

# **The Antenna Installation Overview=**

Version 1.0

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If none of these seem to solve the problem, then it is most likely as good as it is going to get. If the signal is not good enough for the required level of service, contact the Regional Radio Team. **DO NOT REMOVE THE EQUIPMENT IF IT HAS ALREADY BEEN PROPERLY INSTALLED!** ..... 60

# 1 Introduction

*"The true work of art is but a shadow of the divine perfection."  
- Michelangelo*

Installing antennas and radio equipment is very much like painting. Almost everybody can paint a picture, including my two year old son. The one thing that everybody agrees on is that my two-year old son's paintings still leave much to be desired when compared to an artwork by Da Vinci or Van Gogh.

In the end, it is all about technique, experience and an ability to see beyond the obvious. This manual will attempt to teach the reader the finer techniques of installing WiMAX equipment properly and also point out some of the less obvious issues that you might encounter.

Unfortunately, we will have to leave the 'experience' part of the equation as an exercise to the reader...

This manual basically consists of two main parts, the first part deals with the theory and fundamentals of antennas, radio waves, cables and transmission of information. In the second part, we will discuss the more practical aspects of installations like drilling holes, signal testing, running cables and etiquette.



## 2 Fundamentals

### 2.1 Radio Waves

In 1873 a man called James Clark Maxwell put together his theory of electromagnetism. His theory basically consists of four equations (based upon the experiments of other great scientists like Faraday) that, among other things, predicted the existence of radio waves.

It was only about 15 years later in 1888 that Heinrich Rudolf Hertz demonstrated the transmission and reception of electromagnetic waves as described by Maxwell, thereby becoming the first person to intentionally transmit and receive radio waves. It was after these famous experiments that he made the following equally famous statement.

*"It's of no use whatsoever ... this is just an experiment that proves Maestro Maxwell was right - we just have these mysterious electromagnetic waves that we cannot see with the naked eye. But they are there."*

*I do not think that the wireless waves I have discovered will have any practical application."*

*Heinrich Rudolf Hertz – 1888*



Figure 1. Heinrich Rudolf Hertz

#### 2.1.1 Electromagnetic Waves

Radio waves are formed when two basic forces of nature, electric and magnetic fields, work together to create a propagating wave, called an electromagnetic wave.

Most people have a relatively good understanding of magnetic fields (or 'H' fields) and have seen the effects of two magnets pulling or pushing at each other.

Electric fields (or 'E' field), on the other hand, are a little bit less obvious to see unless you know where to look. If you rub a balloon against your head your hair will start standing upright, unless you are bald of course! Electrons are rubbed off of your hair onto the balloon, causing your hair to have a positive electric charge (very similar to the positive terminal of a battery). The positive charge on your hair pushes each other away and makes your hair stand upright.

When you start changing either of these two fields over time, something very interesting happens. It turns out that a changing electric field will create a magnetic field that is perpendicular to the electric field! And as if that is not amazing enough, a changing magnetic field will also create an electric field that is perpendicular to the magnetic field.

So if you create an electric field in a nice up-down wave pattern, the electric field will create a left-right magnetic field which will create an up-down electric field which will create a left-right magnetic field which will create an up-down electric field which...well, you get the point.

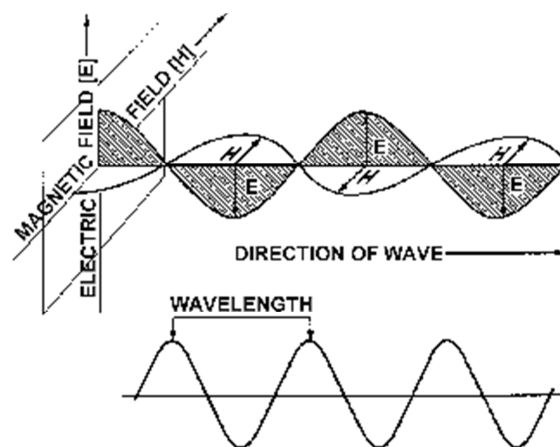


Figure 2. Electromagnetic wave

### 2.1.2 Propagation

This electromagnetic wave, which basically feeds on itself, is travelling along space perpendicular to both the electric and the magnetic field at the speed of light. All electromagnetic waves (EM waves for short) travel at the speed of light.

### 2.1.3 Frequency and Wavelength

If one could now pause the electromagnetic wave, one will notice that wave repeats itself every so often and each of these repeating waves is called a cycle. You can now measure the length of a cycle and this length is called the wavelength of the EM wave.

If you now un-pause the EM wave, you will notice that these cycles will pass by you at a very specific rate. You could, for example, have 10 cycles flow past you in a second. This is called the frequency of the EM wave and is measured in 'Hertz'. In our example, the frequency is 10 Hertz, as there are 10 cycles flowing past you each second.

A typical radio wave will normally have millions of cycles per second. Obviously it is difficult to keep on speaking of two-thousand-four-hundred-and-forty-three million Hertz, so we devised an easier way to express very high frequencies. See the table below.

Unit	Symbol	Description
Kilohertz	kHz	1,000 cycles per second or one cycle every millisecond
Megahertz	MHz	1,000,000 cycles per second or one cycle every microsecond
Gigahertz	GHz	1,000,000,000 cycles per second or one cycle every nanosecond

Now if you are very observant, you will notice that there must be a relationship between the wavelength and the frequency. Since the wave always travels at the same speed (the speed of light), an EM wave that has a long wave length will have fewer cycles moving past you per second than an EM wave with a short wavelength. So, if you know the frequency, you can calculate the wavelength, and vice-versa.

$$\lambda \approx \frac{300}{f} \quad \text{or} \quad f \approx \frac{300}{\lambda}$$

$\lambda$  = wavelength (in meters)  $f$  = frequency (in MHz)

## 2.2 The Decibel – Confusing people since 1924

Let's start off this section by looking at a few interesting numbers.

- The Sun is about 1 400 000 000m in diameter.
- An oxygen molecule is about 0.00000000014m in diameter.
- Typical sensitivity of a radio receiver is about 0.000000003162 milliwatts.

These are some values that are either ridiculously large or small and it is generally very hard to work with such extreme numbers. Unfortunately, when you deal with radio equipment you come across these extreme values all the time, so it is probably wise to see if we can find a way to make these numbers easier to work with.

### 2.2.1 Enter the Decibel...

The decibel scale was introduced for exactly this purpose. The decibel scale can compress large numbers and expand small numbers into a more user-friendly value. For example, I can say that the sun is only 91.5dB meters in size, or that the oxygen molecule is about -98.5dB meters in diameter. Our radio receiver has a sensitivity of about -85dBm.

So how exactly does it work? The decibel scale is actually a way to compare two numbers to each other, or a ratio between two numbers. The equations for calculating decibels are shown below.



$$\text{dB} = 10 \log \frac{Q_1}{Q_2}$$
$$Q_1 = \text{Quantity 1}, Q_2 = \text{Quantity 2} \quad \text{or} \quad Q_1 = Q_2 10^{\frac{\text{dB}}{10}}$$

In the examples above, we expressed the size of the sun and of the oxygen molecule in decibels, relative to 1 meter. We can also say, for example, that the sun is 91.5dB bigger than 1m. We generally just express it as dBm (for decibel meters).

- The Sun is about 1400000000m in diameter.
  - The Sun is about 91.5dB larger than 1m, or 91.5dBm (decibel meters).
- An oxygen molecule is about 0.0000000014m in diameter.
  - An oxygen molecule is about 98.5dB smaller than 1m, or -98.5dBm (decibel meters).
- Typical sensitivity of a radio receiver is about 0.00000003162 milliwatts.
  - Radio can receive signals that are 85dB weaker than 1mW, or -85dBm (decibel milliwatts).

We can use any unit and convert it into decibels if we choose to do so. We just need to remember that the decibel is always a comparison (or ratio) between two numbers and we need to specify what we are comparing it too. Some popular units that you will come across in electromagnetism are shown below.

- dBm: Decibel milliwatts, power relative to one milliwatt.
- dBm : Decibel Watts, power relative to one watt.
- dBi : Gain of an antenna relative to the gain of an isotropic antenna.
- dBd : Gain of an antenna relative to the gain of a dipole antenna.

### 2.2.2 The decibel without using a calculator

Another major advantage of the decibel scale is that it converts multiplication and division operations on the original values into summation and subtraction operations in the decibel scale. Sounds a bit complicated, but what it basically means is that it is easier to do calculations in dB's than with the original values.

When working with decibels, there are three rules of thumb that you need to know. These three rules will help you work very efficiently with decibel values.

- **Rule of 0**
  - Any two numbers compared to itself will be 0dB.
  - Example : dBm is the power relative to 1mW. So 1mW is equal to 0dBm.
- **Rule of 3**
  - When you multiply the original value by two, you add three dB.
  - When you divide the original value by two, you subtract three dB.
  - Example
    - 1mW = 0dBm
    - 2mW = 3dBm
    - 4mW = 6dBm
    - 0.5mW = -3dBm
    - 0.25mW = -6dBm
- **Rule of 10**
  - When you multiply the original value by 10, you add 10dB.
  - When you divide the original value by 10, you subtract 10dB.
  - Example
    - 1mW = 0dBm
    - 10mW = 10dBm
    - 100mW = 20dBm
    - 1000mW = 30dBm
    - 0.1mW = -10dBm
    - 0.001mW = -20dBm

Using these rules, we can get to almost any value that we are interested in. Let's look at another example where we use a combination of these rules.

How many dBm is 50W?

- We start at 1mW = 0dBm.
  - (add 10 dB) 10dBm = 10mW (multiply by 10)
  - (add 10 dB) 20dBm = 100mW (multiply by 10)
  - (add 10 dB) 30dBm = 1000mW or 1W (multiply by 10)
  - (add 10 dB) 40dBm = 10W (multiply by 10)
  - (add 10 dB) 50dBm = 100W (multiply by 10)
  - (subtract 3 dB) 47dBm = 50W (divide by 2)

## 2.3 Antennas

The question that we now need to answer is, how do we create these changing electric and magnetic fields that creates electromagnetic waves? With an antenna, of course!

An antenna is a device that will take an electrical signal from a cable connected to your radio and turn that signal into an electromagnetic wave. In fact, not only will it do that, but an antenna will also pick up an EM wave in the air and turn it back into an electrical current on a cable that your radio can understand.

### 2.3.1 Frequency Range

Unfortunately antennas don't work equally well on all frequencies. Like the strings in a piano, the antenna is designed to resonate at a very narrow set of frequencies. A long string on a piano will resonate at a low frequency and will thus play a low note. Short strings in a piano resonate at high frequencies and plays high notes. Antennas work on the same principle, but instead of sound waves, antennas will resonate when the correct electromagnetic wave comes along (or an electric current when it is transmitting). Long antenna elements will resonate to frequencies with long wavelengths and short antenna elements will resonate with short wavelengths.

Any signal coming into an antenna (either EM wave or electrical current) that is not in the correct frequency range will be rejected by the antenna. A typical WiMAX antenna could be designed to work from 2.3 – 2.7GHz and will only pick up signals in this frequency range.

The antenna's ability to take an electric current and turn it into an EM wave is normally expressed as the voltage standing wave ratio, or VSWR for short. The VSWR is an indication of how much of the energy that is sent to the antenna via the cable is accepted or rejected.

- VSWR of 1:1 means that 100% of the energy is accepted.
- VSWR of 2:1 means that 90% of the energy is accepted.
- VSWR of 10:1 means that 2% of the energy is accepted.

All the energy that is not accepted will be reflected back to the radio. Normally we consider an antenna to be acceptable when the VSWR is lower than 2:1 over the frequency range that we are interested in.

### 2.3.2 Reciprocity

An important principle of antennas is that of reciprocity. This principle states that if two devices communicate with each other by sending a signal through antenna 'A' and receiving it through

antenna 'B' then the exact same amount of power will be transferred if antennas 'A' and 'B' are interchanged.

This means that a pair of antennas in a link will perform equally well in both directions. It means that, fundamentally, antennas can be used equally well for transmitting or receiving.

### 2.3.3 Gain

Apart from just converting electrical signals to EM waves and vice versa, the antenna also has the ability to focus that wave in a specific direction. Because of the focussing effect of the antenna, the signal strength will be stronger on the receiving side of the link. The increased signal strength due to the focussing effect of the antenna is called 'gain'.

It is important to note that the antenna does not amplify the signal like an amplifier would; it simply focuses the energy in a specific direction. If more energy is focused in one direction, less energy is being radiated in other directions.

A good analogy is a torch light bulb. Held up by itself, it illuminates the walls of a room fairly evenly. If however, you put a reflector around it, it will light the wall much more brightly but only in one area whilst the rest of the room is darkening. It does this by 'borrowing' the light it was sending everywhere else and focussing it in a certain direction. We are not adding any extra power to create that bright spot; in both cases we are still using the same bulb and the same number of batteries.

### 2.3.4 Radiation Patterns

It should be clear now that there is a very tight relationship between the gain of an antenna and the pattern in which the antenna focuses the energy. This pattern is called the radiation pattern of the antenna.

When an antenna radiates energy equally well in all directions, the radiation pattern will look like a ball. This type of radiation pattern is called an isotropic pattern and the gain of such an antenna is exactly 1. When describing the gain of other antennas, it is useful to express the gain of these antennas relative to the gain of an isotropic antenna and it then also allows us to use the dB scale.

*0dBi : The gain of an isotropic antenna relative to an isotropic antenna.*

An antenna with a gain of 3dBi will radiate twice as much power in a specific direction compared to an isotropic antenna.

Let's look at an example of a radiation pattern.

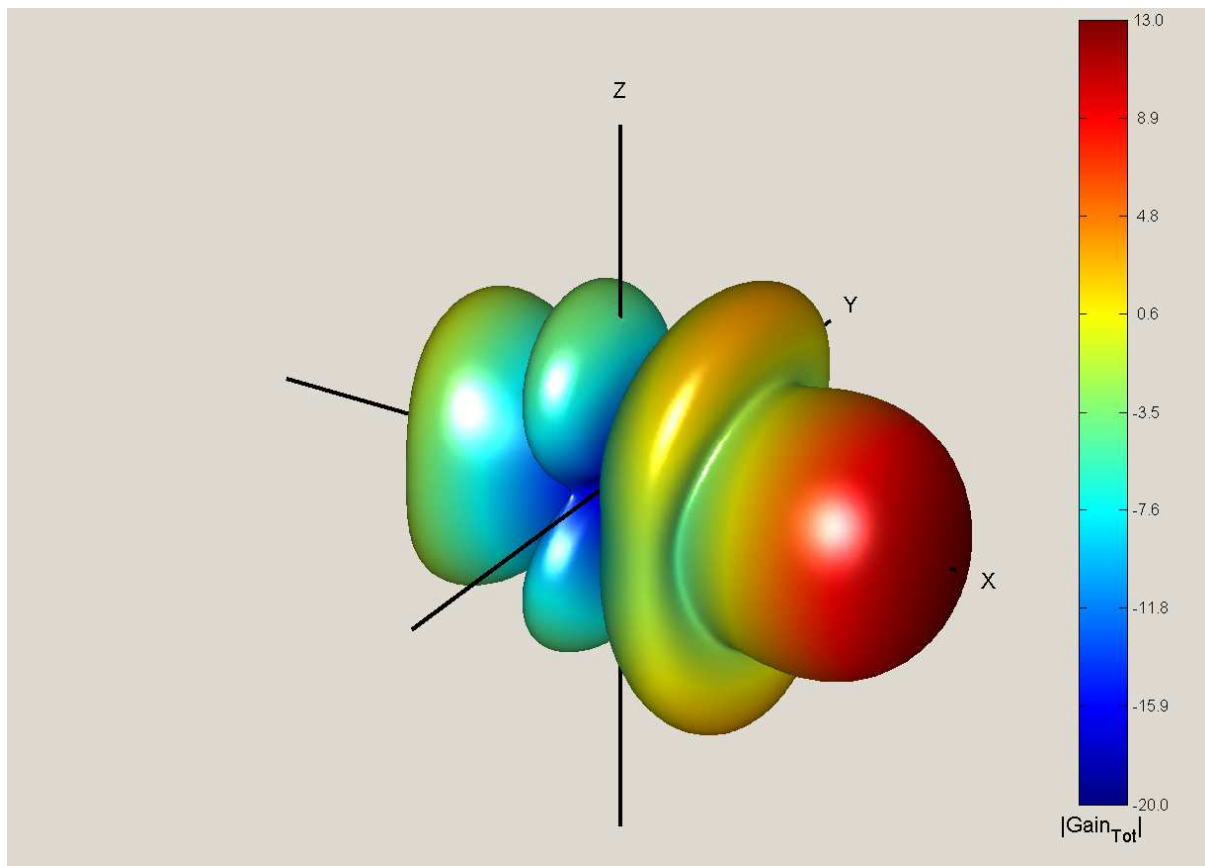


Figure 3. Example of radiation pattern

This is a three dimensional representation of the gain of a 13dBi antenna. 13dBi tells us that the antenna is radiating 20 times more power than an isotropic antenna! But if you look closely at the radiation pattern, you will notice that the gain is only 13dBi in the forward direction. In fact, in most other directions, the gain is LESS than 0dBi, meaning that the antenna is radiating less power in those directions than an isotropic antenna!

Although the 3D radiation pattern is nice to look at, it is unfortunately not very useful if we need to read information off of it. To solve this problem, we can take two cuts through this 3D plot and convert it to two 2D plots.

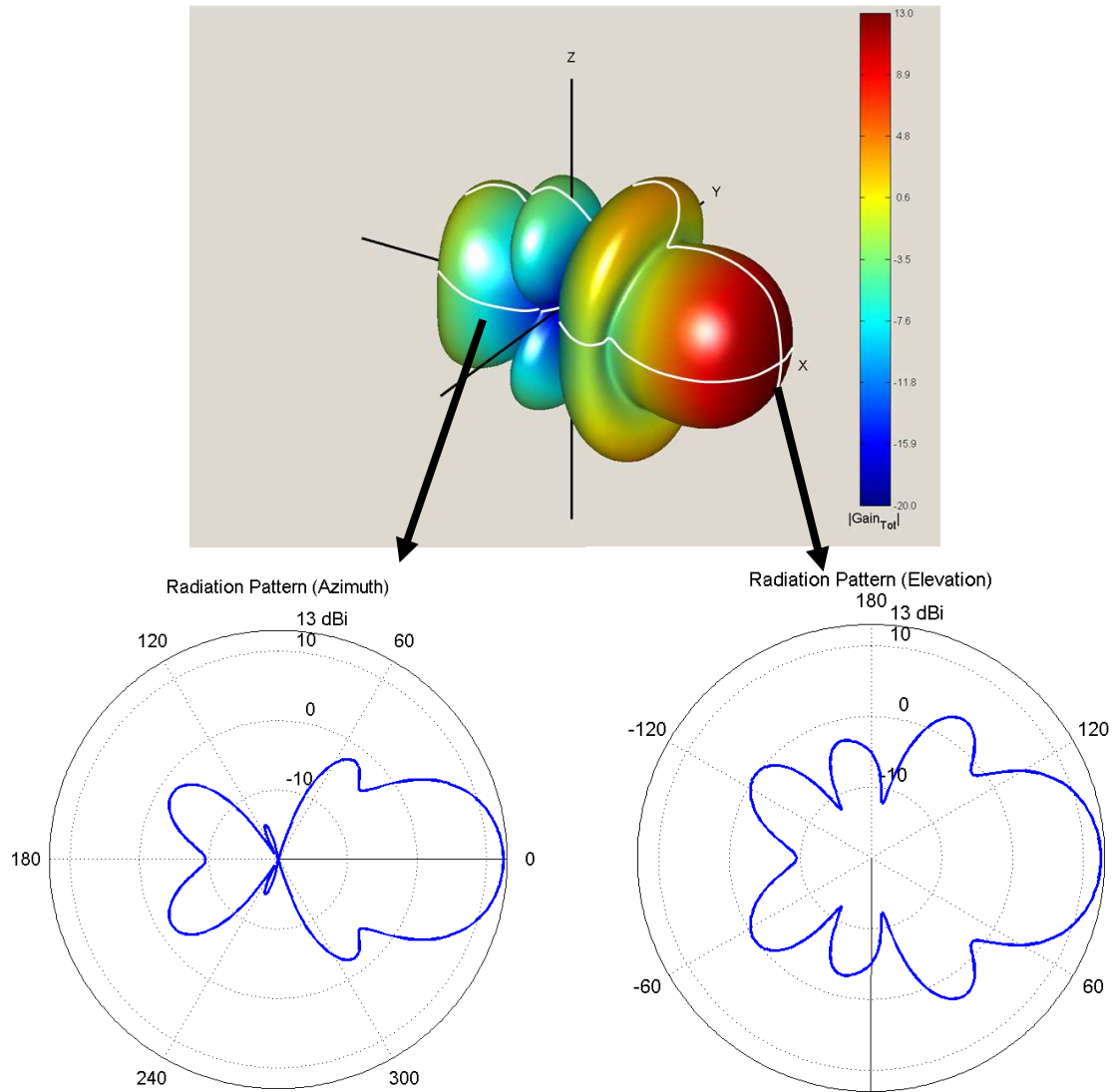


Figure 4. Azimuth and Elevation radiation patterns

These two new plots we can call the azimuth and elevation radiation patterns. Because they are now two dimensional, we can read the actual gain values in the various directions from the graph. We can see, for example, that the gain of the antenna when looking from the rear of the antenna is about -10dBi. If we compare the gain of the antenna in the forward direction to the gain of the antenna in the opposite direction we get a value called the ‘front-to-back ratio’. In this case the front-to-back ratio is  $13\text{dBi} - (-10\text{dBi}) = 23\text{dBi}$ . That means that the antenna is radiating 200 times more power towards the front of the antenna!

Since the gain of an antenna is related to the radiation pattern, we would also expect a high gain antenna to have a much narrower beam. As in the case of our torch, we can get a brighter spot by

focusing the energy into a narrower spot. This is called the beam-width of the antenna. For antennas, we define the width of the beam as the angle over which the gain of the main beam is more than half the maximum gain of the antenna. If we express this in dB, it is the angle over which the gain of the main beam is within 3dB of the maximum gain. We call this the -3dB beamwidth or the half-power beamwidth.

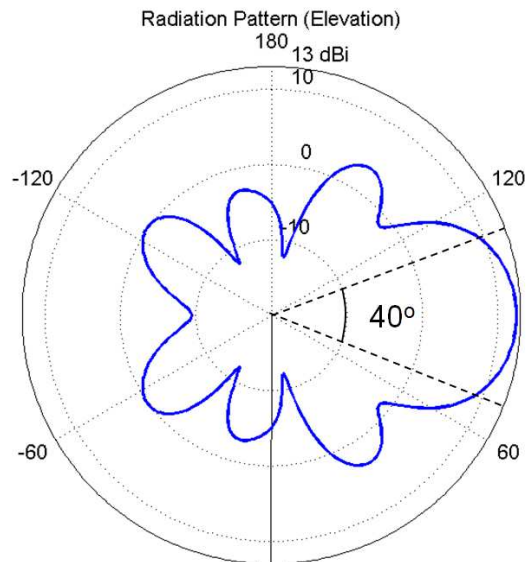


Figure 5. Beamwidth from the radiation pattern

When we look at the elevation pattern of the antenna above, we can see that the maximum gain is 13dBi. The angle over which the beam is within 3dB of the maximum gain, i.e. more than 10dBi, is about 40 degrees and the -3dB (or half-power) beamwidth of this antenna is thus 40 degrees.

The radiation pattern of an antenna is one of the important properties that need to be considered when choosing an antenna for a specific application.

### 2.3.5 Polarisation

We already know that electromagnetic waves consist of electric fields and magnetic fields that are perpendicular to each other. All electromagnetic waves can generally be divided into two groups.

- Linear polarised EM waves
- Circular polarised EM waves

In linear polarised EM waves, the electric field (we ignore the magnetic field when we discuss polarisation) will always stay in one plane, i.e. it will only change in the up-down (or left-right) direction. When you look at the EM wave coming towards you, you will see the electric field always changing in a straight line, either up-down or left-right.

In circular polarised EM waves, the electric field will spin around in a cork screw pattern. In other words, as the wave moves through space the electric field will change from up-down to left-right directions and back again all the time. When you look at the EM wave coming towards you, you will see the electric field spinning in a circular pattern, either clockwise or anti-clockwise.

The polarisation of an EM wave is determined by the antenna that radiated the EM wave in the first place. An antenna could be vertically or horizontally polarised, or it could also be left-hand or right-hand circular polarised.

It is important to use an antenna on the receiving side that has the same polarisation as the transmitting antenna. If you use the wrong polarisation for your receiving antenna, you could lose at least half the power or at worst, almost all the power. The table below shows the effect of using various combinations of polarisations for antennas.

Antenna Combination	Effect
Vertical to vertical	100% signal (0 dB)
Vertical to horizontal	Less than 1% signal (< -20 dB)
Vertical to right-hand circular	50% signal (-3 dB)
Vertical to left-hand circular	50% signal (-3 dB)
Horizontal to horizontal	100% signal (0 dB)
Horizontal to right-hand circular	50% signal (-3 dB)
Horizontal to left-hand circular	50% signal (-3 dB)
Right-hand circular to right-hand circular	100% signal (0 dB)
Right-hand circular to left-hand circular	less than 1% signal (< -20 dB)
Left Hand circular to left-hand circular	100% signal (0 dB)

### 2.3.6 Types of antennas

Antennas are generally classified by their radiation pattern and/or the design. In this section we will discuss the various antennas and group them by their radiation pattern. Where there is more than one design that will have similar radiation patterns, this will be pointed out.



### 2.3.6.1 *Omni-directional antennas*

These types of antennas are used when you would like to cover a 360 degree area around the antenna. Looking at the radiation pattern you will notice that the beam is relatively narrow in the elevation direction and the higher the gain of the antenna, the narrower the beam becomes. You should be careful when you install omni-directional antennas on high structures when you have clients close by, as the beam could be flying straight over them!



## 8 dBi outdoor omni pattern

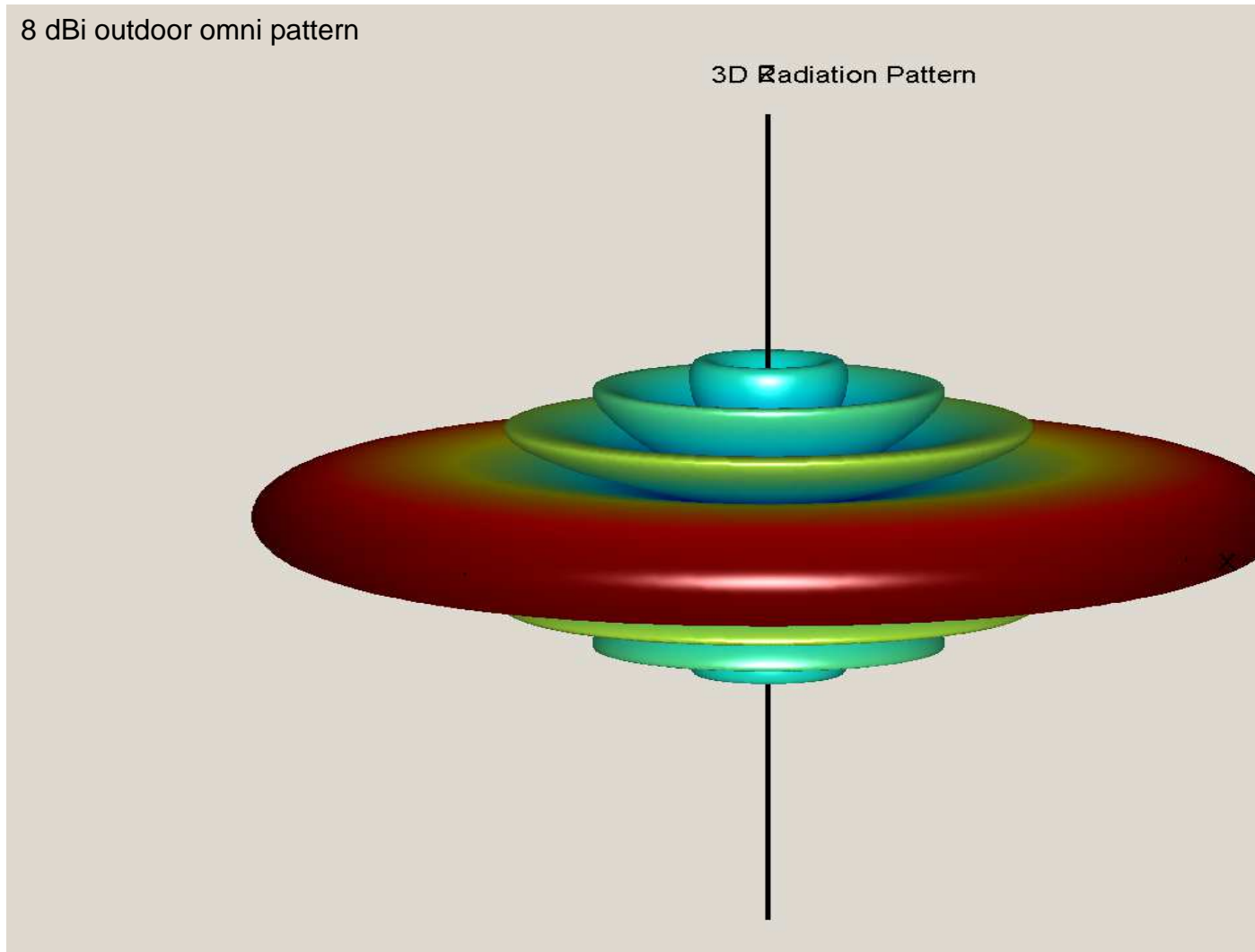


Figure 6. Radiation pattern of an omni-directional antenna

### 2.3.6.2 Sector antennas

If all of your clients are sitting within a 90-180 degree angle from the high-site, you should rather use a sectorized antenna than an omni-directional antenna. A sector antenna will radiate the energy only in a 90 – 180 degree angle, depending on the design of the antenna. Normally the angle over which the antenna radiates is given on the datasheet of the antenna. Note that the elevation radiation pattern is a lot narrower than the azimuth pattern.



16 dBi 90 degree sector pattern

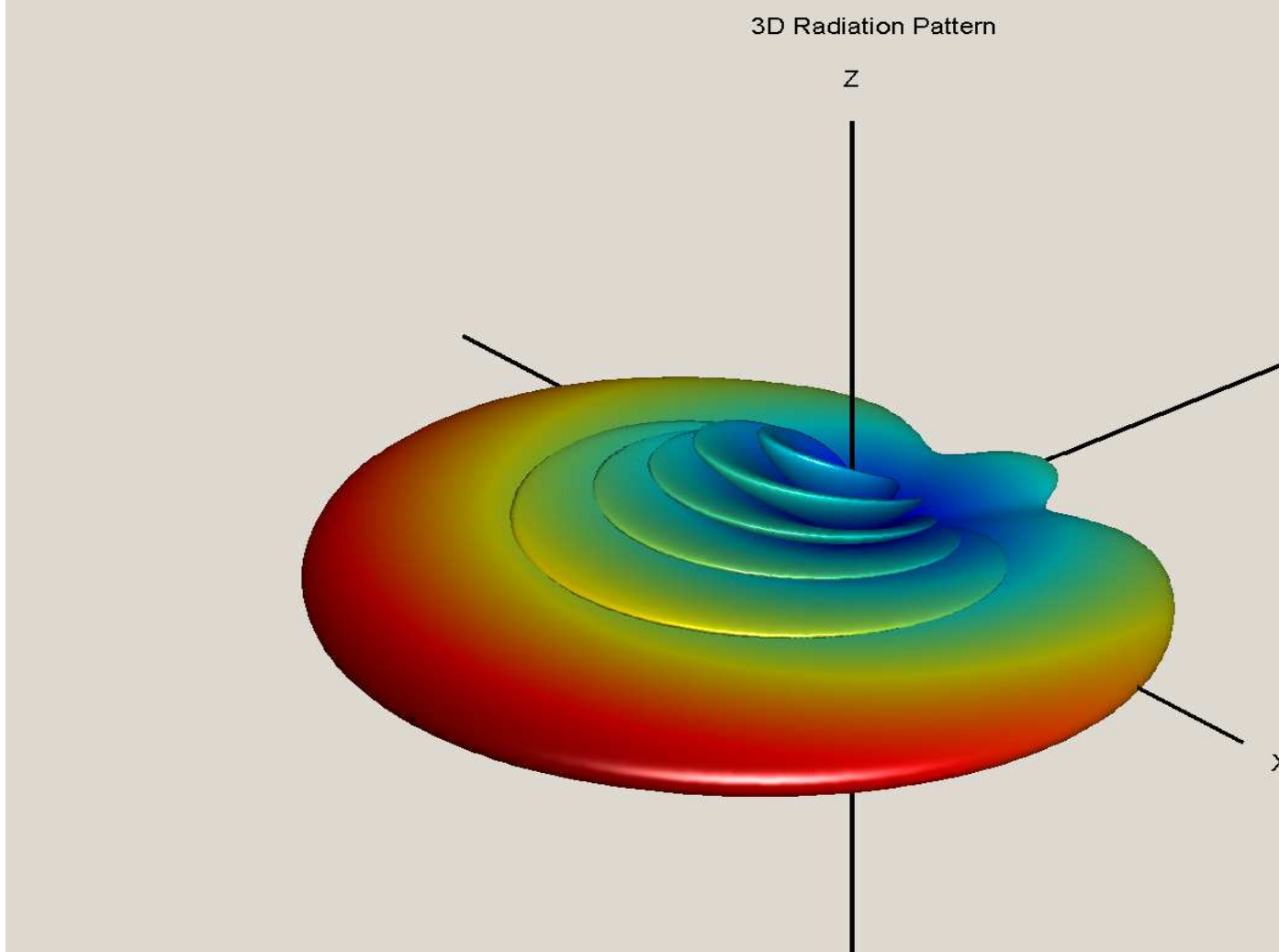


Figure 7. Radiation pattern of a sector antenna

### 2.3.6.3 Panel, Yagi and LPDA antennas

These antennas all share a very similar radiation pattern, but they look vastly different in their physical appearance. This class of antennas are directional and the beamwidths in the elevation and azimuth directions are normally very close.

In practice these antennas will give you very similar performance, as long as you compare antennas with the same gain. In other words, a 13dBi panel, 13dBi Yagi and 13dBi LPDA antenna should give you very similar signal strength readings since they have very similar radiation patterns.

Panel and Yagi antennas are available in a big variety of gain specifications, ranging all the way from 8 to about 24dBi. Higher gain antennas will be bigger than the lower gain antennas. Also, higher gain antennas will have a narrower elevation and azimuth beamwidth. These antennas are normally very popular for CPE devices or for short to medium range point-to-point links.

LPDA antennas are very wide band antennas and are normally used when you need to cover a very wide band of frequencies, like cellular frequencies. Panel and Yagi antennas are narrow band antennas that typically only cover a single set of frequencies.



Quad patch pattern

3D Radiation Pattern

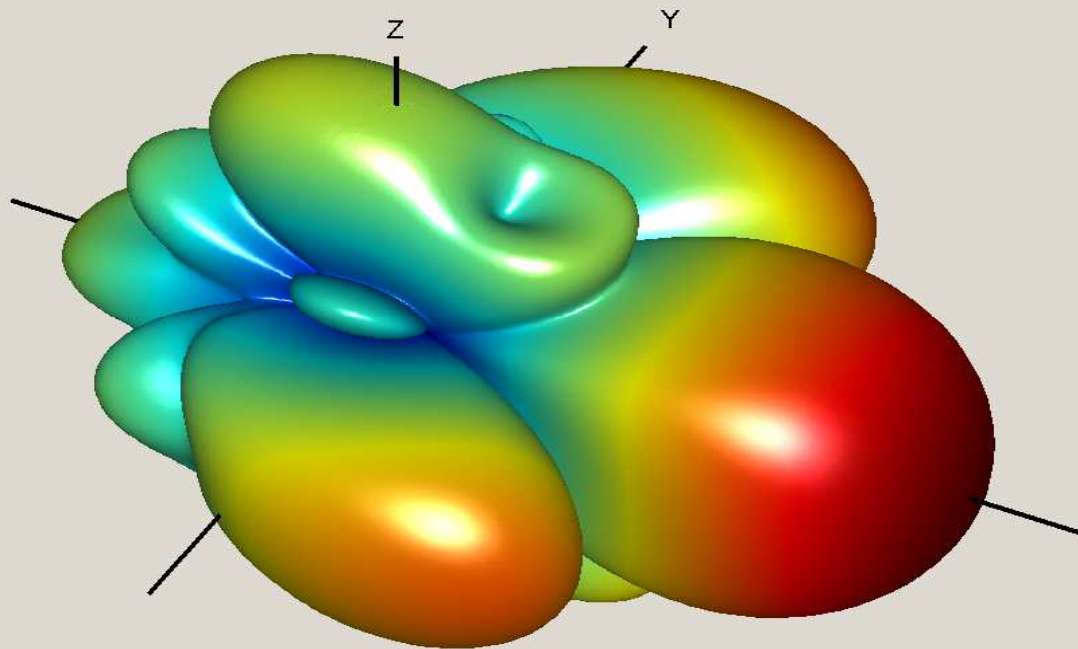


Figure 8. Radiation pattern of panel and yagi antennas

#### 2.3.6.4 Parabolic Grid and Dish antennas

Grid and dish antennas consist of a parabolic reflector that is used to focus the beam in a specific direction, just like the reflector on a torch. These antennas are usually very high gain and are used for medium to very long distance point to point links, or as CPE antennas where very low signal conditions exist. Because of the high gain of these antennas, they often have very narrow azimuth and elevation beams. This makes them very hard to aim and they will need a very rigid structure to be mounted on. Any movement in the mounting structure could cause the beam to completely miss the antenna on the other side of the link and this could cause the link to disconnect completely.



75cm grid dish pattern

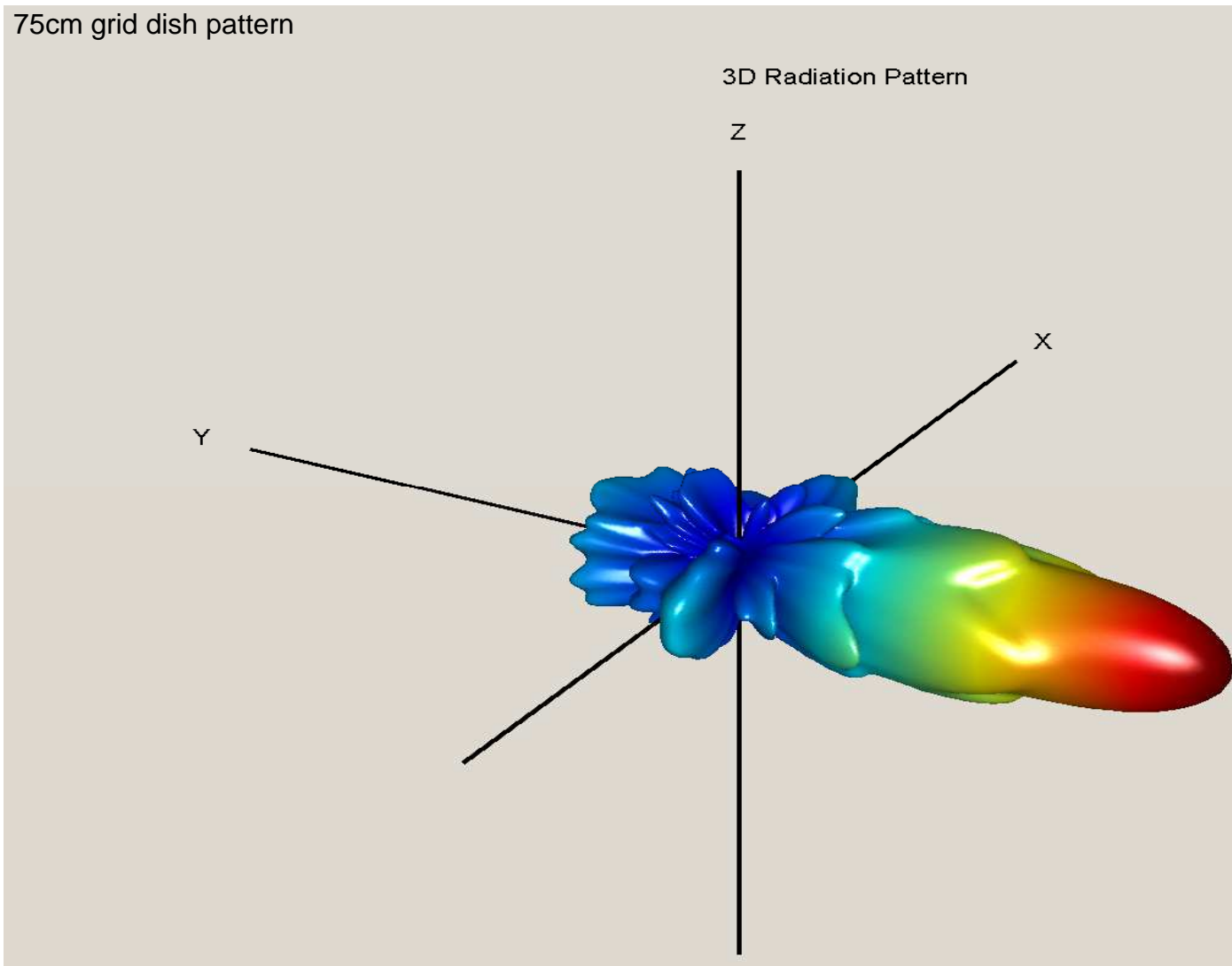


Figure 9. Radiation pattern of a grid antenna

## 2.4 Cables

Under most circumstances, some sort of cable or transmission line is needed to connect the antenna to the radio. It is vitally important to choose the right cable for the application, as the wrong cable could effectively cut off the antenna from the radio and could cause an otherwise perfect installation to not work at all.

There are many different types of transmission lines and cables, but in most WiMAX installations a coaxial cable will be used to connect the antenna to the radio. A coaxial cable basically consists of an inner core and a conductive shield around it. Normally there is a dielectric material in between that acts as a spacer, keeping the inner and the outer from shorting.

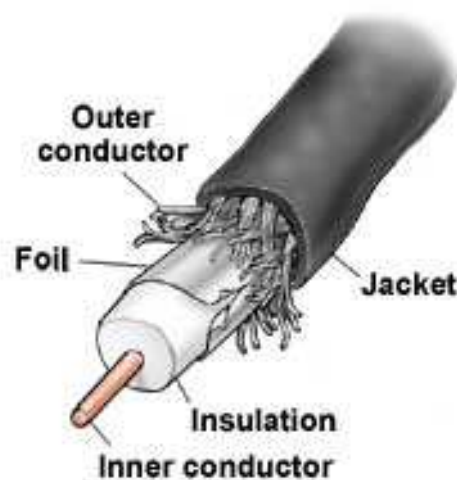


Figure 10. Coaxial cable

There are two main electrical properties of coaxial cables that we need to be aware of.

- **Impedance** : The characteristic impedance of the cable needs to match that of both the radio and the antenna. For most WiMAX applications the radio and antenna impedance is 50 ohm and you thus need a 50ohm cable as well. Coaxial cables are also available in 75ohm variants that look very similar, so be aware of this when buying cables.
  - If the wrong impedance cable is used, the VSWR of the system will be higher than it is suppose to be, which means that a bigger part of the signal is reflected back to the radio instead of going through to the antenna.
  - The impedance of the cable is dependent on the ratio of the diameters of the inner and outer conductor. If this ratio changes (because of damage to the cable), the impedance of the cable changes and will increase the VSWR of the system.
- **Losses** : As the signal travels down a length of coaxial cable, some of it will be absorbed by the cable. This signal that is absorbed will never reach the antenna and will thus reduce the



amount of power that can be transmitted by the antenna and will result in lower signal strength at the receiver.

Unfortunately the cable losses at the wireless frequencies are quite significant. The only way to battle this problem is to use as little cable as possible between the antenna and the radio. Below is a table showing the losses of some different cable types that are available. Note that all these cables are 50ohm impedance.

Cable	Approximate loss per meter (dB)	
	2.4 GHz	5.8 GHz
RG174	1.43	2.30
RG316	1.36	2.19
RG58	0.81	1.35
RG213	0.41	0.72
LMR195	0.61	0.98
LMR400	0.22	0.36

Most WiMAX systems work in the 2.3-2.7GHz frequency range. Let's look at a few examples.

- 10m of LMR195 cable at 2.4GHz will have a loss of 6.1dB. That means that only 25% of the power that you put into the cable actually reaches the antenna. The other 75% of the power is absorbed by the cable.
- 10m of LMR400 cable at 2.4GHz will have a loss of 2.2dB. That means that about 60% of the power that you put into the cable will reach the antenna. The other 40% is absorbed in the cable.

It is clear that LMR400 is much more preferable to use when you need to run a long cable, but even then you are still losing a lot of power in the cable.

**Golden Rule : Keep the coax cable as short as possible!**

When using short cable connections, less than 2m for example, the difference between LMR400 and LMR195 cable is less of an issue. LMR195 cable is obviously a lot cheaper and a lot easier to work with, so it should be used when you only need about 2m of cable.

### 2.4.1 Bend radius of cables

As we mentioned earlier, the impedance of the cable is determined by the physical dimensions of the inner and outer conductor, or rather the ratio of the diameters of the inner and the outer conductors. If you bend the cable too sharply, the outer conductor can be deformed too much and will change the impedance of the cable at the bend, thereby increasing the VSWR.

For this reason, each cable type will have a specific minimum suggested bend radius. As a rule of thumb, the minimum bend radius for coaxial cables is about 6 times the outer radius of the cable, although 10 times the outer diameter is more preferable.

Cable			
	Outer diameter	Minimum bend radius	Preferred bending radius
RG174	3 mm	18 mm	30 mm
RG58	5.00 mm	30 mm	50 mm
RG213	10.3 mm	60 mm	100 mm
LMR195	4.95 mm	30 mm	50 mm
LMR400	10.3 mm	60 mm	100 mm

It should be noted that a 340ml can of Coke (or other suitable soft-drink) is always a good thing to have around when doing installations. Apart from taking care of your thirst, the diameter of the can will also give you a good indication of the minimum bend radius for LMR400 cable and more or less the preferred bend radius for LMR195 cable. The cable should not bend more than the roundness of the can.

### 2.5 Connectors

If you connect a coaxial cable to another or to an antenna by cutting up the end of the cable and twisting the relative conductors together, you create a small length of transmission line with a characteristic impedance that is very different from that of the coaxial line. This will create a badly mismatched point and you will invariably suffer some degradation in the performance of your system.

Enter the coaxial connector. Coaxial connectors aim to join coaxial cable, transceivers, antennas, etc. without changing the characteristic impedance of the transmission line. Some do this very well, others, not as well.

Like coaxial cable, connectors have characteristic impedance and you should match this with the characteristic impedance of your antenna, cables, transceiver, etc. They also have losses associated with them which you cannot ignore.

Here are some common connector types:

Connector Family Name	Image
N-Type	
SMA	
TNC	
MMCX	
U.FL	

Connectors come together in pairs, one named a 'male' connector and the other a 'female'. There is often a lot of confusion about which is which. The rule of thumb is as follows: The gender of a connector is determined by the nature of the centre conductor part of the connector. If it is convex then it is male. If it is concave then it is female. The inner conductor portion of a male connector fits into the inner conductor portion of a female connector. These are the facts of life for coaxial connectors.

In an attempt to control the wireless LAN industry, certain regulatory authorities required manufacturers to use non-standard connectors. These gender-confused connectors are called reverse polarity (often abbreviated as RP). Once you can identify a normal connector by sight, you can tell a reverse polarity connector because its inner conductor connector will be the opposite sex. So a reverse polarity male connector has the same outer body as a normal connector of that type but it will have a female inner conductor connector.

Finally, just to really spice things up, another variation was introduced called 'reverse thread'. In this case, the connector tightens when it is turned anticlockwise instead of clockwise.

Make sure to check exactly what sort of connector you need for an application and then check if it is reverse polarity and / or reverse thread!

### **2.5.1 Waterproofing of connectors**

It is also worth saying that not all connectors were designed for outdoor use. The N-type connector is one connector that was designed for outdoor use and should be relatively watertight when properly fitted. Even so, connectors that are used outdoors should always be sealed off with self-amalgamating tape once connected. In addition to adding another layer of waterproofing, it also protects the connector from other environmental factors that could cause the connector to degrade over time, like acid rain, oxidation and bird poo...

All the other types of connectors mentioned above is definitely not designed to be used outdoors and should only be used indoors or inside a weatherproof enclosure.

### **2.5.2 Fitting connectors and testing**

Due to the fact that these connectors will be used at high frequencies, they should never be fitted in the field, unless you have a portable network analyser or equivalent device that you can use to test the cable.

Fitting coaxial connectors to cables is a specialised task that must be done using the proper tools and the **cable must be tested after the connectors are fitted.** A normal visual inspection, or even a test with a multimeter, will often not show if there is a problem with a cable.

## 2.6 Propagation of Radio Waves

After an EM wave leaves the antenna, it will immediately start spreading out in all directions. While this signal gets spread out all over space, the signal will get weaker and weaker the further it travels from the antenna. In a sense one can think of the signal getting 'diluted' because of the bigger area that is covered.

Under perfect conditions we can calculate the exact theoretical signal strength that you should be able to receive as long as we know how much power was transmitted, the gain of the transmitting and the receiving antenna, the frequency and the distance between the two antennas. The following equation can be used to calculate the signal strength.

$$P_r = P_t \frac{G_t G_r \lambda^2}{(4\pi r)^2}$$

$$\begin{aligned} P_r &= \text{Power received (W)}, P_t = \text{Power transmitted (W)}, \\ G_r &= \text{Gain of receive antenna}, G_t = \text{Gain of transmit antenna}, \\ \lambda &= \text{Wavelength (m)}, r = \text{distance (m)} \end{aligned}$$

Or if you prefer to work in decibels,

$$P_r = P_t + G_t + G_r - 32.45 - 20 \log_{10} r - 20 \log_{10} f$$

$$f = \text{frequency (Hz)}$$

But why should we do the calculations by hand if we can enslave a computer to do it? There are many link calculators available that will calculate any of these values. One such calculator is called the LinkPlanner.

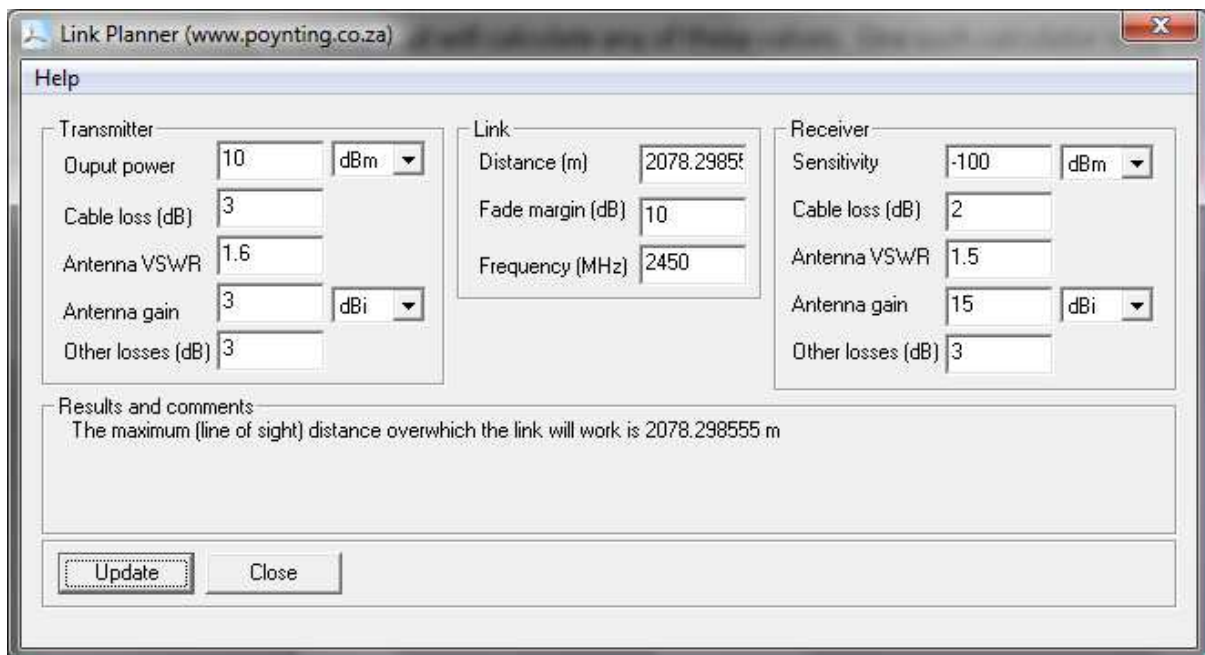


Figure 11. Poynting LinkPlanner software

LinkPlanner programs do not take into account any objects that might be in the way (like trees and buildings) and assumes that you live in a perfect world. Unfortunately that is rarely the case, so these numbers should only be used as a rough estimate.

One way of dealing with these uncertainties is to add a fade margin (which is a fancy word for safety margin). For link shorter than 100m a fade margin of 3dB should be enough. For links less than 1km you should use about 6dB of fade margin and anything more than 1km should allow for about 10dB of fade margin.

### 2.6.1 Obstructions

Due to the major shortage of 'sky-hooks' we often have a very limited choice of mounting options during installations. Because of this it is important to know what to look out for in terms of obstructions.

For WiMAX links we need a clear line of sight between the transmitting and receiving antenna, sort of. Actually we need a bit more than that; we actually need a clearance around the straight line between the two antennas. This area is called the Fresnel zone.

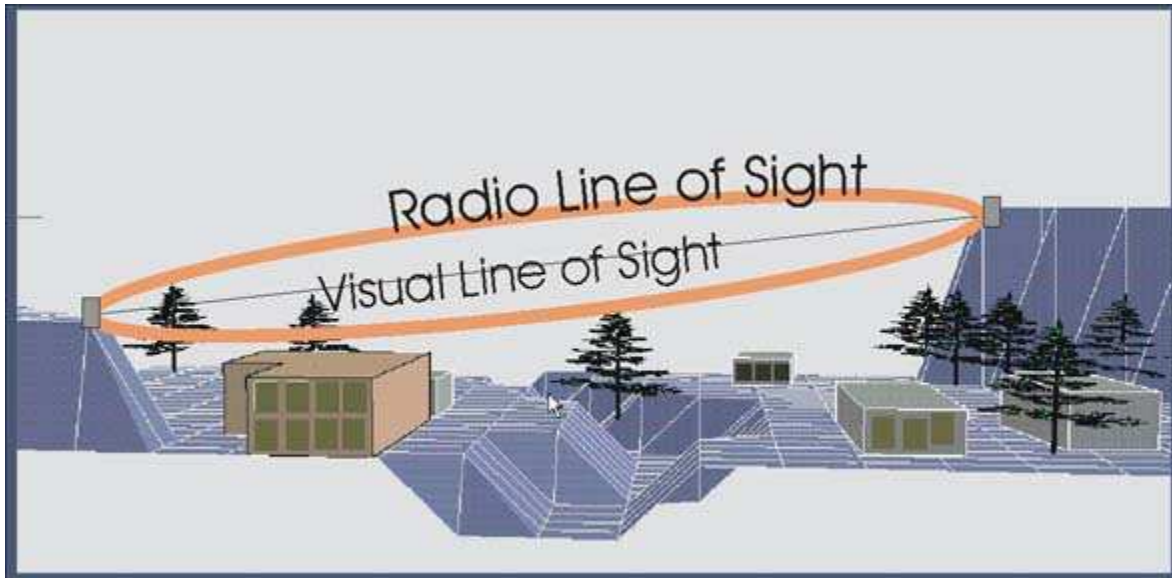


Figure 12. Line of sight and Fresnel zones

The Fresnel zone as a rugby-ball shaped area around the direct line of sight that needs to be clear for the link to work properly. The Fresnel zone is the biggest exactly in the middle of the beam and there are many calculators available that will give you this value. The table below will give you an idea of how much clearance you need around the line of sight for different link distances.

Link Distance [km]	Fresnel zone diameter [m]
1	11.2
2	15.8
3	19.4
4	22.4
5	25.0

It should be noted that the ground could also be an obstruction over long distances. For example, if your two antennas are 5km apart and you have a perfectly clear line of sight, your antennas need to be at least 12.5m off the ground. Anything lower than that and the ground will be in your Fresnel zone and will degrade your signal.

But it is not only at the middle of the link where we need to be aware of the Fresnel zone. We also need to make sure that the objects very close to the antenna will not interfere with the signal leaving the antenna. It is a bit more complicated to calculate the exact clearances close to the antenna, but the values below can be used as a guideline.

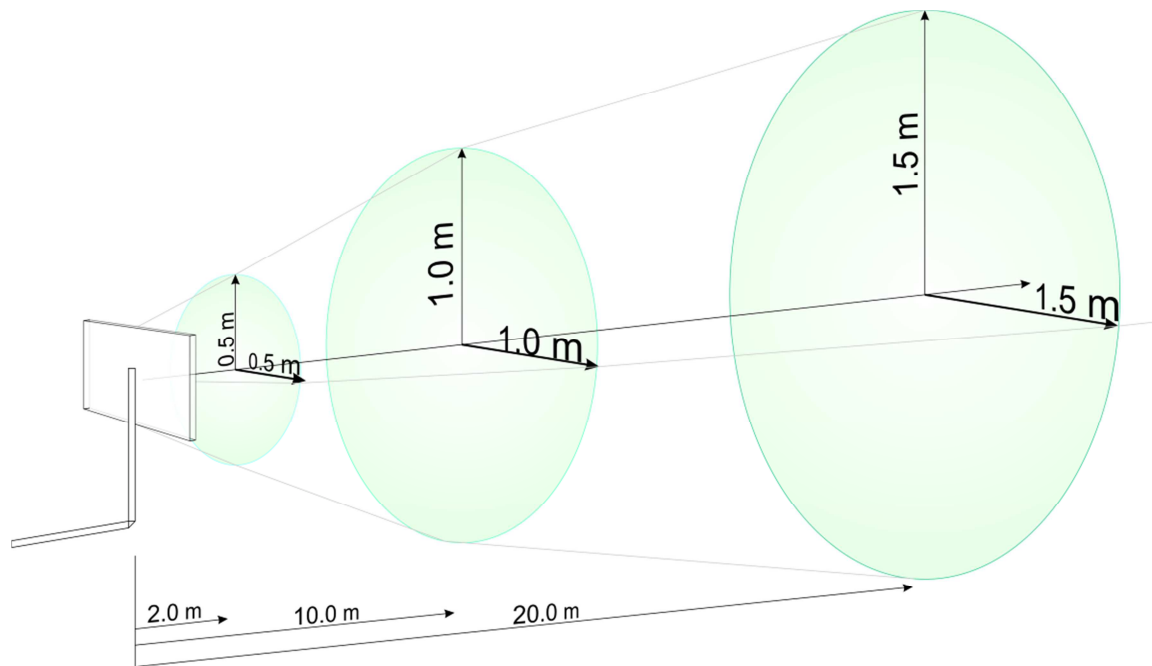


Figure 13. Clearance required close to the antenna

## 2.7 Transmitters

The source of the signals used in wireless networks is the transmitter. These devices usually convert direct current electricity to an electrical signal at the frequency of interest. They also have the ability to modulate the output signal in order to superimpose information on the signal. (More on that later)

### 2.7.1 Power and Impedance

The only parameters of a transmitter that you will need to know about for wireless networking, are its characteristic impedance (almost always 50 Ohms) and its output power.

The characteristic impedance of the transmitter should be matched to that of the cable you run from it and the antenna you intend to use at the other end of the cable.

The output power of a transmitter is usually measured in watts, milliwatts or dBm (if it is for wireless networking.) Typically wireless networking equipment operates in the range of 50 milliwatts (17 dBm) to 10 watt (40dBm)

In some cases the output power of a transmitter can be varied in the configuration of a wireless networking device.

## 2.8 Receivers

Once a wireless networking signal has been generated by a transmitter, transported on a cable, radiated by an antenna, received by another antenna and transported by another cable, it arrives at



a receiver. It is the job of a receiver to separate that signal from others that may be present and prepare it for decoding back into useful information.

### **2.8.1 Sensitivity and Impedance**

Again, the only parameters of a receiver you need to worry about for WiMAX, are its sensitivity and its characteristic impedance (again, almost always 50 Ohms).

The characteristic impedance of a receiver should be matched to that of the cable you are using and the receiving antenna.

The sensitivity of a receiver is the absolute minimum power that an incoming signal must have in order for the receiver to correctly select and prepare the signal for decoding. Below that power, the incoming signal will be decoded incorrectly. Sensitivity is usually expressed in dBm and is in the order of -90 dBm to -70 dBm. Lower values indicate better sensitivity.

Changing the rate of flow of information can change the sensitivity of a receiver. (Usually, the higher the data rate, the worse the sensitivity.)

## **2.9 Transceivers**

Often, a transmitter and a receiver can be built in such a way that they share the same connection to an antenna or cable. When the transmitter transmits, it does so right onto the same connection that the receiver is listening on. This single device is dubbed a transceiver.

WiMAX products are almost exclusively based on transceivers. Each device is capable of transmission and reception but it is vitally important to realise that they cannot do both at the same time. We have already mentioned the vast differences in the typical transmitted powers of these devices as compared to the miniscule signals they can receive. The receiver parts of these transceivers cannot detect such tiny signals at the same time the transmitter portion is booming away right on the same physical connection. In fact, it is important to note that even if the transmitter and receiver are separate, but close together, the transmitter will drown out any distant signal that the receiver was trying to detect.

## **2.10 Transmission of Information**

Now we have reached the point where we can discuss clearly the lifecycle of a radio signal from creation (transmitter) to transportation (cable) and conversion to and from electromagnetic waves (antenna)... so what? Who cares about these signals if we cannot use them for something?

It didn't take long for mankind to realise that we could add meaning to these signals by changing them over time in some organised way to represent symbols. Morse code is an excellent example of this. A signal is turned on and off in a series of long and short bursts to indicate letters. These bursts are interpreted by someone at some distance and converted back into letters.

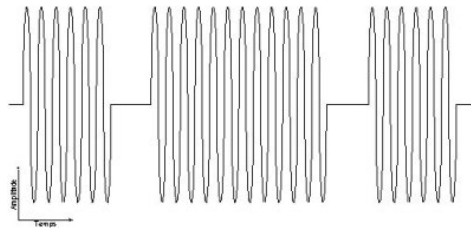
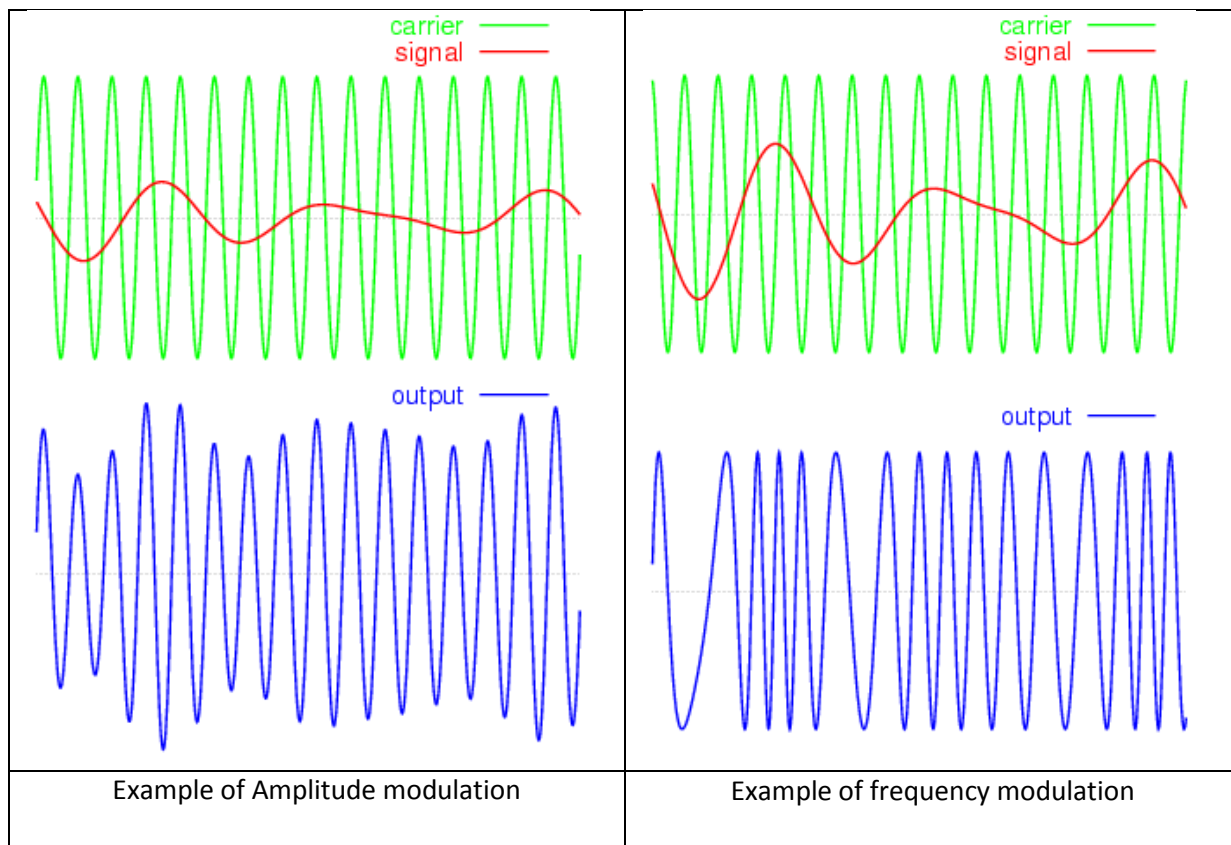


Figure 14. Short-long-short morse sequence modulated onto a carrier signal.

### 2.10.1 Modulation

A pure radio frequency signal is a wave with the same shape as the sine function. If left alone, this signal it is called continuous wave and is of very little use for transporting information. There are three basic ways in which the signal can be changed (modulated) in order to convey some meaning. Firstly, the amount of signal can be changed over time. This is called amplitude modulation (AM). Secondly, it can have its frequency increased or decreased over time. This is called frequency modulation (FM). Finally, it can be shifted forwards in time or backwards in time. This is called phase modulation (PM).

These techniques can be used alone or together to superimpose some meaning onto a radio signal.



## 2.11 Throughput, symbol rates and bit rates

Since most of the information that will be sent over a WiMAX link will originate from a computer of sorts, it is obviously useful to send the information in digital form (that is 1's and 0's). When we are sending digital information we are often interested in knowing how fast the information is flowing from one point to another, but there are a number of different ways of expressing the speed at which the data flows. To make some sense from all these numbers, we need to understand how bits and bytes are encoded onto the EM wave that is eventually sent over the air.

### 2.11.1 Symbols and symbol rates

Let's assume that the information that we would like to transmit is in digital form. That means that we will have a very long string of ones and zeros that we would like to transmit from point A to point B.

One way that we can approach this problem is to send one bit at a time. Although this will work, it is probably not the most efficient way of doing it. Let's use an analogy to explain bit rates and symbol rates.

Suppose that two people are each standing on a building that is some distance apart. They would like to send digital information from one building to another and they are going to use flags to do so.

They agreed beforehand that they will use a white flag and a black flag, where the white flag represents a 1 and the black flag represents a 0. They can change flags at a rate of one flag per second.



Figure 15. The flag analogy

In this example, the flag is a **symbol that represents one bit**. So if they change flags once every second, the symbol rate (also called baud rate) is 1 symbol/second. The bit rate is also 1 bit/second (or 1 bps).

If they now decide to use four flags instead of two, they can represent more than one bit per flag.

Flag (or symbol)	Bit sequence represented by flag
Black	00
White	01
Blue	10
Red	11

If they keep on waving one flag per second, they still have a **symbol rate of 1 symbol/second**. But since each symbol now represents more than one bit, the **bit rate has increased to 2 bps**.

We can now take this even one step further. Let's add another four flags to the mix.

Flag (or symbol)	Bit sequence represented by flag
Black	000
White	001
Blue	010

Red	011
Green	100
Yellow	101
Orange	110
Brown	111

Still waving one flag per second, the symbol rate stays at **1 symbol per second**. Each symbol now represents three bits, thereby increasing **the bit rate to 3bps**.

We can decide to jump between various numbers of symbols as we require. If the weather rolls in, we could decide to fall back to using only four or even two flags, as they are easier to distinguish from each other. So we can have reliable communications under any conditions, although it might be a little slower when the conditions are not perfect.

Digital data is encoded onto radio waves using the same concepts, but just a lot more complex than our flag analogy.

A real example of this is 802.11a at full rate (54 Mb/s). The modulation scheme is very complicated (64 state quadrature amplitude modulation and convolutional coding on 48 data sub-carriers). The baud rate is 250,000 symbols per second and each symbol represents 216 bits of data so the bit rate is 54,000,000 bits per second or 54 Mb/s (million bits per second).

### 2.11.2 Noise and Interference

Noise plays a big role in radio communications. It takes the form of a signal around the frequencies of interest and it is generated by the natural environment through which an electromagnetic signal passes and even by the receiver itself.

When a signal is received by a receiver, there needs to be a certain ratio between the power of the signal itself and the power of the noise mixed in with the signal. This is often called the signal to noise ratio. If this ratio is big enough, then the signal is easily discernable from the noise and it can be readily demodulated and converted into the original information it was carrying. If the ratio is too small though, the number of errors in the demodulation (caused by the noise) will exceed the system's capacity to deal with them.

Usually in wireless networking the majority of the noise that may cause problems is generated by the receiver itself. Typically the sensitivity of the receiver is nothing more than the power at which

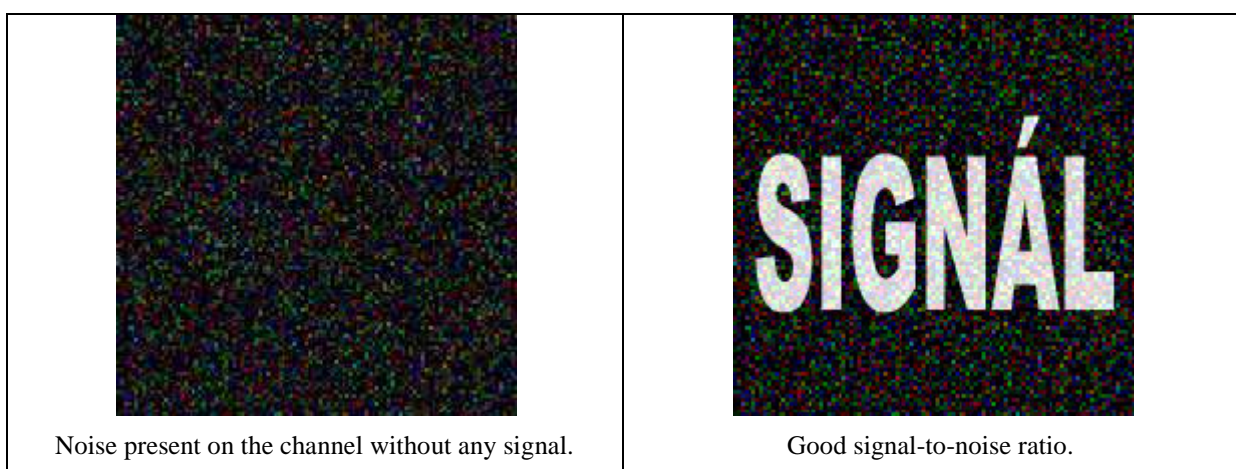
the signal to noise ratio is large enough for the system to work as advertised (assuming the manufacturer is aware of how noisy the receiver is).

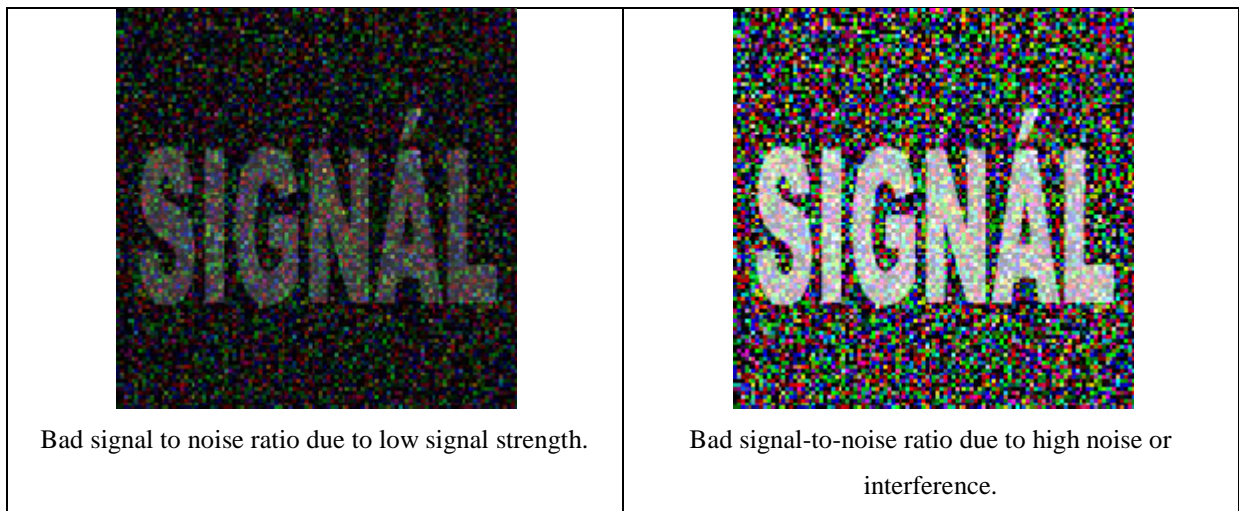
Sometimes, however, an external artificial signal creates a level of noise so high, that it exceeds the natural noise in a system. In these cases, we usually refer to that artificial signal as *interference*. Interference can be caused by similar equipment transmitting on the same channels, other equipment with poor filtering, poorly shielded electronics, etc. The effect of interference is that it desensitises your receiver. That is, you need a higher strength original signal in order to distinguish it from the interference and demodulate it. For WiMAX installations, we are interested in the ration of our signal (or carrier signal) and the combination of the noise and interference. This ratio is called CINR, or Carrier to Noise + Interference Ratio. Although this is technically different from the SNR, they are often used interchangeably.

The only way to get a better CINR is to either increase the signal while keeping the noise/interference the same, or decrease the interference and keep the signal the same, or a combination of these two.

Fortunately antennas allow us to very efficiently increase the CINR by using higher gain antennas. A higher gain antenna will firstly increase the signal strength in both directions of the link. Secondly, the antenna will cut out more of the interference in the area around the antenna due to the narrower beamwidth.

It is important to note that an amplifier does NOT increase the CINR of a receiver. An amplifier will normally amplify both the wanted signal and the unwanted noise and interference, leaving you with exactly the same ratio between the signal strength and the noise.





## 2.12 Lightning and Surge Protection

There are few things as sad as a beautifully set up radio installation silenced in a few milliseconds by Mother Nature. Lightning can cause tremendous damage to sensitive equipment like radio receivers without even striking close to them. Indeed there are few electronic devices that can handle a direct lightning strike without severe damage.

Fortunately, there are several steps that one can take to reduce the possibility of damage from a lightning strike.

### 2.12.1 Basic Lightning Protection

Currently, preventing lightning strikes is not feasible. They will occur at some time or other, so when you install sensitive equipment indoors and out, take some time to plan how you will protect that equipment. Also, always remember that this is a game of statistics. You will rarely ever have perfect protection, but you can certainly give your equipment much better odds than it would otherwise have.

***Essentially the idea behind lightning protection is to allow the strike to happen whilst safely conducting it around your equipment (rather than through it) to ground.***

#### 2.12.1.1 The 'Rolling Ball' Model

The belief used to be that "lightning strikes the highest point", but it has since been proven that this is, in fact, an old wives' tale. A more modern approach is the so-called 'rolling-ball-model'.



Figure 16. The rolling ball model

The rolling ball model may be used practically as follows: Suppose you had a giant beach ball fifty meters in diameter. (That's very big). If you rolled that ball (without deforming it) over a building or structure in every way possible, then anything it touches is potentially at risk of suffering a direct lightning strike.

Practically you can see that merely placing an antenna on the side of a building is not a fail-safe way of protecting it. Rather a well grounded spike mounted horizontally above that antenna might do the trick.

There are many, many configurations of lighting protection, but all the good ones obey the rolling ball model. That is, the giant beach ball can only touch the lightning protection structure and not the antenna or device it's protecting.

### 2.12.2 Basic Surge Protection

Using the rolling-ball-model might prevent a direct strike on your antenna or device, but that does not mean you don't need further protection. Surges are the silent killer of sensitive electronics, and you need to take care to protect against them.

#### 2.12.2.1 Induced Transients

If lightning strikes near an electronic device or an antenna (particularly an antenna), the massive fields that are created can induce a surge transient on wires connected to the device or, in the case of an antenna, across the feed. These transients can be the death of WiMAX equipment.

#### 2.12.2.2 Inline Protection Devices

Inline protection provides a good means to prevent damage from transients. Usually inline protection devices will not survive a direct strike, but they will effectively reduce the likelihood of damage from transients.





Figure 17. In line coaxial surge arrestors

Inline protection devices come in coaxial form (for use on RF lines) and many others including Ethernet protection. They work by momentarily shorting the signal lines directly to earth during the transient and then returning to their normal state. **Make absolutely sure you earth them correctly or they won't work!**

### 2.12.3 Earthing

One of the key aspects in lightning protection is good earthing. Lightning strikes connect a cloud to earth. We define earth as the 'zero potential' and the better connected to earth your equipment is, the closer it will stay to zero potential during a strike. If you are doing an important installation that requires solid lightning protection, make sure that the building itself is properly earthed (with earth spikes) and that the earth points are well connected with heavy gauge copper running over as short a path as possible. Poorly connected earths can end up many hundreds or even thousands of volts apart during a lightning strike. In a case such as that, good inline protection devices will be ineffective and you are likely to suffer damage.

### 3 Signal Testing and Site Surveys

*“There are two possible outcomes: if the result confirms the hypothesis, then you've made a measurement. If the result is contrary to the hypothesis, then you've made a discovery.”*

*-Enrico Fermi (1901-1954)*

There are few things as frustrating (or as humiliating) as doing a proper, really good looking installation and only finding out afterwards that you are unable to get a working link. For this reason, it is often wise to do a site survey before drilling any holes in walls or roofs.

When doing site survey's it is important to place the antenna as close as possible to the final installation position. Remember that objects close to the antenna could still have an influence on the antenna even if they are not directly in the path of an antenna.

Also check with the client that the spot where you would like to install the antenna is actually suitable. A client might decide that you are not allowed to install the antenna at the perfect (electromagnetically speaking) position, because it looks ugly from the street.

#### 3.1 Preparation for site surveys and installations

It is quite important to be well prepared for a site survey. Apart from looking stupid, it will waste a lot of time running around on the client's roof trying to figure out where the base station is located.

Studying the pre-survey document will give you a lot of information that should allow you to find the base station with the least amount of effort. Let's have a look at an example of a pre-survey document and what sort of useful information is available.

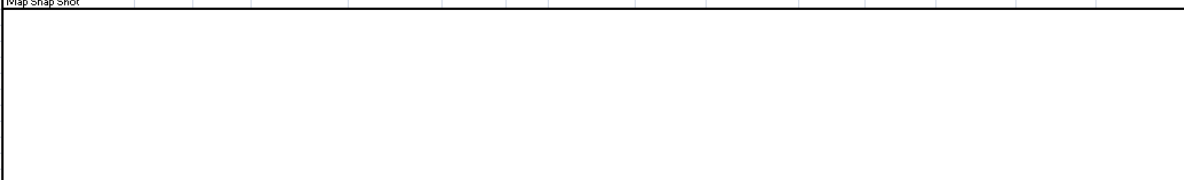
PRE SURVEY RADIO INFORMATION															
Client Name				Poynting				Region				Northern Gauteng			
Latitude DMS (VGS 84)								Date				12-Aug-09			
Longitude DMS (VGS 84)															
Latitude DD (VGS 84)															
Longitude DD (VGS 84)															
Service Profile Required															
VIMAX BroadBand 1024 kbps															
Client				New				X				Upgrade			
Physical Address								RSSI (Measured)				CINR (Measured)			
33 Thora Crescent - Vynberg															
Calculated															
Choice	BS ID	BS Sector	BS Name	BS Status	BS Announced Date	ASN	Azimuth From CPE (True North)	Height Above Ground [m]	Frequency	Signal Strength [dBm]	Antenna Gain [dBi]	Received Signal Strength [dBm]	CINR [dB]	Compliance to service profile (RSSI and CINR)	
Option One	19071	3	Vynberg Industrial	Operational			107	3		-70	20	-50	>=23	Yes	
Option Two	14971	2	Innistree_Park	Operational			278	3		-79	20	-53	>=23	Yes	
Option Three	13861	2	Silvela	Operational			357	3		-79	20	-53	>=23	Yes	
Map Snap Shot															
															
Comments :															
No other feasible options.															
Information Provided by							Installers Details								
Name							Nathaniel Naidoo								
Date							13-Aug-09								
Department							Mobile Engineering - Network Quality								
Cell Number															
Requested by							Cell Number								
Name							Heidi Morrison								
Department							Vodacom Business								
Date							12-Aug-09								
Cell Number															

Figure 18. Screenshot of a pre-survey sheet

The first sheet gives the client’s details, GPS coordinates and the three options to which they should be able to connect to.

One of the vital instruments that you should have for each installation team is a GPS. Program the address of the client into your GPS beforehand. This will prevent you from having to wander around in unknown territory.

It is also worthwhile looking up the position of the client and the base station on a map or program like Google Earth.

- Draw a line from the client’s house to the base station.
- Look for any landmarks that you should be able to spot from the installation site. This will help you find the initial direction to the base station.
- Also look out for any large buildings or other objects that could possibly be in the way. Remember that the line of sight that is calculated by the computer does not know that there are high riser buildings around; it only takes the actual ground profile into account.

In addition to the actual locations, you will also find the expected signal strength (or RSSI : Received Signal Strength Indication) and signal to noise ratio (or CINR : Carrier to Interference + Noise Ratio) values from the various base stations. Use these values as a guideline when you are aligning the antenna. Keep in mind that the CINR could be different (generally worse) due to other interference

that the software might not be aware of. Things like indoor wifi routers would decrease the CINR, for example.

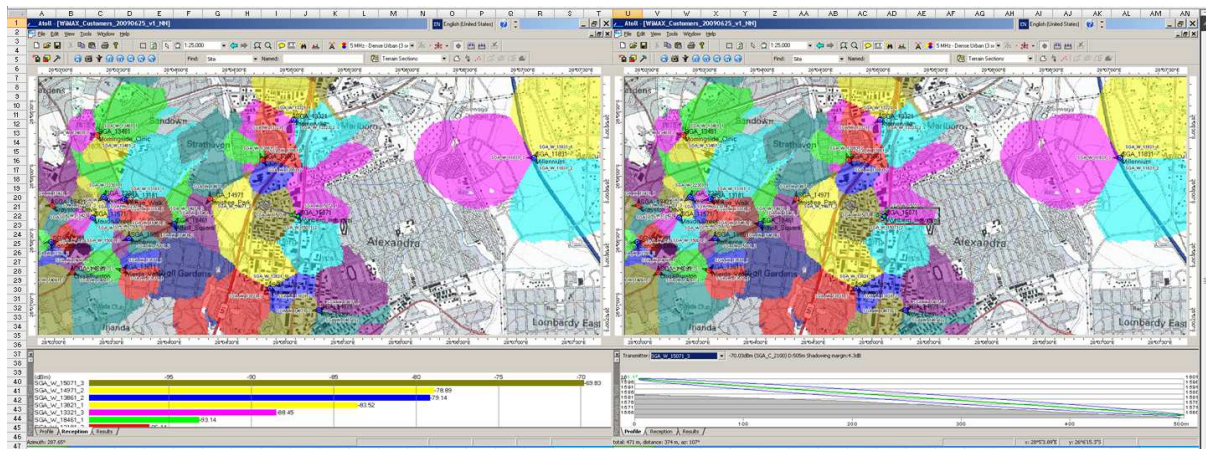


Figure 19. Screenshot of a pre-survey sheet

The next sheet shows you some maps and coverage information for the various base stations in the area. It also gives you a graphical representation of the expected RSSI from the various base stations and the line of sight and Fresnel zone clearance to the base station.

## 4 Practical Installations

*“There are only two types of people in the world. There are those that learn from other people’s mistakes, and then there are the rest of us.” - Unknown*

Knowing the theory of antennas and WiMAX in general still does not guarantee a successful antenna or CPE installation. All our knowledge of antenna gain, patterns and modulation will be of little help when the rain comes pouring into you client’s home because you did not waterproof the hole for the cable in the wall!

In this chapter we will discuss some of the more practical issues that you need to be aware of when doing an installation.

### 4.1 Mounting the antenna or CPE

#### 4.1.1 Choosing a mounting position

Let’s look at a few issues that need to be taken into account when choosing the position where you must mount the antenna.

- Line of sight to the base station
  - The position of the antenna must be chosen so that you will have line-of-sight to the base station where you intend connecting.
- Obstructions (trees, walls, etc.)
  - Make sure that the line of sight will be clear of any trees, walls, roofs and any other obstructions close to the antenna. Keep in mind that the Fresnel zone must be clear, not just the straight line from the antenna.
- Client preference
  - The client may not necessarily agree with your electromagnetically perfect spot that you have chosen for the antenna. Always try and accommodate the client as far as possible.
- Cable length, especially for indoor CPEs
  - When running RF coax cable, it is important to mount the antenna as close as possible to keep the cable losses as little as possible. This will often be determined by the location of the client’s PC or server room.
  - If the client’s PCs or server room is inaccessible or too far away, rather place the CPE elsewhere and run a separate Ethernet cable from the CPE than trying to run long lengths of coax cable.

- For outdoor CPE's it is not as big a problem as you can run up to 50m of Ethernet cable to the external CPE.
- Other antennas or radio devices
  - CPE antennas must always be at least 1.5m away from other antennas like Wifi or TV antennas. CPE's could cause interference or receive interference from other transmitting antennas.
  - Also keep the minimum pole sizes in mind if you decide to use an existing mounting pole. The same minimum specifications must be met if you intend using an existing mounting pole.

#### **4.1.2 Mounting pole and brackets**

It is very important to make sure that the right size pole and bracket are used for installations. If the pole is too long it could move too much in the wind and cause the beam of the antenna to miss the base station, or even worse, snap off completely. Below are the minimum specifications for a given mounting pole length.

- Up to 75cm:
  - 38mm aluminium pole
  - Small three-legged bracket, 15cm offset from wall
- Up to 2m:
  - 50mm aluminium pole, 1mm wall thickness
  - Medium three legged bracket, 25cm offset from wall

Never attempt to use a pole that is longer than 2m. If you require more than 2m of pole to achieve clearance or for whatever reason, refer the situation to the Regional Radio Team.

#### **4.1.3 Rawl bolts and other fasteners**

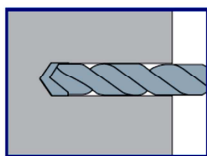
Rawl bolts are used to mount the three legged bracket to the wall. If these bolts fail for whatever reason, the whole antenna and pole will come off the wall and not only will the client lose their internet connection, it could possible damage vehicles, equipment, dogs and kids.

It is important to note that the CPE antennas that you will install could have significant wind loading and will pull rawl bolts out of the wall relatively easily if they are not installed correctly. Below are the specifications required for a proper WiMAX installation.

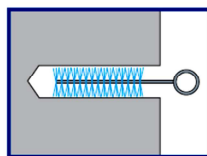


Figure 20. Rawl bolt suitable for mounting brackets to walls

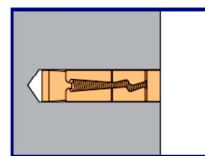
- Always use high quality rawl bolts, preferably well known brands like Rawl and Fisher.
- Use M8 10L rawl bolts
  - The correct size hole for these rawl bolts are 12mm
  - The correct depth of the hole is 55mm
  - Torque the bolt to 7.5Nm



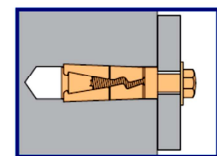
1. Drill a hole of required diameter and depth. Note: When fixing into brickwork, mortar joints should be avoided.



2. Remove debris and thoroughly clean hole with brush and pump.



3. Remove bolt and washer. Insert bolt and place fixture over thread.



4. Replace washer and bolt and tighten to recommended torque.

Figure 21. TIP : When inserting the rawl bolt sleeve into the hole, first screw the bolt in so that the tip protrudes from the sleeve. This will prevent dust from falling onto the thread and seizing up the bolt.

#### 4.1.4 Drilling holes

The single biggest problem with a hole in the wall is that it can't be undone or moved. For this reason it is vitally important that you get it right first time. Below are some tips on drilling proper holes for WiMAX installations.

- Measure/mark off where you intend drilling the holes.
  - When drilling holes for bracket, make sure that you are not pushing the bracket too hard against the wall when marking the positions. Three legged brackets tend to spread open and will cause the pole to be skew.
  - For three legged brackets, make sure the two holes that are on the same level are actually level. Use a spirit level to check this BEFORE drilling any holes. If they are not level, the pole will be skew.

- Check the hole positions AGAIN.
  - Measure twice, drill once.
    - Set the depth on the drill to the correct value.

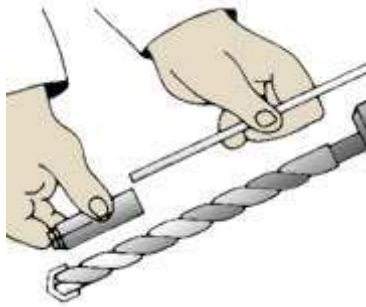


Figure 22. Setting the drill depth

- NEVER DRILL ON GUT FEEL !!!
- Use a proper SDS drilling machine with depth adjustment for the holes. An SDS drill will give you more control and will drill much neater holes much faster than a normal hammer drill.
  - Use the correct size SDS drill bit



Figure 23. SDS drills and drill bits

- When drilling holes through a wall, be careful that the hammer action does not remove large chunks of plaster from the other side of the wall.

## 4.2 Waterproofing

Water ingress into antennas, cables and homes is one of the major problems in the installation industry. It is actually surprisingly hard to keep water from seeping into the minutest of holes and cracks. Although most of the equipment for outdoor use is designed to be weatherproof, a little bit of common sense and awareness will go a long way to keep the water out of your equipment.



### 4.2.1 Waterproofing Connectors

One of the most common entries for water is found where the antenna is connected to the cable. Often this connection will not be inside a weatherproof enclosure and often it is assumed that a connector that is connected to a cable will be waterproof.

There are some type of connectors that are designed to be waterproof to a degree, like the N-type connector, but even so it is still good practice to add an additional layer of protection around the connector. Water can generally slip in either directly between the two matching connectors, or it can seep through the crimped part behind the connector. It is therefore important that the connector be sealed off all the way to the cable itself, covering both connectors.

The correct way to waterproof a connector pair is to use self-amalgamating tape. One such tape that is recommended is 3M Scotch 23 Rubber Tape. **Normal insulation tape is NOT a self-amalgamating tape and should NOT be used to waterproof connectors!**



Figure 24. Scotch 23 self amalgamating tape for waterproofing connectors

#### **Instructions**

For an N-type connection, cut off a piece of tape that is about 15cm long. Start where the two connectors meet up and wind the tape around the connectors. The tape should be stretched to about 3 times its original length while winding it around the connector. Move your way towards the cable making sure that each winding overlaps about half of the previous winding.

Once you've reached the cable, turn around and repeat the process in the other direction until you reach the cable again. Make sure that the cable is covered a distance of about the width of the tape away from the connector.

Finish the process at the same point where you started.



Figure 25. Example of a connector pair sealed with self-amalgamating tape

#### 4.2.2 Running the cable

Water will often flow down a cable quite nicely. It is therefore important to keep this in mind when running the cable from the antenna into the building. Below are a few tips in this regard.

- Always mount an antenna in such a way that the cable leaves from the bottom of the antenna/CPE.
- Where the cable enters a building, make sure the cable makes a half loop BELOW the hole. Water will then drip off the cable instead of running right up against the hole and whatever seal (or shortage there-of) is present at the hole.

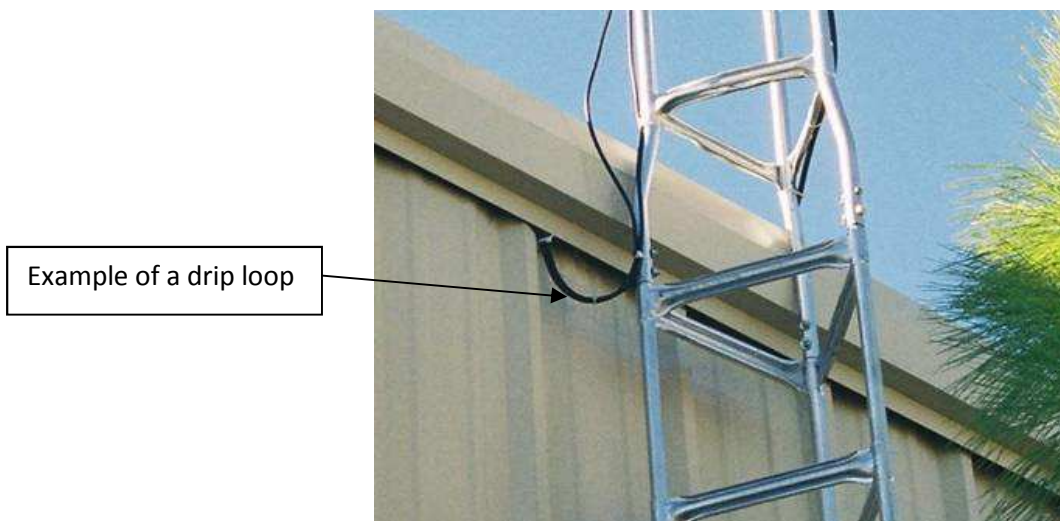


Figure 26. Creating a drip loop before entering the building

#### 4.2.3 Strain relief

Cables should never be allowed to simply hang from an antenna or external CPE. Normally connectors are not designed to take a lot of pulling force and they could easily be damaged if they are pulled hard. Even the weight of a cable hanging on the connector could damage the connector and/or antenna over longer periods.

It is therefore necessary to strain relief any cables that comes out of an antenna or CPE. The preferred way of doing this is to use cable ties and tie the cable down to the mounting mast or

bracket as close to the antenna as possible. Be careful not to pull the cable too tight before tying it to the mast!

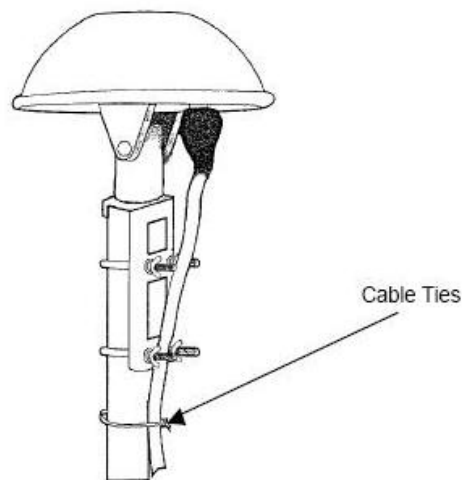


Figure 27. Using a cable tie to strain relief a cable

Also keep in mind that the cable ties that you are using will be standing in the sun for (hopefully) the life time of the antenna. **Only use high quality cable ties!** Many of the cheaper versions will perish within a few months and will simply fall off on its own.

One brand of cable ties that works very well is **Hellerman Tyton**.



**HellermannTyton**

Figure 28. High quality cable ties from Hellerman Tyton

#### 4.2.4 Running the cable neatly

Once the cable leaves the antenna, it needs to run all the way to the CPE device in the building. Remember that the client will often measure the quality of your installation by the neatness of your

work rather than the actual signal strength and CINR. **If a client is going to complain about your work, it will most likely be related to the way the cable was run/installed.**

So to save you the headaches of a complaining client, it is definitely worth getting it right first time. Below are a few tips in this regard.

- NEVER use a glue gun to fix a cable to a wall. Use a nail cable saddle.
- Use the correctly sized nail cable saddles to run the cable along a wall.
  - If you don't have the right size, drive to the nearest hardware shop and buy them. NEVER attempt to use a cable saddle that is too small or too big. A cable saddle that is too small will look ugly and will most likely damage the cable. A cable saddle that is too big will cause the cable to hang loose and will not look neat.



Figure 29. Nail cable saddles used to run cables neatly

- Make sure the cable runs perfectly horizontally or vertically. **Use a spirit level!**
  - The human eye can spot an off-level cable to less than a degree.
- Where ever possible, run the cable along a corner of a wall or roof. This will make the installation look a lot neater.
- When going around corners, make sure that you do not bend the cable more than the specified bend radius.

### 4.3 Obstructions

In the previous chapters we referred to the Fresnel zone and the impact on long distance links. In this section we are going to look in more detail on how to handle obstructions, especially close to the antenna, in more detail.

It is important to remember that objects close to the antenna will also affect the performance of the antenna, even if it is not directly in the path of the antenna.

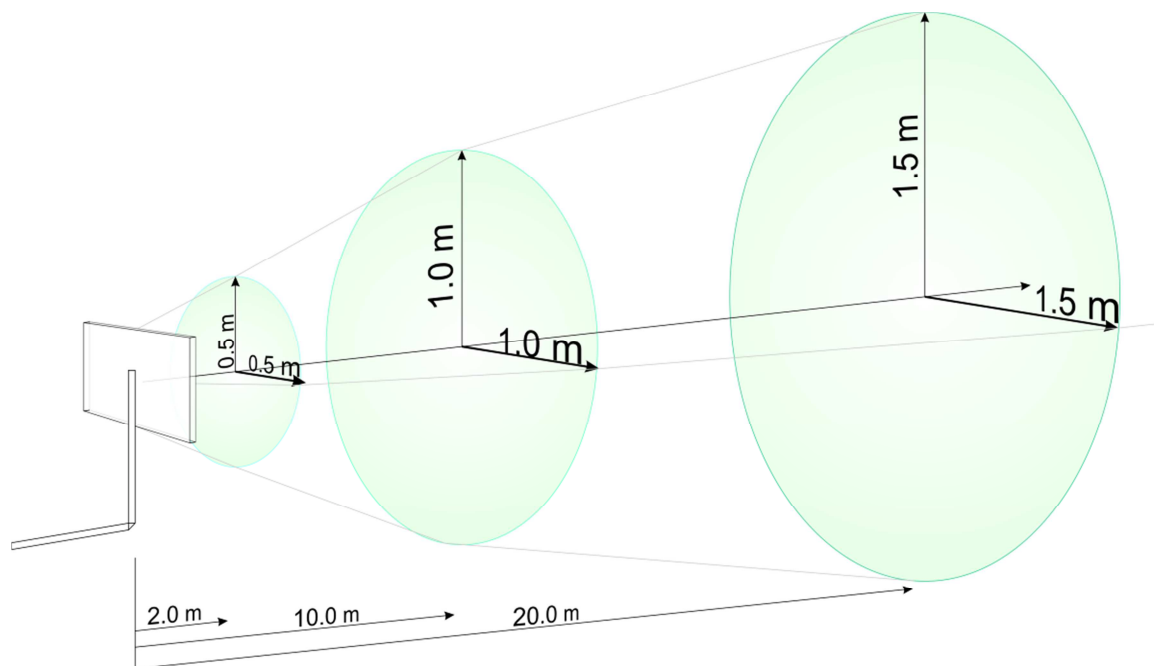


Figure 30. Clearance required close to the antenna

This image shows the area in front of the antenna that needs to be clear for the antenna to work properly.

### 4.3.1 Walls and roofs

Close to the antenna, one needs to make sure that the beam of the antenna will clear the roof and walls of the building, especially if the antenna is pointed parallel to the wall. Below are some examples of good and bad installations in terms of nearby obstructions.

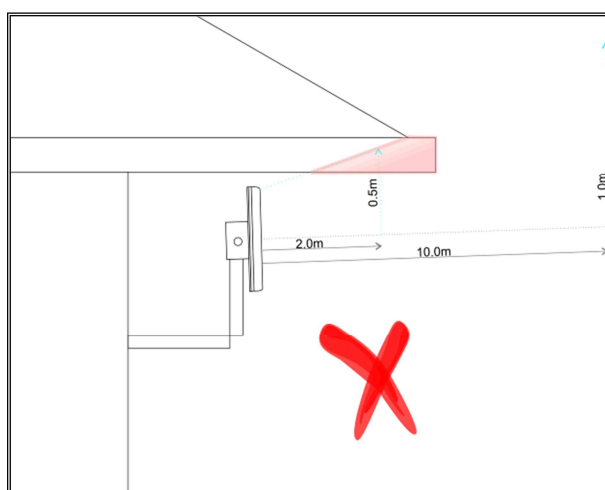


Figure 31. Roof interferes with the Fresnel zone of the antenna

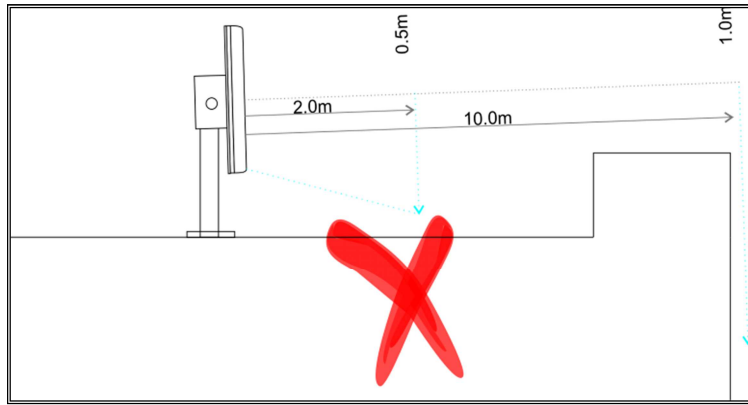
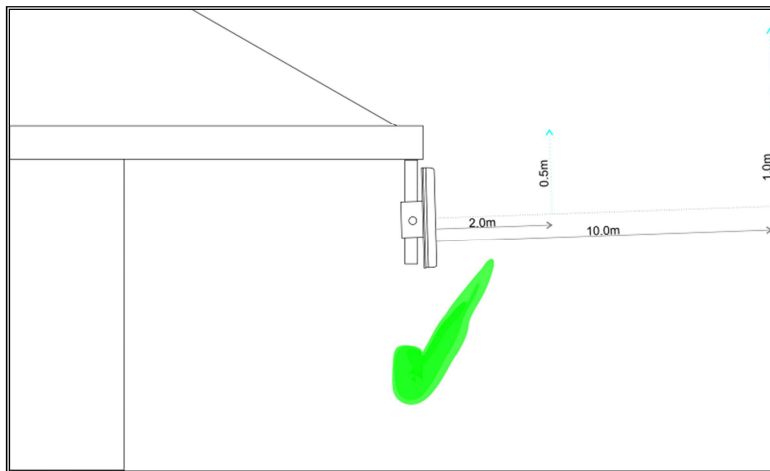
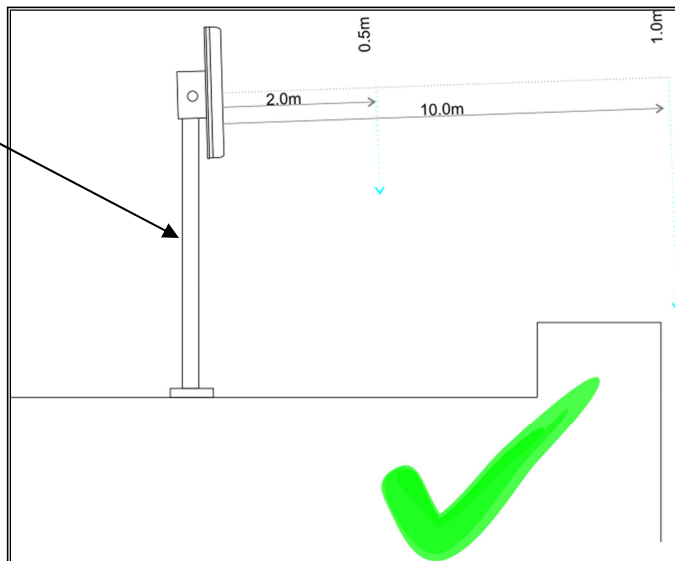


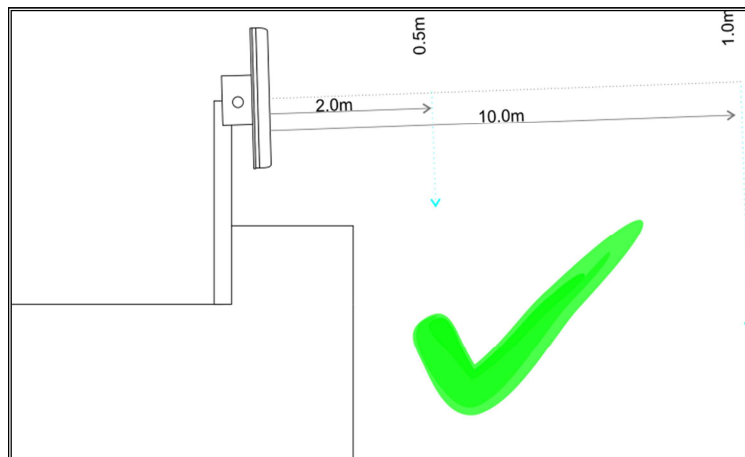
Figure 32. Wall interferes with the Fresnel zone of the antenna

In these two examples, the wall and the roof interfere with the Fresnel zone of the antenna and will thus block a part of the signal.



Be careful!!!  
Mounting pole  
could be too long.





The last three examples show you some alternatives to the first two bad cases. Just be aware that the mounting pole could be too long in some cases, in which case you will have to find an alternative mounting position.

#### 4.3.2 Trees

The other major obstruction that is usually close to the installation site is trees and other vegetation. It is not advisable to try and go straight through a tree of any sorts, even if you are able to get a strong enough signal during your sight survey. Trees have a nasty habit of growing and changing over time and seasons, so you have no guarantee that your link will still be working in 6 months' time.

If it is not possible to get clear line of sight to the required base station due to tree cover, the installation should be stopped and the situation referred to the Regional Radio Team.

### 4.4 Aligning the antenna

It might sound relatively obvious, but it is important to aim the antenna in the direction of the base station. This is one of the factors that are often not done properly and can have a huge influence on the quality of the installation.

#### 4.4.1 Beamwidth in practice

We already covered radiation patterns and beamwidth in the earlier sections. In this section we are going to look at the implications in real life installations.

The 20dBi flat panel antenna has a beam width of 20 degrees. This may sound like a lot, but keep in mind that this is the -3dB beam width. Normally we will try and get much closer to the maximum value than 3dB, typically we should be within 1dB of the maximum which means that the beam that we are working with is actually much narrower.

To put this in real terms, imagine looking through a 35mm pipe (roughly the diameter of the inside of a toilet roll) that is 100mm long. This is about a 20 degree beamwidth. If we narrow this down to 10 degrees, the pipe would be double the length. This will give you an idea of the accuracy that is required for this antenna.

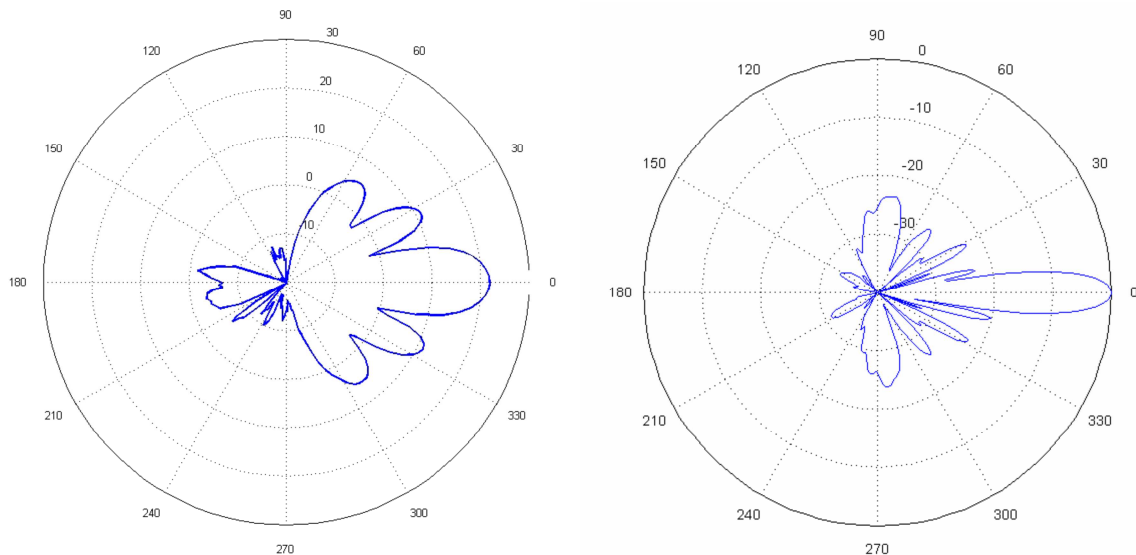


Figure 33. Azimuth radiation patterns of the 20dBi panel (left) and the 24dBi grid (right) .

If we are using a grid antenna, the problem is much worse due to the higher gain. For the grid antenna with 24dBi gain, the -3dB beamwidth is about 8 degrees (looking down a 200mm pipe) or only 4 degrees (400mm pipe) if we would like to be within 1dB.

#### 4.4.2 Aligning the antenna

Here are some tips for aligning antennas properly.

- Aim the antenna roughly in the right direction and hand tighten the bracket.
- You should be able to pick up a signal on the WiMAX device and get an indication of the RSSI (signal strength).
- Start by adjusting the antenna left and right. Move the antenna in very small increments, leaving it to settle in position before checking the RSSI each time.
  - Touching the antenna might influence the signal, so it is important that you are not holding the antenna during the alignment process.
- Once the azimuth is maximised, tighten the brackets so that the antenna will stay in its elevation position by itself, but you can still move it by hand.
- Repeat the aligning process in the elevation (up-down) direction, again using small steps and removing your hands from the antenna before checking the RSSI.



- Once you found the maximum elevation point, tighten the brackets properly.
- Check the RSSI in the final position. If it is off the maximum by more than a dB, loosen the antenna and repeat the process.

## 5 Etiquette

*“Etiquette means behaving yourself a little better than is absolutely essential.”*

*- Will Cuppy*

Any installation has two major parts to it. The first is the technical aspect and this we have covered in detail over the previous chapters. The second part is dealing with the client.

Dealing with the client is every bit as important as doing a proper technical installation, if not more. Unfortunately people can often be very difficult for absolutely no reason at all and the key to a successful installation is to not give them a reason to be difficult to begin with.

### 5.1 First impressions

Your client will decide within the first 15 seconds of meeting you whether they like you or not. This first 15 seconds will most likely determine how the client treats you, what they think of your capabilities as an installer and what they think their internet connection is going to be like.

It seems pretty unfair, but unfortunately this is a fact of life. The good news is that you can most likely win over your client’s trust by making sure that the first fifteen second is as positive as it can be for your client.

#### 5.1.1 Calling the client to arrange access

This call will probably be the first contact with your client and will make up a big part of their first impressions. Below are some tips to create a good impression.

- Speak slowly and clearly
- Be friendly
- Always treat your client like the most important person you know
- Introduce yourself and your company
- Politely tell the person why you are calling
- Ask the person if it would be possible to arrange access for the installation team (as compared to telling him that you need to do an installation)
- Ask the person when it would suit them.

#### 5.1.2 Arriving at the gate

When showing up at the client’s gate, keep in mind that this will be the first time they meet you face to face. This meeting will also form a major part of the client’s impression of your team and their capabilities.

- Dress neatly and make sure your clothes are clean. Keep a clean shirt in your vehicle if you are going to visit multiple clients.
  - Rather change to your work clothes after you met your client for the first time.
- Don't immediately start unpacking all your gear. Wait until you met the person first.
  - Standing at someone's gate with a ladder over your shoulder, toolbox in one hand and a cigarette in the mouth certainly does not create the impression of a very professional installer.
  - A clipboard, pen and a friendly smile will get you a lot further.
- Introduce yourself in a friendly manner.
  - Remember that people are generally very wary of people standing at their gates. The client is more likely to expect a criminal or salesperson at their gate than an installer. A friendly introduction will help set their minds at ease.

## 5.2 During the installation

- Before you start drilling holes and climbing around on their roof, give your client an overview of what you intend doing.
  - Show the client where you intend mounting the antenna, drilling through the wall, placing the internal CPE (if any), etc.
- If the client approaches you with a question or comment, give them your full attention. Stop whatever you are doing, get off the ladder and listen to what they are saying to you.
- Always be friendly towards the client.

## 5.3 After the installation

- Clean up after yourself. Use your vacuum cleaner to clean up any dust that you might have created during your installation (when drilling for example).
- Take the client through an explanation of what you did and how it all works. Show them that it works.
- After packing away all your gear, just inform the client that you are on your way. Thank the client for his hospitality (whether they deserve it or not).

# Appendix

## 1 Troubleshooting Guide

It is always useful to carry an extra set of everything along when doing installations. Certain components can get damaged very easily and it is a big waste of time having to drive back to your office to fetch a new antenna (for example) because the one you had fell off the roof and is now destroyed.

### 1.1 Low signal strength (RSSI)

If you have completed the installation and you find that the signal strength is significantly less than you expected, it will most likely be one of the following problems. **The assumption is that you did a sanity check BEFORE you started the installation and that you are comparing the measurements to those you took earlier on the same day!**

- Faulty or misaligned antenna
- Faulty cable
  - Damaged cable
  - Damaged connector
- Faulty CPE

Start the troubleshooting processes by replacing one item at a time until the faulty part is found.

1. Replace the CPE with another unit. Compare the signal strength.
2. Try and readjust the antenna next.
  - a. If the signal strength does not improve by re-aligning, replace the antenna with another unit and re-align.
3. Replace the cable between the CPE and the antenna.
  - a. Do not rip the cable out of the mountings just yet, run your new cable temporarily in a window. Connect up the temporary cable and compare the signal strength.

**If none of these seem to solve the problem, then it is most likely as good as it is going to get. If the signal is not good enough for the required level of service, contact the Regional Radio Team. DO NOT REMOVE THE EQUIPMENT IF IT HAS ALREADY BEEN PROPERLY INSTALLED!**

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