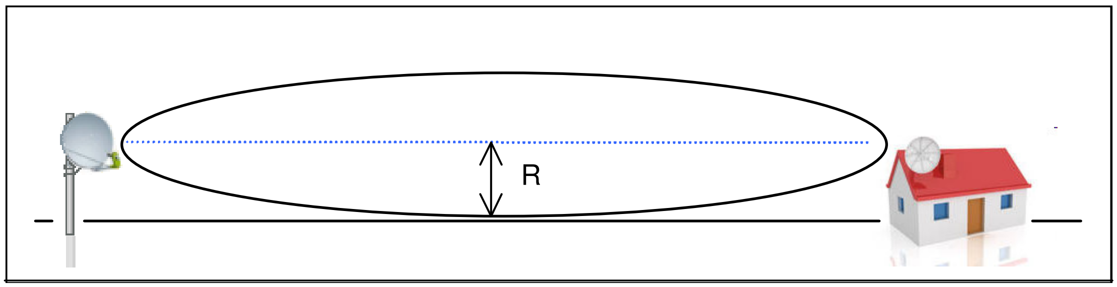
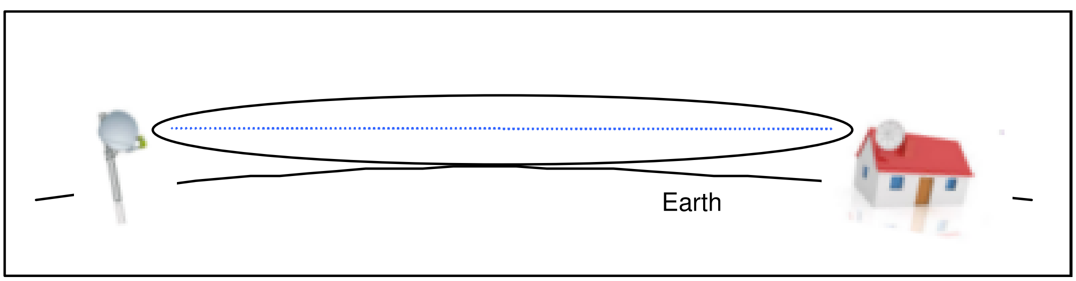
Explanation of Line-of-Sight

The term 'line-of-sight' is very often used incorrectly or is misinterpreted. When an RF link is installed, it is essential that there is a clear path between the transmitting antenna and the receiving antenna to obtain the maximum signal strength. This path however, is not just a simple straight line, like tying a piece of string from one to the other. The transmitted radio signal spreads out forming an ellipse shape, which is widest at the mid distance. This area within this ellipse is known as the Fresnel zone, and for maximum received signal, this zone must be clear and unobstructed.
Any buildings or trees that protrude into the zone, will reduce the received signal strength. Remember also that this zone is three dimensional so buildings or obstructions to the side may also affect the signal.



For long distance links of a few kilometres or more, the curvature of the earth must also be taken into consideration. Because of the earths radius, the receiving antenna will appear to be below the horizon. As an example, at a distance of about 20Km, the transmitting antenna would need to be raised by 6 metres to clear the horizon. The following diagram shows a typical site, illustrating both the Fresnel zone and earths curvature (exaggerated to show the effect).



Calculating the Fresnel zone and effect of the earth's radius

The formula for calculating the Fresnel zone is as follows:

$$R = 17.32\sqrt{\frac{D}{4f}}$$

Where R is the radius of the Fresnel zone in metres
D is the link distance in kilometres
f is the frequency of transmission in GHz

The formula for calculating the effect of the earth's radius is as follows:

$$H = \frac{D^2}{8 \times Er} \times 1000$$

Where H is the height in metres required to allow for the earth's curvature
D is the link distance in Km
Er is the effective radius of the earth. This is usually taken as 4/3 of the actual radius to allow for atmospheric refraction i.e. 8,504Km

The following table shows Fresnel zone radius and earth's curvature for a range of distances and frequencies.

		450MHz		1394 MHz		5.8 GHz	
Link Distance	**Curvature Allowance**	**Fresnel Radius**	**Antenna Height**	**Fresnel Radius**	**Antenna Height**	**Fresnel Radius**	**Antenna Height**
km	mtrs	mtrs	mtrs	mtrs	mtrs	mtrs	mtrs
1		12.9	**12.9**	7.3	**7.3**	4.0	**4.0**
2		18.2	**18.2**	10.3	**10.3**	5.2	**5.2**
3	0.2	22.3	**22.5**	12.6	**12.8**	6.4	**6.6**
5	0.4	28.8	**29.2**	16.3	**16.7**	8.2	**8.6**
10	1.5	40.8	**42.3**	23.1	**24.6**	11.7	**13.2**
15	4.0	50.0	**54.0**	28.3	**32.3**	14.3	**18.3**
20	6.0	57.7	**63.7**	32.7	**38.7**	16.5	**22.5**
25	10.0	64.5	**74.5**	36.5	**46.5**	18.4	**28.4**
30	13.0	70.7	**83.7**	40.0	**53.0**	20.2	**33.2**
35	18.0	76.3	**94.3**	43.3	**61.3**	21.8	**39.8**
40	24.0	81.6	**105.6**	46.2	**70.2**	23.3	**47.3**

Note that the antenna height means the height of both the transmit and the receive antenna i.e. for a link distance of 20Km both the transmit and receive antennas must be 22.5mtrs above ground level (at 5.8GHz). The two antennas do not have to be at the same height. As a rough guide, if the transmit antenna is at 16mtrs the receive antenna should be at about 29mtrs giving a total height of 45mtrs.

Calculating transmission range

If the two antennas are in 'free space', for example miles up in the air away from the ground or any obstructions, a theoretical distance can be calculated based on signal strength, antenna gain and receiver sensitivity. For our equipment, fitted with 20dB antennas, this theoretical distance is about 68Km. Although some suppliers may quote these theoretical distances as the range of their equipment, they are almost impossible to achieve in practice. There are a number of factors that will reduce the maximum useable distance.

Firstly, and most importantly, there must be clear line-of-sight as described above. Use the table above to obtain the correct antenna height for the link distance, but remember that this height is not just ground clearance, it must clear any obstruction, buildings, trees etc. Any obstructions within the Fresnel zone will reduce signal strength considerably.

There are also several other factors such as reflections from the ground or buildings, absorption and the effect of different weather conditions. Reflected signals from the ground or nearby buildings will also arrive at the receiver, but may be out of phase with the direct signal, causing interference and loss of signal strength. The ground and foliage can absorb radio signals and this effect may vary depending on weather conditions, when wet for example.

Because of all these variable factors, it is difficult to forecast with any accuracy the range that can be achieved on any given site. We tend to make an allowance, called a 'fade margin' to cover this variability. You must also remember that the achievable link distance depends on the bandwidth required. If you are transmitting one single camera or small amounts of data over the link, then this will work well with a fairly low signal strength. If you are transmitting more data, such as 3 or 4 cameras, then you will require a much higher signal strength to obtain the bandwidth.

Example field trials.

The following examples are from tests carried out in the field.

30Km link (The Naze to Orford)

We decided to carry out a test mainly over water so that we could guarantee a fairly clear line-of-sight. We chose the east coast since it is near our office.
The equipment used was a pair of 5GHz units, the VTX4056A transmitter and VRX4056A receiver. Each unit has an integral 20dB antenna.

One engineer set up the transmitter on a 2metre high tripod, at the Naze (grid ref: 51^0 51' 54.6N – 1^0 17' 18.56E) in a location about 20 metres above sea level.
The receiver was set up in Orford (grid ref: 54^0 05' 44.07N – 1^0 31' 33.26E) about 30 metres above sea level.

From our table, we should have been 33 metres high at each end, so our Fresnel zone was not completely clearing the ground. It was reasonably clear to the sides, although passing quite close to the tall cranes at Felixstowe about one third distance from the Naze.

We obtained excellent results with a very strong signal strength (about –58dBm)

5Km link (Cambridgeshire Fens)

For this test we travelled to the Old Bedford river, near Welney. This offers a long stretch of absolutely straight river bank with very few obstructions.

The equipment used was a VTX4056E transmitter and VRX4056E receiver. These units have separate antennas, so we could test various antenna combinations.

The transmitter was set up on the river bank, mounted on a 2 metre high tripod. The receiver was set up on a similar tripod at various positions along the bank.

Because we were only 2 metres high at each end, we knew the range would be limited, because we were not clearing the Fresnel zone and there would also be considerable reflections from the ground (and water).

With 20dB antennas on both ends, we obtained a good signal at 5.5Km (at this point we reached a large bridge over the river). The signal strength was measured at –68dBm.
We continued down river to a point at 7.5Km, although now the bridge (a metal road bridge) was in the way, causing some obstruction. We still obtained a reasonable signal at –76 dBm. This is probably just below the lower limit of an acceptable signal, but could obviously have been improved considerably by raising the antennas.

Reservoir near Liverpool.

A customer fitted a VTX4056E transmitter and VRX4056E receiver with a pair of 20dB antennas. The site was a reservoir and the objective was to transmit one PTZ camera over the reservoir, a distance of about 700 metres.

It was thought from their description, and from looking at Google Earth, that there was fairly clear line-of-sight. In fact, after installation there were problems, with the signal being unreliable and sometimes dropping out. It appeared worse in bad weather, when it was wet.

On investigation, we discovered that the receiving building was in a dip and there was no line-of-sight to the transmitter. In the way was a 12 foot high metal fence and fairly large dense trees. In dry weather the signal just about penetrated the trees, but at a fairly low signal strength. The wet trees were enough to block the signal. To solve the problem, the antennas were mounted on a pole to increase the height above the tree line.