document is crafted with care and precision, involving many hours of research and the collaboration of many members from the development teams.

Readers' feedback is actively sought to help us improve on future revisions and publications. If there are any items that you feel are in error or areas that could be altered to better suit your needs, you can contact us through e-mail at techpubs@airtegrity.com. Please be sure to include the title and revision of the document.

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1 Network Planning Procedure

To ensure an effective and reliable wireless link, AirTegrity Wireless recommends that network and path planning be initiated before beginning installation of any hardware. Radio signals dissipate when they travel and there are many other factors that affect a radio signal as it moves through free space. ALL of these must be taken into account. The effectiveness of a radio link depends upon the overall installation, including calculating the Fade Margin.

Network planning must include the following steps:

1. Plan the physical layout.

Determine the location of each unit in the wireless network. Determine the number of sites. Map the location of your planned links, their physical location and surrounding terrain. Measure the distance between the AirTegrity units using GPS, map or other distance measurement tools. Determine Line of Sight and plan for any physical obstacles that may block the radio path.

2. You also need to understand how antennas work and learn how to estimate antenna gain in three-dimensions, specifically the effect of the radiation pattern on antenna gain. See the [Antenna Considerations](#) section. Determine the requirements of the Fresnel Zone.
3. Determine the antenna mast height requirements. Determine the cable requirements, including routing, between antenna and unit. Determine environmental requirements. This task is greatly simplified by using the “AirTegrity Link Budget Calculator”

For detailed instructions, see the sections [Determining Cable Requirements](#) and [Fade Margin](#).

4. Determine the EIRP (Effective isotropic Radiated Power) of the transmitting radios. See the EIRP section [EIRP](#).
5. Determine the transmitted signal Path Loss. See [Propagation Loss](#) section.
6. Determine the Received Signal Strength. See the [Rx Signal](#) section.
7. Determine the Fade Margin. See the [Fade Margin](#) section.
8. The performance of your system is also affected by radio interference. See the [Interference](#) section.

NOTE: This document is an information guide only and should be used only by those qualified by their radio network experience and training to carry out wireless network installations. AirTegrity cannot accept responsibility for the performance of poorly designed networks.

2 Antenna Considerations

Antenna selection is a critical part of network planning and this section provides some basic information about antenna parameters and how to select antennas for use in your wireless system.

There are a number of factors to consider when selecting the most appropriate antenna for any wireless application.

Antennas are tuned to operate on a specific group of frequencies. The manufacturer also fixes other specific attributes such as beam width and gain. Antennas should be selected and placed according to your site and your application.

In general, the larger the antenna, the higher the gain and the larger the mast required. It is best to use the smallest antenna that will provide sufficient protection from interference and enough signal at the far end of the link to provide good reception even with fading.

Several antenna types are appropriate for the type of installation discussed in this guide. Semi-parabolic grid antennas are typically used where wind loading is an issue. Solid antennas should have the option to add a radome to reduce wind loading, as a means of ice protection, where necessary, and to prevent birds from roosting on the antenna feeds.

For short links (or links where the appearance of the antenna is a problem) panel, patch or planar antennas might be appropriate. With these antenna types, the front-to-side, front-to-back, and cross-polarization characteristics are not as good, so it is important to carefully examine interference potential.

Consult your antenna vendor and installer for specific information on the antenna types, their use, and their performance.

The following are some examples of antenna types suitable for use with AirTegrity systems:

- Parabolic Dish
- Semi Parabolic Grid
- Yagi
- Omni Directional
- Patch
- Panel

Each antenna has different characteristics in Gain, Front to Back Ratio, Lobe Pattern and Beam Width. Antennas focus and absorb radio energy in specific directions. Specifications vary according to the design of the antenna.

To ensure the best range and interference suppression, the outdoor antenna should be directional, focusing the radio energy in one direction. This reduces interference from other systems operating at the same frequency.

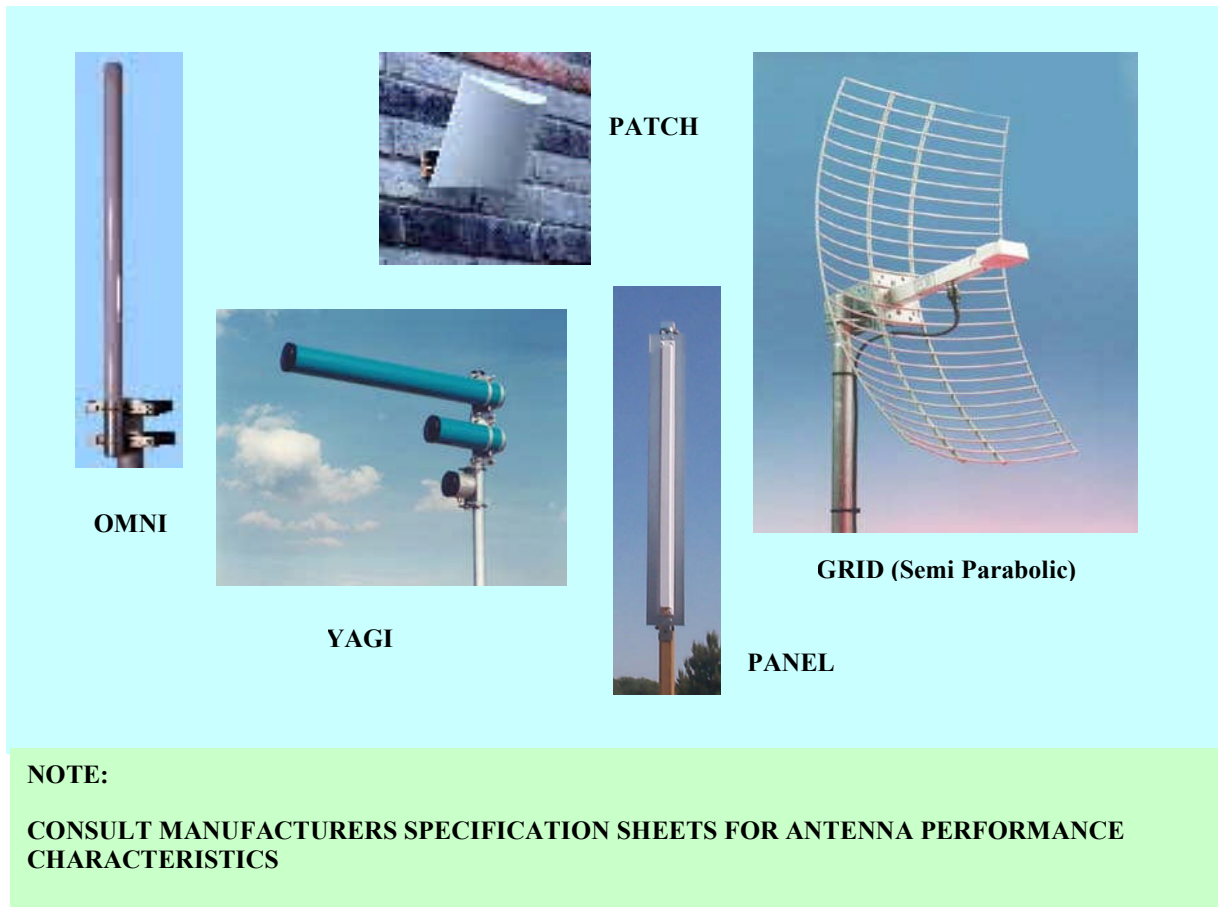
When you select an antenna, pay particular attention to the gain specification. When selecting antennas, choose a type with a gain that provides at least 15 dB fade margin for the link.

Antenna gain is specified in either dBi or dBd. When an antenna is specified in dBd, add 2.14 dB to the value to convert it to dBi.

**SAFE OPERATION AND PERFORMANCE OF AIRRUNNER SYSTEMS REQUIRES CORRECT
ANTENNA INSTALLATION.**

ANTENNAS SHOULD ALWAYS BE INSTALLED BY AN EXPERIENCED PROFESSIONAL AND FOLLOW
ACCEPTED STANDARDS FOR SAFETY, ELECTRICAL, GROUNDING AND ENGINEERING.

Examples of antenna types are shown below:



2.1 Minimal Antenna Clearance

The minimum clearance above obstructions for an AirTegrity antenna installation is as follows:

Link Distance	Antenna Height	Free Space Loss
0.5km/0.3miles	2.0mt/7ft	98dB
1.0km/0.6miles	3.7mt/14ft	104 dB
5.0km/3.1miles	11.1mt/34ft	118 dB
10km/6.2miles	18.2mt/56ft	124 dB
20km/12.5miles	36.4mt/110ft	130 dB

Note: Any obstruction in the Fresnel Zone **must** be cleared, usually by increasing the antenna height. See the section, [The Fresnel Zone](#).

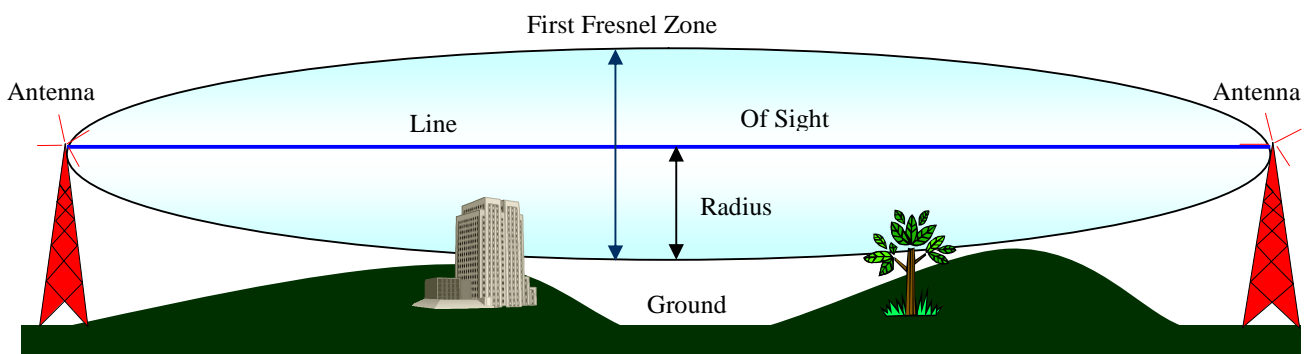
Note: There is also a correction factor added to compensate for curvature of the earth. This correction factor is not required when the correction value is negligible, < 10 km. **AirTegrity's Path Calculator Spreadsheet takes this variable into account automatically.**

2.2 The Fresnel Zone

Because radio waves have a definite size, they need a definite amount of obstacle-clear space surrounding the line of sight between antennas. If the RF waves bump into obstructions along their path, they can lose a significant portion of their signal strength.

The *Fresnel Zone* is an area around the line of sight between antennas that should be kept clear of obstructions. In the following figure, a building and a large tree, lie deeply within the Fresnel Zone. Unless you can move the building and cut down the tree, you won't receive a full signal at either antenna.

The amount of signal loss depends on how deep the obstructions intrude into the Fresnel Zone (and other factors such as the size of the obstacle).



2.2.1 First Fresnel Zone

From the figure, you can see that the *first Fresnel Zone* is an ellipse when viewed from the side. Imagine a spherical balloon. When you pull on the opposite ends, the balloon takes the shape of a three-dimensional ellipsoid. As long as 60 percent of the first Fresnel Zone is clear of obstructions, the link behaves essentially the same as a clear free-space path.

If 80% of the first Fresnel Zone is clear, obstructions in the outer 20% introduce little signal loss to the link. If only 60% is clear, signal loss is significant.

For longer links, AirTegrity recommends having a full path analysis done that takes the curvature of the earth and the topography of the terrain into consideration.

2.2.2 Fresnel Calculations

The following equation calculates R , the Radius of First Fresnel Zone at some point between two radio towers. Looking at **Radius** in the preceding illustration, you can see that R is the distance from the line of sight to the outer edge of the First Fresnel Zone. The illustration draws a radius approximately midpoint between the radio towers; however, the following formula applies at any point between the towers.

The second formula simply calculates 60% of the radius of the First Fresnel Zone, which must be clear of all obstructions.

$$R = 72.1 \times \sqrt{f^{-1} \times D_1 \times D_2 \div (D_1 + D_2)}$$

$$R_{60\%} = 0.60 \times R$$

where

R ≡ Radius of First Fresnel Zone (in feet)

$R_{60\%}$ ≡ 60% of Radius of First Fresnel Zone (in feet)

f ≡ Frequency of radio in GHz

D_1 ≡ Distance of obstruction to first tower (in miles)

D_2 ≡ Distance of obstruction to second tower (in miles)

For example, suppose
Frequency = 2.40 (GHz)
 D_1 = 0.10 miles
 D_2 = 4.90 miles

Then
 R = 14.57 feet
60% of R = 8.74 feet

2.3 Antenna Planning and Selection Fundamentals

AirTegrity strongly recommends that experienced professionals carry out network planning, antenna selection and installation.

Considerations for antenna selection include:

1. Operating Frequency
2. Link type (point to point, multipoint or meshed)
3. Coverage requirements
4. Gain required
5. Elevation of base and remote sites
6. Path obstructions
7. Co-location requirements
8. Environmental conditions
9. Regulatory restrictions in regard to EIRP
10. Aesthetic requirements

Antenna selection is part of network design and antenna appropriate to the operating environment should be selected.

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 client sites.

Often height is required to clear obstacles from the base to client sites. A solution is to use down-tilt sectorised 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 prevents radio coverage all the way to the horizon. This has the benefit of not only minimizing interference at the base from distant signals, but also enables re-use of the frequency at another cell.

Antennas for the same wireless link must also both have the same polarization to work effectively. The orientation of the antenna will change the orientation of the signal. The transmitting and receiving antennas should be both polarized either horizontally or vertically. Adjacent antennas on different frequencies can be cross-polarized to help reduce interference between the two if regulatory environment permits.

3 Determining Cable Requirements

If you plan outdoor antenna(s) for your AirTegrity Wireless Routers, you will need 50-ohm coaxial cable to connect the Router’s radio port(s) to the antenna(s).

There is always some RF energy loss with cables. Generally, the more flexible types of cables have higher losses than the stiffer cables.

You should minimize the length of each coaxial cable because the signal loss for each cable is roughly proportional to its length. Your cabling plan should include the type of cable, the lengths for each connection, and the estimated losses for each connection.

Refer to the cable and connector manufacturer’s specifications for the specific losses.

Typical Cable losses at 2.4 Ghz follow:

- *Times LMR 400* = 6.9dB/per 100ft or 2.3dB/10m
- *Belden 9913* = 7.8dB/per 100ft or 2.6dB/10m
- *Andrew VX15-50* = 2.2dB/per100ft or 0.73dB/10m

4 EIRP

EIRP stands for *Effective Isotropic Radiated Power* and is the net radiated power observed on the main lobe of an antenna. The formula for EIRP follows:

$$\text{EIRP} = \text{Tx POWER (dBm)} - \text{CABLE LOSS (dB)} - \text{CONNECTOR LOSS (dB)} + \text{Tx ANTENNA GAIN (dBi)}$$

EIRP calculates the net transmitted power, because it takes into account the connector and cable losses, as well as the antenna gain. Many antennas provide a directional gain along their main lobe, which in effect amplify the radiated power seen by the receiver. Cable and connector attenuate the transmitted signal.

EIRP and all variables in the formula are measured in dBm.

5 Propagation Loss

Propagation loss (or Free Space Loss) is defined as the attenuation (or reduction) in the intensity of RF signal energy as it travels through the air or free space. As the RF wave travels away from the transmitting antenna, its energy spreads out over an increasing area. The RF energy per unit area gets smaller even though the total energy doesn't change. Propagation loss varies inversely to the square of the distance. i.e. if you double the distance, you will reduce the signal strength to 1/4.

Propagation loss in free space is the major contributor to signal attenuation in most wireless systems. When the intended locations of the base and remote stations have been determined, measure the line of sight distance and then calculate the RF attenuation using the AirTegrity Link Budget Calculator. Distance and obstructions in the RF path are the prime factors in ensuring a proper fade margin, and thus a reliable link.

The calculation indicates the feasibility of your radio link over a given distance and path. Link budgets are typically expressed in decibels (dB).

The formula for calculating Propagation or Free Space Loss is:

$$\text{PROPAGATION LOSS} = 36.6 + 20 \text{ LOG } 10 (\text{F}) + 20 \text{ LOG } (\text{D})$$

Where F is the frequency in MHz and D is the distance in miles.

Typical propagation loss at 2.4 Ghz follow:

0.5 mile = 98 dB	1.0 miles = 104 dB	3 miles = 114 dB
5 miles = 118 dB	10 miles = 124 dB	20 miles = 130 dB

5.1 Calculating Path Loss

Path loss is the total RF attenuation (reduction) throughout the system between antennas. This includes the factors previously discussed: (1) propagation loss as the RF signal travels through the air, (2) weather conditions, terrain, interference, etc. Note that connector and cable losses are accounted for in the EIRP and RX Signal calculations (below).

The AirTegrity Link Budget Calculator will calculate the path loss based on climate and terrain.

6 Received Signal Strength

The Received (Rx) Signal is the net usable signal for the receiver. It is the total of the effective output power (EIRP), less the overall path loss, plus the receiving antenna gain, less receiver cable loss, and less receiver connector loss.

$$\text{Rx SIGNAL} = \text{EIRP} - \text{PATH LOSS} + \text{Rx ANTENNA GAIN} - \text{Rx CONNECTOR LOSS} - \text{Rx CABLE LOSS}$$

7 Fade Margin

Fade margin is the difference between the Rx Signal available to the receiver, and the receiver sensitivity (the minimum signal strength it needs to decode a packet of data). The formula is:

$$\text{FADE MARGIN} = \text{Rx SIGNAL} - \text{Rx SENSITIVITY}$$

The fade margin is the excess signal strength that provides a margin of safety for changing interference and weather conditions. The fade margin calculation is often referred to as the Link Budget Calculation. The reliability of a link depends upon the fade margin.

Theoretically, the fade margin could be zero dB and the receiver would have just enough sensitivity to receive the transmitted signal. However, the fade margin must compensate for additional losses, such as weather and multipath interference and other dynamic power dissipating factors.

AirTegrity recommends fade margin for its Access Point Routers be at a **minimum** 15 dB.

All variables in the FADE MARGIN formula are measured in decibels referenced to one milliwatt (dBm); specifically, where 0 dBm is equal to one milliwatt of radiated power.

7.1 Alternate Fade Margin Calculation

An alternative way to calculate the Fade Margin is to calculate *System Gain*. The System gain of a radio (system) link is the difference between the transmitted power (*Tx*) and the receiver sensitivity (*Rx*).

The formula that defines the system gain follows:

$$\text{SYSTEM GAIN} = \text{TRANSMITTED POWER} - \text{RECEIVER SENSITIVITY}$$

In this case,

$$\text{FADE MARGIN} = \text{SYSTEM GAIN} + \text{ANTENNA GAIN} - \text{CABLE/CONNECTOR LOSS} - \text{PATH LOSS}$$

NOTE: Use the “AirTegrity Link Budget Calculator” for calculating your links’ fade margin.

At this point, you need additional information before you can set the fade margin in your network to the recommended 15 dB. See the sections on [EIRP](#), [Propagation Loss](#), [Calculating Path Loss](#), and [Rx Signal](#) that follow.

8 Interference

An important aspect of planning your wireless system is the avoidance of interference. Good planning for frequencies and antennas can overcome most interference challenges. Effects within the system or outside the system can cause interference.

Co-channel interference occurs when another RF link is using the same channel frequency. Adjacent-channel interference occurs when another RF link is using an adjacent channel frequency. In selecting a site, a spectrum analyzer should be used to determine if any strong signals are present at the site and, if they are, to determine how close they are to the desired frequency. The further away from your proposed frequency, the less likely they are to cause a problem. Antenna placement and polarization, as well as the use of high-gain, low side-lobe antennas, is the most effective method of reducing this type of interference.

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