White Paper

WIRELESS EXCELLENCE

Microwave Radio (MW)

Antenna Alignment for Microwave Systems

White Paper

About Wireless Excellence

Founded in 1995 and with headquarters in Oxford UK, Wireless Excellence Limited is a leading designer and supplier of outdoor and indoor Broadband Wireless communication products.

With a complete range of solutions including Radio, Microwave, Millimeter-Wave, Free Space Optics, WiFi and WiMax solutions, customers in over 60 countries have chosen Wireless Excellence as the "one stop shop" solution of choice for dependable wireless networking.

About Microwave

Using the latest RF technology, our microwave links operate in all the popular bands from 6-38GHz, distances over 40km and net throughput up to 311 and 622Mbps. Our advanced Indoor units provide a common platform with flexible IP/Ethernet, Gigabit Ethernet, PDH (16xE1/T1) and optional SDH interfaces, to which traffic can be allocated under software control.

Flexibility, performance and low cost of ownership are ensured.

Abstract

This technical paper describes in detail the techniques used to ensure the proper alignment of antennas used in terrestrial microwave radio systems. Radio operators, engineers and installation professionals can use this document as an on-site reference for antenna alignment.

Introduction

One of the most important elements of a wireless backhaul deployment is the antenna system. Proper alignment of that antenna system is critical to the performance of any backhaul radio system, as it is fundamental to the high link availability that is the ultimate goal when designing high-performance wireless systems. Engineering a wireless link for the highest achievable system gain while minimizing or eliminating the potential for interference will help reach the goal of high availability. This paper will address in a generalized fashion the steps required to align an antenna pair for a terrestrial microwave radio system. There are two fundamental phases to this process: 1) pre-alignment or coarse-tuning; and 2) final alignment or fine-tuning.

Pre-Alignment

The pre-alignment phase involves settings on the antenna prior to installation and/or turn-on of the radio electronics. The final alignment includes all steps taken after the radio electronics have been installed and turned on.
Most antennas have three adjustments for alignment:

- Polarisation
- Azimuth (left and right)
- Elevation (up and down)

Coarse-tuning the antenna at time of antenna installation will ensure that adequate signal is available for the fine tuning phase of the installation.

Polarisation Pre-Alignment

The polarisation of an antenna is defined as the orientation of the "E" field of the RF beam. If the "E" field is vertical, the antenna is said to be vertically polarised and, conversely, if the "E" field is horizontal the polarisation is said to be horizontal. On most solid reflector and panel antennas, the polarisation can be identified by the orientation of the feed horn or panel assembly. On grid antennas, polarisation is easily identified by the grid pattern. For example, if a grid antenna is mounted with the reflecting elements oriented vertically it will produce a vertically polarised signal. Most antenna vendors clearly mark their antennas and feed assemblies for easy setting of the desired polarisation. It will be necessary to consult the installation instructions for the specific antenna under alignment to determine how polarisation is indicated.
Prior to raising the antenna to the tower or rooftop mounting position, the polarisation should be verified and adjusted to correspond to the antenna data sheets.

Azimuth Pre-Alignment

Two methods are suggested for the azimuth adjustment. One method uses a compass while the other method uses binoculars or a spotting scope. Once the antenna is securely mounted at its permanent location on the rooftop or tower, coarse-tuning the azimuth is required so that sufficient signal is present for fine tuning.
If the path length is short enough and conditions are clear, the distant end may be seen with a pair of binoculars or a spotting scope. Figure 1 shows the top view of the mounted antenna. The binocular or spotting scope is held against the top rim of the antenna and the antenna is adjusted in azimuth so that the distant antenna is centred in the field of view of the binocular. Once the antenna is coarse tuned for azimuth, proceed to the elevation pre-alignment.

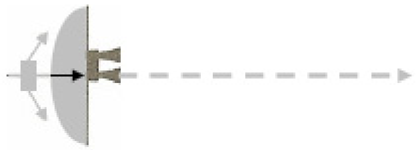


Figure 1 – Antenna, top-down perspective

If path analysis documentation is available at the time of installation and the distant end antenna location is not easily seen, a compass can be used for azimuth pre-alignment. Most microwave link analysis documents will contain specific information regarding the antenna's height, polarisation and azimuth (compass heading). After determining the azimuth of the antenna from the link analysis documentation, use a compass to determine the antenna direction from the tower or rooftop location. Understanding how to use a compass is important when determining the direction an antenna should be aimed. Figure 2 shows an example of a sighting compass manufactured by Brunton. A sighting compass is preferred because it allows you to sight objects in the distance while observing the compass in a mirror. A sighting compass will also be marked with azimuth bearings as well as quadrant bearings. Compasses without azimuth bearings are more difficult to use for this purpose.

Figure 2 – Sighting compass

Before using the compass, magnetic declination needs to be determined and set in the compass. Magnetic declination is the difference between true north (the axis around which the earth rotates) and magnetic north (the direction the needle of a compass will point). A topographical map of the region where the link will be deployed is required to determine magnetic declination. The magnetic declination in the map area should be printed on the map. Figure 3 shows the magnetic declination for the United States.

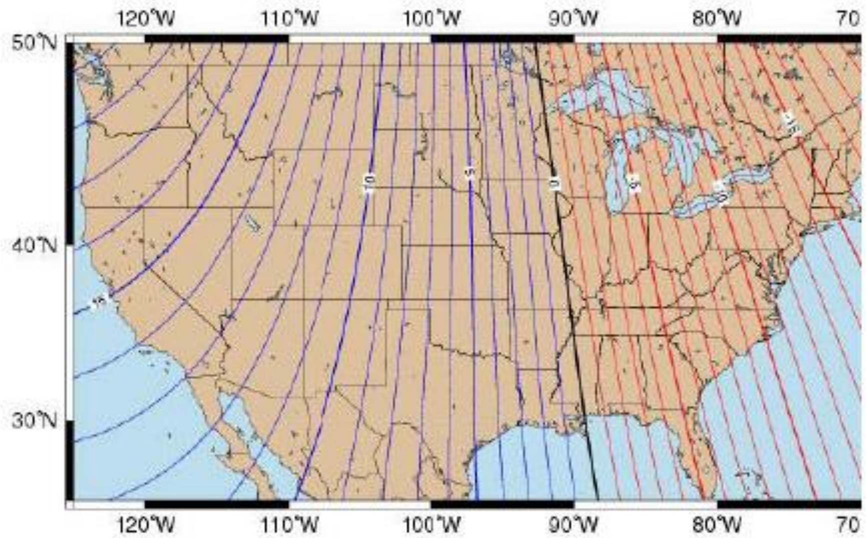


Figure 3 – Magnetic declination map

After finding the declination on the map, that information needs to be transferred to the compass. If the Brunton compass is used, turning the declination setting screw on the side of the compass until the reading on the graduated circle in the compass lines up with the index pin at the top of the compass sets the proper declination. For many other types of compasses you can set the declination by simply rotating the graduated circle on the outside of the compass until it lines up with the indicator marker at the top of the compass at the proper declination. If neither of these methods is obvious on your compass, check with the user's manual that came with your compass, as it should have instructions for setting the declination. Once the declination has been set on the compass, any reading obtained from it will be accurate. Otherwise, you may simply aim the compass to magnetic north, and make adjustments to bearing knowing the declination offset that applies. It is often helpful to locate a landmark along the path that is in-line with but below the path to aid in setting the antenna azimuth. Figure 4 is an aerial view of a proposed radio link, indicated in red, originating from a water tower. This view clearly shows how the billboard sign across the highway from the tower is an ideal landmark to aid in antenna alignment. The installers have determined from their compass reading that the path line just to the left (counter clockwise) of the billboard. By aiming the antenna just to the left of their identified landmark, the billboard, the installers can be assured that the antenna azimuth is in the proper direction. Also note that the reading from a magnetic compass can be inaccurate if used near a large metal structure such as a tower. Once you have determined the direction the antenna should point and identified a landmark along the path, aim the antenna to shoot over the landmark, tighten the mounting hardware and proceed to the elevation pre-alignment.

Figure 4 – Microwave link, aerial view

Elevation (Tilt) Pre-Alignment

In most cases, adjusting the antenna for vertical plumb (0 degrees elevation) is recommended for coarse-tuning the elevation adjustment. Figure 5 shows the use of a level to plumb the antenna. The use of the level requires that the level reach from top rim to lower rim. If the level is too short it can be attached to a straightedge that is long enough for this purpose. Some antenna vendors provide a vertical elevation scale on the mounting hardware to aid in this adjustment, eliminating the need to use a level.

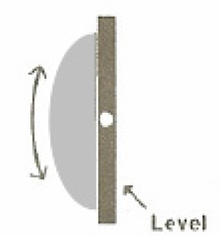


Figure 5 – Use of level to establish vertical plumb

While a 0 degree pre-alignment elevation setting is suitable for most paths, it may be necessary to calculate the tilt angle if significant differences exist between the two antenna heights. Figure 6 shows the parameters for calculating the angle for the difference in elevation of two antennas.

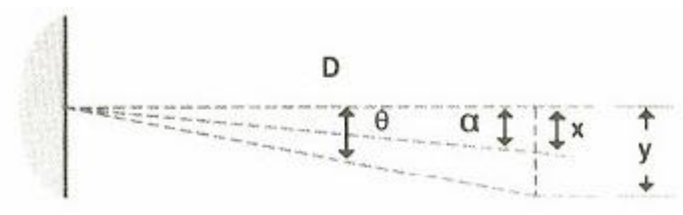


Figure 6 – Calculating required tilt angle

Vertical angle calculations:
Tan $\alpha = X/D$
Where:
X = Antenna Height Difference, in Feet
D = Path Length, in Feet
2Θ = Antenna 3 dB Beamwidth
α = Angle to Lower Antenna

Therefore:

$\alpha = Tan^{-1}(X/D)$

Once the angle is calculated, mechanical elevation can be set. Some antenna vendors include an elevation scale on the mounting hardware. Simply set the elevation according to the installation instructions included with the antenna mounting hardware. If no such scale exists, Figure 7 shows the parameters required to calculate the amount of tilt required.

Where:

R = Radius of Antenna, in Inches

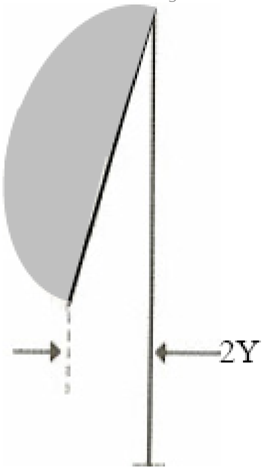
α = Angle to Lower Antenna

Calculate:

$R \tan \alpha = Y$

2Y = Distance between bottom of antenna and plumb bob (in)

The method of adjustment of the antenna tilt is shown in Figure 7.



If the above procedures are followed, the required final antenna adjustment will be minimal and the possibility of peaking on a side-lobe will be minimized. These coarse-tune adjustments can be conducted prior to the installation of the electronics. When the electronics are installed and turned on, the final adjustment of the antenna is made.

Antenna Final Adjustments

Prior to the final adjustment of the antenna, some preliminary measurements can be made. Decide which method is to be used to indicate when the antenna is adjusted to peak power. Two methods are usually available, DC voltage at the RSL (receive signal level) test point and RSL indication in software/firmware. The first method is recommended as this is typically a near-real-time reading. Changes in signal strength are immediately conveyed to the installer by variations in the DC voltage present at the RSL test point on the face plate of the radio. This type of reading allows for precise positioning of the antenna.
As an alternative to the voltmeter, most radio systems have RSL information available through an integrated management interface. This may be an internal http server, telnet, serial or proprietary interface. Many of these types of interfaces offer only snapshots of current performance data while others may only refresh at factory set time intervals. Using these types of interfaces for antenna alignment should be considered only as a last resort. Time delays in relaying signal strength information to personnel aligning the antennas can cause misalignment and lengthen the duration of the alignment procedure.

Since the antennas at both ends of the links have been coarse-tuned for azimuth, elevation and polarisation, sufficient signal should be present to commence with the fine-tuning of the antennas.

While monitoring the receive signal level with a voltmeter or through the management interface, fine tune the azimuth, elevation and polarisation for maximum receive signal. Perform the final tuning adjustments one end at a time. It is necessary for one antenna to be stationary while the other is being adjusted.

Figure 8 shows a sample of an RSL chart from a typical microwave link. Note that as voltage decreases, signal strength increases. This relationship will vary by model and manufacturer so consult the radio documentation so that there is clear understanding of the relationship between the RSL test voltage and signal strength. If the peak of the antenna pattern is broad and hard to find, then the antenna can be swung for equal signal strength drop off in each direction. The distance between these points can be measured in number of turns or distance. The final adjustment can be set to the half-way point between these two points.

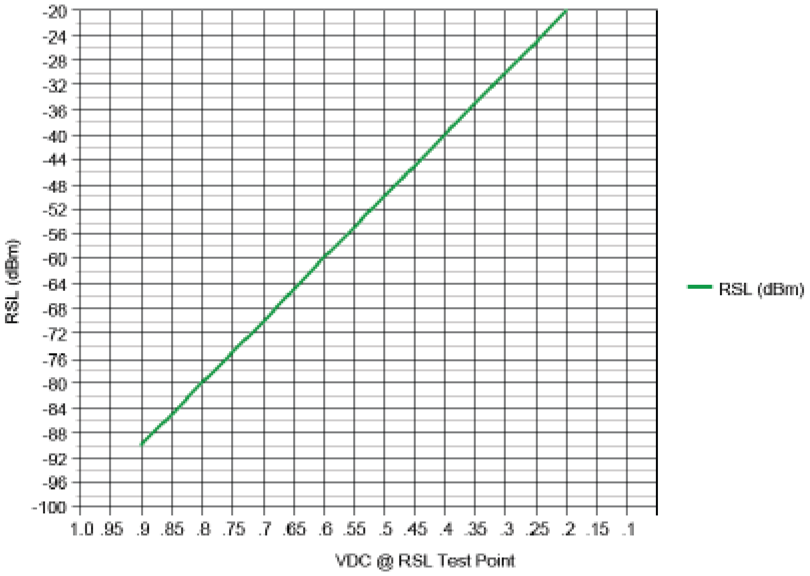


Figure 8 – Sample RSL Chart

Some antennas have polarisation adjustment. The mechanics of adjustment should be verified by the manufacturer's instructions. The polarisation is adjusted in the same manner as azimuth and tilt. If the antenna structure is not perfectly vertical, polarisation adjustment may be necessary.

Once the antenna is set at peak level, tighten all adjustments and mounting hardware. Continue to monitor the RSL while doing this to ensure final tightening of the hardware has little to no effect on RSL.

The calculated receive signal strength should always be attained or exceeded. Repeat the procedure at both ends of the link until the calculated RSL is achieved. If the RSL is worse than the calculated value after the above procedures, rotate one feed assembly or panel 90 degrees. The RSL should drop by greater than 20 dB.

A lower than expected RSL that is attained with good cross-polarisation discrimination (>20dB) is indicative of a faulty antenna feed system, a defective transmission line or an obstructed path. Verify that calculated insertion loss through the transmission line is within limits and replace antennas or transmission system elements with known good devices until the fault is found.

Antenna Adjustment for Minimum Interference

So far, we have discussed how to adjust the antenna for maximum receive power. If it is determined that interference is present, then the antenna can be adjusted to minimize the interference.

The antenna data sheets will specify the antenna polarisation. It should be determined if there was a reason for selecting a certain polarisation during the link design process.

The possible sources of interference are:

a. Interference from other sources (out of your control);
b. Interference from sources within your control, such as adjoining radios in a backbone or hub.

There are various methods for determining the presence of interference. A simple method is to use a DC voltmeter connected to the RSL test point on the radio that indicates receive level. When the receiver's distant transmitter is turned off, the receive level meter may still indicate a received carrier. If the level is high enough, threshold degradation may occur. This will be evidenced by a high bit error rate or complete loss of synchronization from the far end.

The absence of an indication of signal level above the receiver's threshold is not necessarily an indication that interference does not exist. RF levels below the receiver's threshold may be difficult to detect at the RSL test point. Radio systems operating at complex orders of modulation can still be affected by co-channel interference well below threshold. A better method is to connect a spectrum analyzer to the antenna to measure the level and frequency of the interference. More advanced radio systems offer integral spectrum analyzers that are useful in analyzing the properties of signals present at the antenna. If it is determined that interference exists, many techniques can be used to avoid the identified interferer. Some of these techniques use the unique properties of the antenna to suppress the interfering signal.

The antenna has characteristics that can be used for reducing interference. The first characteristic is polarisation discrimination. If two antennas are opposite in polarisation, there will be 20 to 30 dB of isolation between them. Rotating an antenna or antenna feed assembly 90 degrees can be an effective countermeasure to interference. While observing the interference at the receive signal level test point or on a spectrum analyzer, the polarisation can be adjusted for minimum interference rather than peak power. Make sure that whatever adjustments are made to polarisation on one end of the link are duplicated at the other end.

There is another adjustment of the antenna that can be used to minimize interference. Figure 9 shows the side lobe pattern of a typical antenna. The plot is a polar plot that shows sharp drops in power response between the lobes of the antenna.

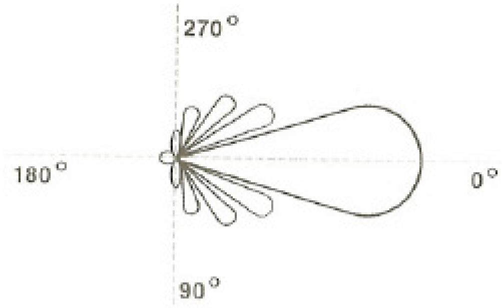


Figure 9 – Side lobe pattern

Figure 10 shows what can be done to combat an interfering source. Since the antenna has valleys between the side-lobes and a relatively broad power response at the peak, it can be seen that a slight rotation or tilt of the antenna can make a significant difference in the power level of the interfering signal. This can be used to reduce interference without significant loss in power of the intended signal. This adjustment will help only if there is an angle between the two antennas relative to the angle of the interference source.

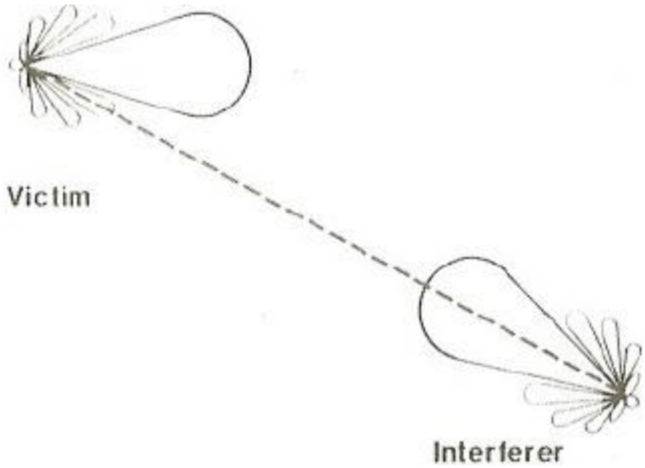


Figure 10 – Using side lobes to combat interference

Conclusion

The importance of proper antenna alignment cannot be overstated. Any misalignment results in lower system gain which directly affects the availability of the microwave link. Always consider using a professional services organization with a proven track record of successful point-to-point microwave system installations. Finally, schedule annual maintenance on the antenna system to ensure all mechanical connections remain secure and have not shifted.

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