ZumLink Network Planning

This document discusses various factors for successful Network Planning including:

- Fresnel Zones
- Multipath propagation
- Antenna and radiation patterns
- RF environment

The ZumLink 900 Series is designed with certain features and settings for a successful RF network link. These settings are also presented in this document.

1.1. Fresnel Zone

The Fresnel Zone is a cylindrical ellipse centered on the line of the direct RF transmission path between a transmitter and a receiver. The area that the RF transmission spreads out into is the Fresnel Zone.

The size of the ellipse is determined by the frequency of operation and the distance between the two sites.

- The longer the distance, the bigger the Fresnel Zone.
- The higher the frequency, the smaller the Fresnel Zone.

There are an infinite number of Fresnel Zone, however, only the first 3 have any real effect on RF propagation.

Encroachment of the Fresnel Zone by obstacles like the ground, foliage, buildings, water, etc. can cause reflected signals. The receiver cannot distinguish between the main signal and a reflected signal. A reflective signal is shifted in phase from the main signal and is combined with the main signal at the receiver.

- The phase shift of reflected signals from the 1st and 3rd Fresnel Zone when combined with the main signal can have a positive effect.
- The reflected signal from the 2^{nd} Fresnel Zone when combined with the main signal will have a **negative effect**.
- If the reflected signal is 180° out of phase with the main signal, the two signals will cancel each other out, leaving no signal at the receiver.

Minimizing out-of-phase signals and reflected signals from the 2^{nd} Fresnel Zone from reaching the receiver maximizes the signal strength at the receiver.

> **Important!**: The general rule of thumb is that the 1st Fresnel Zone would ideally be 80% clear of obstructions, but **MUST BE** at least 60% clear.

The radius of the Fresnel Zone (R) is determined using this calculation (based on Figure 1):

R(feet) = 72.05 * √[d(miles) / [4*freq(GHz)]]

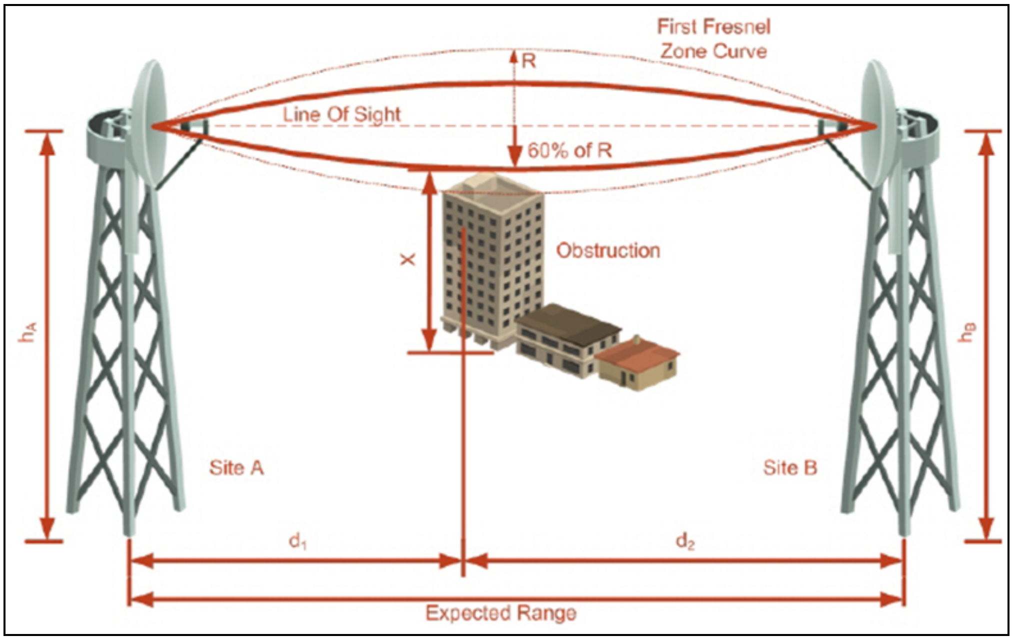

Figure 1: Encroachment of the Fresnel Zone by a Building

1.2. Multipath Propagation

Multipath Propagation is very similar to the Fresnel Zone. Here, multiple signals arrive at the receiver from multiple paths. These signals are generated from reflections off of objects like vehicles, buildings, etc. (Figure 2)

The reflected signals vary in signal strength and phase which is mainly influenced by the additional distances the signal travels compared to the main signal. The reflected signals effectively reduce the RF energy received by the receive antenna.

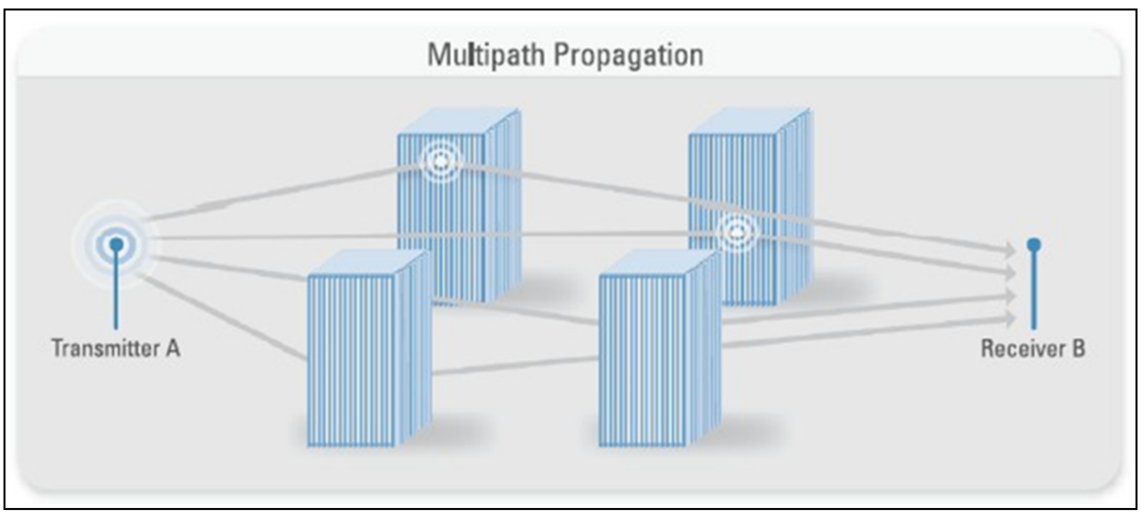

Figure 2: Multipath Propagation

1.3. Antenna

The antennas in network link are impacted by:

- Antenna Height (on page 4)
- Polarization (on page 4)
- Gain (on page 4)
- Radiation Pattern (on page 5)

1.3.1. Antenna Height

The height of the antennas will play a major role in the performance of a RF link. Ideally, optimum results are achieved if the antennas are located where there is no encroachment to the 1st and 2nd Fresnel Zones. Antennas come in several types with different polarization and radiation patterns.

1.3.2. Polarization

The antenna polarization (vertical, horizontal, right-hand circular, and left-hand circular) and the polarization of the obstruction can have varying degrees of effect on the RF link performance.

If using a vertical polarized antenna and the signal is reflected off of a horizontal object within the 1st Fresnel Zone, the phase shift would have a negative impact to the receive signal.

This is opposite to what was described in the Fresnel Zone (on page 2) section. In this case:

- The 1st and 3rd Fresnel Zone's reflections can have a negative impact.
- Reflections from the 2nd Fresnel Zone can have a positive impact.
- Using horizontally polarized antennas instead would revert this back to normal operation.

If using a circular polarized antenna, encroachment of the Fresnel Zone has no effect because a reflected circular polarized signal changes rotation upon deflection, resulting in the signal being invisible or significantly attenuated at the receiving antenna.

> **Example**: A right-hand, circular, polarized signal reflected off an obstacle becomes a left-hand, circular, polarized signal which is not detectable to a right-hand, circular, polarized antenna.

1.3.3. Gain

Antenna gain is measure of the antenna’s ability to direct RF energy in a particular direction. The gain is typically measured in dBi, when compared to an isotropic antenna with no gain, or dBd, when compared to a dipole antenna. A plot of the gain as a function of direction is called the radiation pattern.

1.3.4. Radiation Pattern

The radiation pattern of an antenna can also play a role in defining the generation of a reflected signal and the direction of the Fresnel Zone.

- Omni-directional antennas radiate in all directions except upward from the top of the antenna and downward from the bottom of the antenna (Figure 3).
- Directional antennas have a narrower radiation pattern but with a higher gain, more directed beam width (Figure 4).
  - Directional antennas can be used to avoid some obstructions or reflective surfaces.

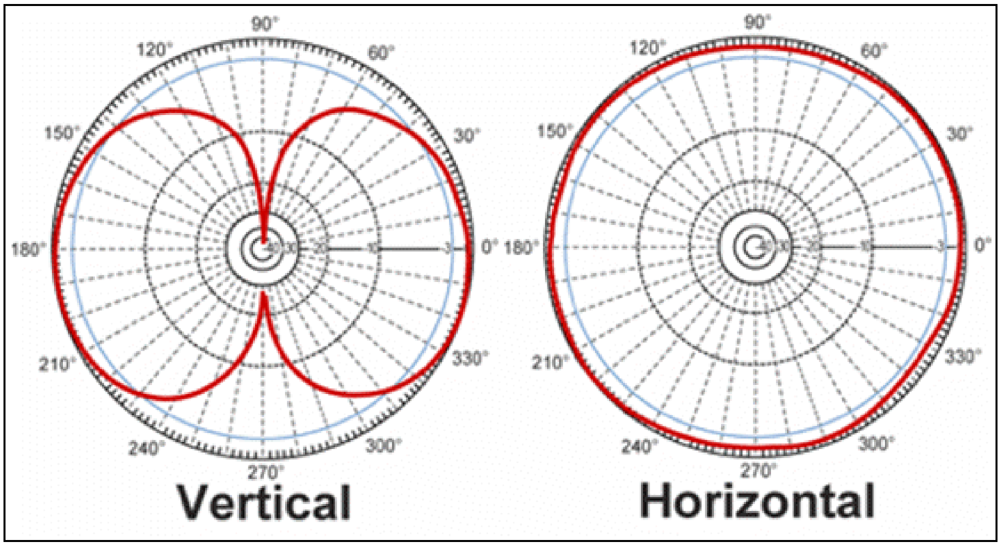

Figure 3: Omni Directional Antenna Radiation Pattern

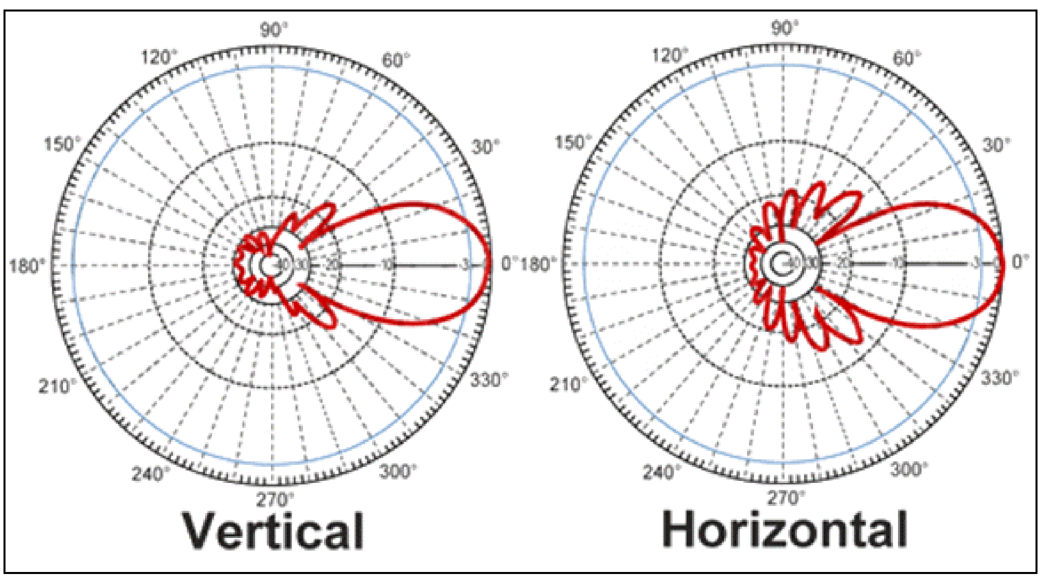

Figure 4: Directional Antenna Radiation Pattern

1.4. Network Planning

When planning a network, the most important factor is to verify at least 60% of the first Fresnel Zone is clear of obstructions (i.e., trees, buildings, hills, etc.) The importance of this increases as the distance between transmitter and receiver increases. By ensuring at least 60% of Fresnel Zone is clear of obstructions, the signal strength at the receiver is maximized by reducing the out of phase signals / reflections from reaching the receiver.

Network planning includes:

- Path Study (on page 6)
- RF Environment (on page 6)
- Link Margin (on page 6)

1.4.1. Path Study

An RF path study is recommended for both short and long range RF links, even where the Fresnel Zone is 60% free of obstructions. A path study provides the link margin and the difference between the signal level received and the signal level required by the radio at each site. There are a number of different software applications available for this. One key is to have antenna details like radiation pattern, location, height and to ensure the software application utilizes the latest geographical maps.

1.4.2. RF Environment

Another important factor is to consider the network's RF environment, specifically noise and interference on channels. Sources of noise and interference include co-locating a site with multiple radios operating at the same band. The co-located radio may transmit, generate noise, and create multipath interference on the receive frequency. Finally, variations in the atmosphere / earth may case the link margin to vary over time. These various factors can be significant causing variations in link margins of up to 6dB.

1.4.3. Link Margin

A smaller link margin reduces the safety margin, increasing the risk of the networks susceptibility to interference, atmospheric condition, etc.

If the network is located nearby other radios operating in the same band, a scan of the frequency spectrum is recommended to determine the frequencies of operation. These radios may be transmitting (or generating noise) on the receive channel causing interference on the receive channel disrupting the ZumLink network.

> **FREEWAVE Recommends**: Based on these factors, FreeWave recommends a ZumLink network with a 20dB link margin is used to ensure a robust RF communication network link.

1.5. ZumLink 900 MHz Series

The ZumLink 900 Series radios offer five different RF data rates that have different bandwidths with different modulation schemes. ZumLink employs GFSK, 4GFSK and 8GFSK modulations. These modulations are:

- Less susceptible to noisy environments than higher order QAM modulations.
- Conducive to support longer ranges, requiring lower SNR than higher order QAM modulations.
- Require lower power than higher order QAM modulations, facilitating solar and battery applications.

Also, with the increase in the bandwidth, there is a decrease in the number of available channels.

ZumLink 900 MHz Series					
RF Data Rate	115.2 kbps	250 kbps	500 kbps	1 Mbps	4 Mbps
Bandwidth	230.4 kHz	345.6 kHz	691.2 kHz	1382.4 kHz	3225.6 kHz
Modulation	2 level GFSK	2 level GFSK	2 level GFSK	2 level GFSK	8-ary FSK
Channels	112	55	36	18	7

These examples are the best way to convey how the architecture of a link will determine the performance of that link:

- Short Range RF Link (on page 7)
- Long Range RF Link (on page 7)

1.5.1. Short Range RF Link

The first example uses a 1,000 foot link where the antennas are roughly 6 feet off the ground.

- When using omni-directional antennas, the ZumLink 900 MHz radio establishes a link at both RF data rate of 1 Mbps and 4 Mbps but no data can be exchanged at 4 Mbps.
- The inability to pass data at 4 Mbps is due to reflections caused by encroachment of the Fresnel Zone, which at this distance and frequency is 16.5 feet in diameter.
- With 6ft. tall antenna, the Fresnel Zone is encroached by more than 60% and would have to be raised to at least 10ft to get above 60% encroachment.

1.5.2. Long Range RF Link

The second example involves a 10 mile link where the antennas are roughly 50 feet off the ground.

- When using omni directional antennas, the ZumLink 900 MHz radio establishes a link at both RF data rate of 1 Mbps and 4 Mbps but no data can be exchanged at 4 Mbps.
- The inability to pass data at 4 Mbps is due to reflections caused by encroachment of the Fresnel Zone, which at this distance and frequency is 119.1 feet in diameter.
- With 50ft. tall antenna’s, the Fresnel Zone is encroached by more than 60% and would have to be raised to at least 72ft to get above 60% encroachment.
- Even though there are also reflections at the 1 Mbps rate, this rate has a smaller bandwidth and utilizes a modulation that is more forgiving in multipath environments and less susceptible to noisy environments.

When replacing the omni-directional antennas with Yagi antennas or circular polarized panel antennas, the data throughput realized is consistent with results during lab or bench testing at both the 1 and 4 Mbps rates.

- Both antenna types have a reduced radiation pattern that is directed and helps reduce Fresnel Zone encroachment caused by the ground.
- The circular polarized panel is right hand polarized and has the added benefit of ignoring reflected signals which become left hand polarized.

This example demonstrates how the wider bandwidth and modulation of the 4 Mbps negatively impacts operation using omni-directional antennas and how this can be overcome by using different antenna types.

1.6. ZumLink 900 MHz Series Settings

See the **LAN5522AA ZumLink RF Network Link Application Note** for important settings that impact the ZumLink network performance, specifically radio settings to optimize RF network link reliability and data throughput.

Learn More

For additional product information about the , visit http://support.freewave.com/.

For additional assistance, contact a local reseller, or contact FreeWave Technologies, Inc. at 303.381.9200 or 1.866.923.6168, or by email at moreinfo@freewave.com.

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The ZumLink complies with FCC Part 15 rules. Operation is subject to the following two conditions: 1) This device may not cause harmful interference and 2) this device must accept any interference received, including interference that may cause undesired operation.

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