White Paper

Signal Clarity

Factors Influencing Signal Clarity

Signal clarity, or in techno-talk "signal-to-noise ratio" and "Eb/No," is a key factor in optimizing the performance of any wireless communications product. Some of the factors affecting signal clarity include:

Signal strength **-** Obviously, a strong source signal allows for better reception over long distances than a weak source signal. However, the FCC limits unlicensed signal transmission strength to one watt maximum and six dB watts of EIRP. Effectively, this allows for a maximum signal gain equivalent to four watts. A signal conditioner at the receiving end, such as Solectek's ODU, can enhance the signal-to-noise performance by an order of magnitude.

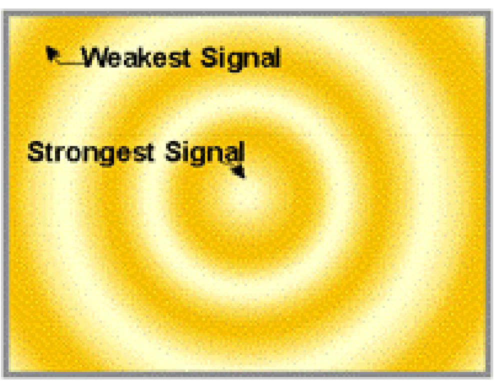
Distance **-** RF signal strength declines with distance. Also, the potential for temporary interference and signal fading increases with distance. As explained in coming pages, a signal can be modified in several ways to make it suitable for the distance it must travel.

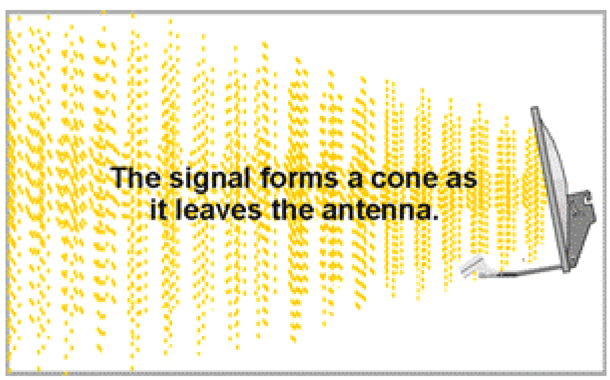
Interference **-** Atmospheric interference can result from rain, snow, hail or lightening in the signal path. RF interference normally results from other nearby RF activity in the same band (in-band interference). Only very strong out-of-band activity can interfere with a 2.4 GHz signal.

Line of sight **-**RF line of sight requires a wider band of free-space signal path than visual line of sight. Signal clarity is best when the line of sight between antennas is precisely focused and free of all obstructions. Obstructions within the RF line of sight can absorb the signal and sap it of strength or deflect the signal and cause multiple copies of the same signal to arrive at the receiver out of phase.

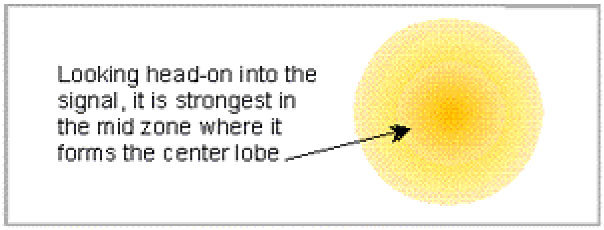
Wave Transmission

The way radio waves fan out from their source resembles the way waves of water fan out from a vibrating object in a pool. Signal strength decreases as the signal fans out further from the first wave.

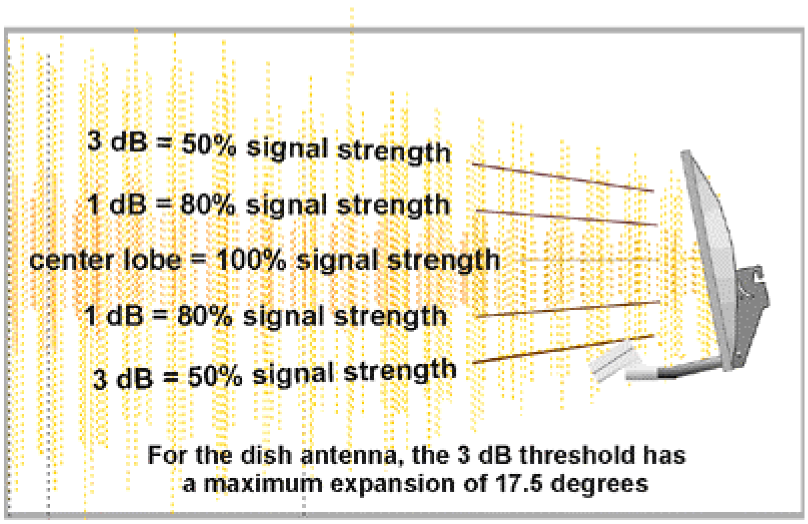




An antenna deflects the waves and channels them in one direction. They then form a more focused conical shape and have greater strength. The signal is not spread evenly throughout the cone. In the same way that light is focused by a magnifying glass, an RF signal shaped by an antenna is strongest within a narrow area at the center of the cone. We refer to the area where signal strength is strongest as the center lobe.



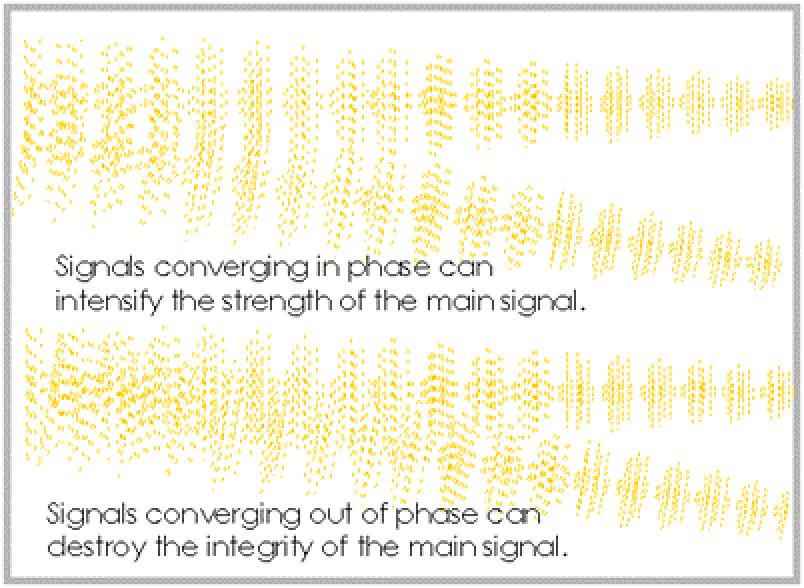
The width of an RF signal depends on how the antenna shapes that signal and the distance from its source. Since the signal fades out gradually at the outer edge of the cone, it is not meaningful to measure from the edge. And since the signal widens with distance, if we measure its width in feet and inches, we cannot determine the signal's profile unless we know the distance from its source. To avoid measuring from a nebulous edge, we measure signal beam width at different bands within the signal, and to skirt the distance vs. shape dilemma, we measure based on degrees of expansion across the center, rather than feet and inches. We measure signal strength in terms of decibels (dB units). The number of decibels indicates threshold points at increasing distances away from the center point where the signal is strongest. For example, the beam width of the dish antenna we define as 17.5 maximum at 3 dB elevation. As the next drawing shows, the higher the number of dB units, the lower is the signal strength relative to the strength of the center lobe signal.



Waves can be deflected by objects in their paths. If a deflected wave from an outer band of the cone passes back through the center lobe, it can either strengthen that signal or reduce its strength, depending on how the waves are aligned when they collide. Minor glancing deflections change the angle of the waves very little, so they remain generally in phase with the wave at the center lobe.

Within the signal span, there are zones where deflected signals are generally in phase with the center lobe signal, and there are other zones where deflected signals are generally out of phase with or the center lobe signal. We refer to these zones as Fresnel (frnl) zones. In the first Fresnel zone and all the odd numbered Fresnel zones, deflected signals are generally in phase with the center lobe signal. In the second Fresnel zone, and all even-numbered Fresnel zones, deflected signals are up to 180 out of phase with the center lobe signal. The first Fresnel zone surrounds the center lobe signal. If more than 40% of the area below the center lobe in the first Fresnel zone is obstructed, your RF line of sight is not sufficiently clear.

Signals deflected from the second Fresnel zone can degrade the main signal severely because they are 180 out of phase with the main lobe signal. To avoid this problem, you must place your antenna at an optimum height that is out of range from F2 deflections. (An antenna can be set too high as well as too low.) Where deflection and diffraction from ground-based objects cause interference, even a small relocation of the AIRLAN antenna often produces a substantial improvement.



Signal Focusing

As your transmission distance increases, it is necessary to compensate for the distance by selecting an antenna with a narrower and more focused beam.

You achieve the following benefits by confining the signal within a narrow, focused beam:

You reduce the strength of the Fresnel zone reflection, thus reducing the potential for interference due to obstructions within the Fresnel zone. You reduce interference with other RF devices that may be operating in the same frequency range at distances closer than the target antenna. You concentrate the strength of the signal at the point of reception.

For unlicensed operation, the FCC limits the effective transmit power (due to signal gain) to four times one watt maximum, or its EIRP equivalent. The more concentrated the signal, the lower the power must be. Solectek's reflector (dish) antenna produces 21 dBi using a transmit power of 15 dBm, which is less than one watt.

The antennas at both ends of the link can enhance signal gain, and a signal conditioner, such as Solectek's ODU, can enhance the strength of the signal at the receiving end. The total gain for a connection between two antennas is the sum of the gains for both antennas.

The receiving antenna should pick up a signal so long as it lies within the range and width of the signal. However, optimum long-distance reception results when the antenna faces the center of the signal's main lobe. That is why you obtain the best reception over long distances when you aim the antennas precisely at each other and the signal path is not obstructed.

When spanning long distances, even a highly focused antenna can have a very large cone. For example, the Solectek dish antenna is designed to span distances up to 25 miles. Specifications for its bandwidth and the vertical and horizontal size of the radiation beam are as follows:

3 dB elevation beam width: 17.5 degrees maximum
3 dB azimuth beam width: 17.5 degrees maximum
1 dB azimuth beam width: 8 degrees maximum

We can use these specifications to calculate the height of the midzone region of the cone for a span of 25 miles. Using 8 degrees as the maximum beam width at 1dB, we come up with a mile high cone at 1 dB. However, the midzone region of the first Fresnel zone is only 116 feet high. Even with very high gain antennas, much of the cone and, more significantly, some portion of the first Fresnel zone is likely to intersect with the ground.

Line of Sight

The success of an RF link depends on a clear line of sight. An unobstructed line of sight is called a free space path. An acceptable line-of-sight for an RF signal is defined as at least .6 clearance in the first Fresnel zone. This means that for successful RF transmission, at least 60 percent of the area between the center lobe and the bottom of the first Fresnel zone must be a free-space path.

A large obstruction can reduce or totally block the signal. The bending of signals as they pass around obstructions or are deflected by them is know as diffraction. A reduction of the strength of a signal is known as attenuation.

If an antenna points out of a window made of normal glass, the glass will attenuate the signal to some extent. Some types of mirrored glass increase the level of attenuation. Likewise, signals passing through the side of a wooden building or a forest are attenuated. Wet leaves can affect a signal substantially. If possible, it is best to keep all such obstructions out of the signal path.

When a totally clear and direct line of sight is not feasible, position the antennas as far away from obstructions and as high as possible, and keep the loss of free path space as low as possible.

Space that is free enough for visual sight may not be free enough for RF line of sight. But on the other hand, a workable RF signal path may not allow for visual sight. For short connections, it is possible to make a satisfactory link where the signal is visually blocked, so long as the RF signal cone between the antennas is only partially blocked.

RF signals can bend around minor obstructions. They can even penetrate through some obstructions that would block a visual path. You can listen to an AM or FM radio inside a building. Although the AIRLAN uses much weaker signals, it may be possible to make an AIRLAN connection where there is no visual path. But for good signal quality, you should keep the RF line of sight as free as possible from all obstructions.

Antenna Height

When calculating the right height for antennas, the height of the first Fresnel zone needs to be added above the height of objects along the wave path to achieve a line of sight. If solid objects, such as walls, hills, trees, or buildings obstruct the RF line of sight, you need to relocate the antennas.

For long distance links, Solectek engineers use a tool called the Range Program to calculate the required height for an antenna. The calculation must take into account such factors as:

The distance between the antennas
The proposed height for the other antenna
The curvature of the earth (significant factor on flat terrain where spanning distance exceeds seven miles)

Where the Fresnel zone is most likely to intersect with the ground
The height of the Fresnel zone in the area where it is most likely to intersect with the ground
The height of objects on the ground
Atmospheric attenuation and rain margin

Contact Solectek for further information.

Alignment Tools

Since a Solectek wireless link can span up to 25 miles between antennas, you may need to work out the azimuth bearings and elevation before you install the antennas. You may need the following tools to make the installation:

A radiophone to communicate with colleagues who are adjusting the antenna on the remote units
A compass or global positioning system (GPS)
An AIRLAN antenna alignment utility

Stable Antenna Positioning

For optimum performance, you may need to make very precise line-of-sight adjustments to your antennas. To secure the precise alignment of your antennas, it is necessary to maintain the antenna in a rigidly stable position. This can be difficult to achieve if you are using a dish antenna, which catches a lot of wind, mounted high on flexible mast. Ensure that your mast is rigid by using heavy guy wires at each ten-foot interval from the top to the bottom of your mast.

Conclusion

RF signal clarity is one of the key factors in obtaining a high performance wireless data communications link. While it is possible to transmit successfully over short distances with some obstructions in the line of sight, it becomes increasingly difficult to maintain a clear signal as the transmission distance increases. To achieve a clear signal between distant locations, you must maintain the clearest possible RF line of sight.