TIL-TEK

Application Note No. 13

Calculating Required Elevation Beamwidth

General

When using omnidirectional or sectoral antennas, one of the first steps in selecting an antenna is the determination of an adequate elevation beamwidth to serve all remote sites. The purpose of this application note is to provide a method to calculate the required elevation beamwidths of omnidirectional or sectoral antennas at base station sites. From the information calculated, an antenna with optimum performance for the specific application can be selected more effectively.

Note: ***Calculations and examples below do not account for equivalent earth radius or fresnel zone clearance as these are discussed in a separate application note entitled "Calculating Radio Path Clearance". To note also is that for paths of 10 km or less, the effect caused by the equivalent earth radius only adds a maximum of 1.5m additional height requirement and considered insignificant.***

In order to calculate the required elevation beamwidth, the following information is required :

1: The elevation ***Above Mean Sea Level*** (AMSL) of both sites.
2: Selected antenna height ***Above Ground Level*** (AGL) of both sites.
3: Distance between the sites.

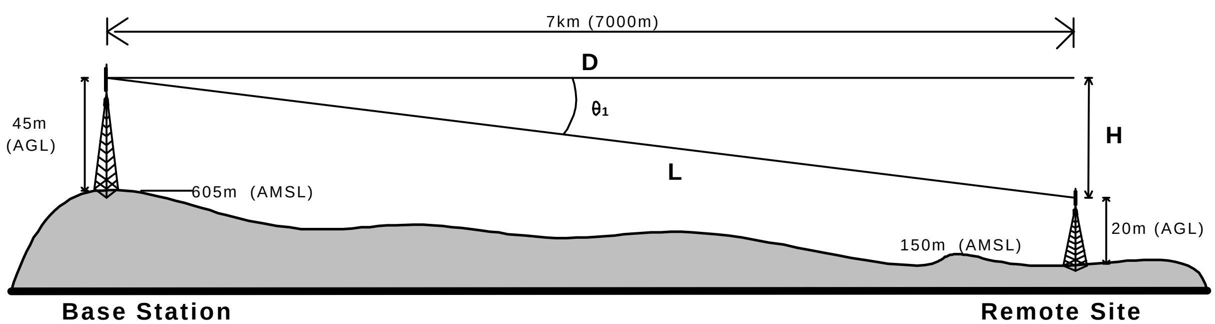

Figure 1

Theory

As can be seen from Figure 1, the line depicting the horizontal, the line between both antennas and the line from the horizontal line to the remote antenna form a right angle triangle where;

D	=	The horizontal distance between the two sites.
L	=	The line between the two sites.
H	=	Distance between the two antenna heights
Angle "$\mathbf{2}_1$"	=	The coverage angle below horizontal

Since the above does form a right angle triangle, the following relationships apply;

$$\tan \mathbf{2}_1 = (H \div D)$$

$$\mathbf{2}_1 = \tan^{-1} (H \div D)$$

Example 1

Based on data supplied in Figure 1, calculate the required elevation beamwidth of the Base Station antenna.

The difference between the two antenna heights which form the **"H"** side of the triangle is;

$$(605m + 45m) - (150m + 20m) = \mathbf{480m}$$

The angle $\mathbf{2}_1$, below the horizontal is therefore calculated as;

$$2_1 = \tan^{-1} (480 \div 7000m) = \mathbf{3.92^o}$$

Based on the above calculations, the antenna selected for the base station site must have adequate elevation beamwidth to cover a minimum of ~4º "below horizontal".

Note: ***"Below horizontal". This can be misleading since the base station antenna's elevation beamwidth's centre is normally aligned to horizontal and if so, an antenna with an elevation beamwidth of $\geq$8º will be required.***

Based on the above, the selection of possible antennas would be either standard antennas with 8º of elevation beamwidth or antennas with a combination of electrical and / or mechanical down-tilt to provide coverage of 4º below horizontal.

Example 2

Based on data supplied in Figure 2, calculate the required elevation beamwidth of the Base Station antenna which will provide coverage to both remote sites.

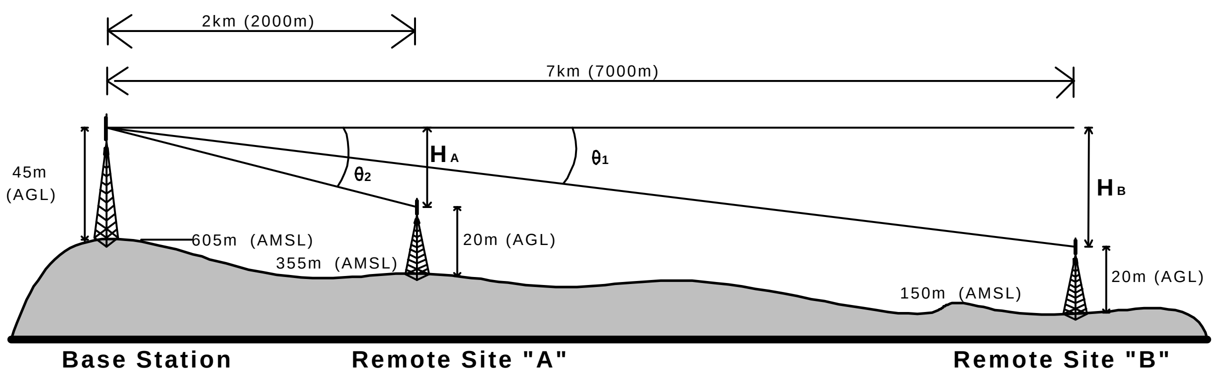

Figure 2

From the data supplied in Figure 2, one approach is to align the centre of the elevation beamwidth to horizontal and simply calculate the elevation beamwidth requirements for closest site (Remote Site "A").This would yield the same results as in Example 1.

The above method is often utilized but is not the optimum as it does not align the antenna's maximum gain point directly at the far site where it is more than likely required. The optimum method is to select an antenna which will centre it's elevation beamwidth at the far site and also provide adequate elevation beamwidth to cover nearby remote sites.

Example 2 (cont'd)

By selecting an antenna as above, optimum performance in gain will be provided and at the same time the possibility of causing interference with existing and / or future adjacent systems will be minimized. To do the above, both angles below horizontal must be calculated and the antenna(s) selected accordingly. The procedure is as follows:

1: Calculate the angle below horizontal of the farthest site "2_1"

The difference in height between the antenna at the base station and the antenna at remote site (H_B) is;

$$(605m + 45m) - (150m + 20m) = \mathbf{480m}$$

The angle 2_1, below horizontal is;

$$2_1 = \tan^{-1}(480 \div 7000m) = \mathbf{3.92^o} \quad \textbf{or} \quad \mathbf{\sim 4^o}$$

2: Calculate the angle below horizontal of the nearest site "2_2"

The difference in height between the antenna at the base station and the antenna at remote site (H_A) is;

$$(605m + 45m) - (355m + 20m) = \mathbf{275m}$$

The angle 2_2, below horizontal is;

$$2_2 = \tan^{-1}(275 \div 2000m) = \mathbf{7.82^o} \quad \textbf{or} \quad \mathbf{\sim 8^o}$$

3: Select an appropriate antenna

Based on the results above, an antenna with an elevation beamwidth of +/-4º (or 8º), aligned 4º below horizontal, as illustrated in Figure 3, would provide optimum coverage. This can be realized using either;

a) An omnidirectional antenna with an elevation beamwidth of 8º and 4º of electrical down-tilt.

b) In the case of a sectoral antenna site where the azimuth beamwidth is not exceedingly wide ($\leq$90º), a sectoral antenna with an elevation beamwidth of 8º, mechanically tilted down 4º.

c) In the case of a sectoral antenna site with a wide azimuth beamwidth, ($\geq$90º), a sectoral antenna with an elevation beamwidth of 8º and 4º electrical down-tilt. 4º.

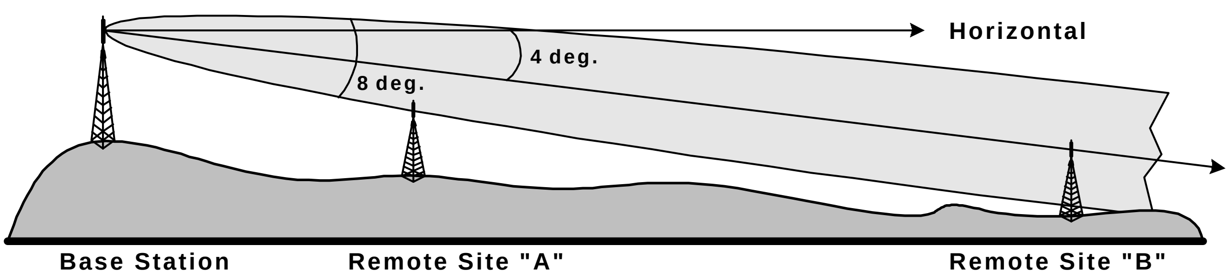

Figure 3