EMClarity White Paper

BASIC PATH CONSIDERATIONS FOR A MICROWAVE LINK

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1.0 Summary

There are a number of factors to be checked when considering a possible path for a microwave link. Ideally, a microwave link would operate between two points without passing through any material substances, including the atmosphere and rain, and without any objects being anywhere near the path of propagation. Such a link is closely approximated by a typical link between an earth station and a geostationary satellite where the only intervening material is about 12km of atmosphere in the 36,000km between the earth station and the satellite. The closer the satellite link line of propagation is to vertical through the atmosphere, the smaller the atmospheric effects on the signal propagation.

A terrestrial microwave link usually has a propagation path approximately horizontally through the atmosphere and this adds a number of complications to the analysis of the path. It is not the intention of this note to go into these issues in great detail but rather to outline the basic points for a good understanding of how terrestrial microwave links work and what to be aware of when considering a microwave link installation.

2.0 Noise and Interference

There are two main sources of noise that can limit the performance of microwave links. The first is the noise due to natural sources and this is a significant difference between a terrestrial link and a satellite link. A satellite terminal basically looks into deep space where the effective noise from all sources is quite small in the microwave frequency range. Typically, most of the natural noise for a satellite terminal comes from the noise from the temperature of the earth that is picked up in the earth station antenna sidelobes.

A terrestrial microwave antenna typically looks along the horizontal and so will pick up nearly all the noise emitted by the earth in the microwave band. This gives a terrestrial microwave antenna an effective noise temperature of about 300K so there is little point in using expensive low noise receivers with microwave links.

Noise originating from man made sources is usually referred to as interference. This is a significant issue with links that operate in the class license band where there are only very basic constraints on the emitted power levels of the transmitters. This issue will not be dealt with further in this note.

For links in the licensed bands, the regulations are nominally set up to avoid direct, high signal level interference from other links operating in the same or adjacent bands. Furthermore, the general noise level from other microwave links and sources such as radar and satellite communications is controlled such that the in band noise from all such sources should not materially affect the performance of the link.

Interference that is out of the band will be removed by the sharp front end filtering in EM Clarity links. The planning should ensure that signals in the same channel or in the immediate adjacent channels are sufficiently small to be negligible.

It is not only microwave signals that can cause interference. High level signals at lower frequencies may leak in at various sites but in most cases this can be prevented by proper

installation techniques such as fully shielded cables, low impedance earths, use of shielded rooms where the internal equipment is housed and well regulated and filtered power supplies. [SEE EMCLARITY NOTE XYZ for more information on interference, its causes, identification and resolution]

3.0 Path Analysis

The first basic requirement for a microwave link is that there is a clear line of sight(optical) between the two paths. If the antenna at one end cannot be seen from the other end, either by eye or with binoculars, then it is very unlikely that the link will performance satisfactorily.

The next requirement is that no objects such as hills, buildings and trees are within a certain radius of the nominal line of sight. This radius is referred to as the Fresnel zone and is dependent on the frequency and the distance between the two antennas since it is determined where the path length from each antenna to the object is one half wavelength longer than the direct path length between the antennas.

The Fresnel radius is a maximum at the midpoint and gradually decreases towards each antenna. The radius in metres is given by:

$$R = 17.3(D_1D_2/(Fx(D_1+D_2))^{1/2} \qquad (1)$$

Where R is in m

D_1 and D_2 are in km and are the distance to the obstacle from each antenna

F is in GHz.

Close to either antenna, the formula can be approximated by

$$R = 17.3(D_1/F)^{1/2} \qquad (2)$$

And at the middle the maximum value of R is given by

$$R = 8.67(D/F)^{1/2} \qquad (3)$$

Where $D = D_1 + D_2$ is the total distance between the antennas.

The above formula is suitable for high gain, narrow beamwidth antennas with a gain greater than 25dB or so.

Example: Consider a 20km path where a building about 3km from one end is seen to be reasonably close to the line of sight between the antennas. Assume that the link frequency is 8.2GHz.

Equation (2) gives the Fresnel zone radius as 9.6m which would be about the minimum radial spacing between the building and the line of sight.

At the 10km point the Fresnel radius is 13.5m whereas say 100m from the antenna, the radius is 1.9m.

The effect of the obstacle close to or within the Fresnel zone depends on the type of object and how close it is to the line of sight. Smooth objects such as grassy hills or a building roof can have a much more significant effect than angular obstacles such as the corner of a building or dispersed obstacles such as trees.

It may be necessary to use precision optical measurements and/or Google Earth to determine how

still perform quite well when this is included in the planning. If all obstacles are well clear of the Fresnel zone then the next step is to consider atmospheric and earth curvature effects.

4.0 Atmospheric and Earth Curvature Effects

Microwaves signals are not significantly affected by fog, dust and pollution levels. Rainfall has little effect on frequencies below about 8GHz but the attenuation caused by rain increases quite quickly and the frequency and rain fall rate increase. Rainfall is then a major factor for paths longer than 10km and for frequencies higher than 10GHz or for short paths(5km or so) at 18GHz and higher.

For path lengths longer than about 10km the curvature of the earth and the effect of the atmosphere on the propagation direction have to be taken into account. The microwave signal typically travels horizontally through the atmosphere and the dielectric properties of the atmosphere may change with height. This can cause the microwave beam to bend up or down and so to change the effective curvature of the earth. This may effectively move objects below the propagation path into the Fresnel zone or in some cases right into the path which can cause large increases in the path attenuation.

The science of atmospheric propagation has been studied for many years and the engineering of links to compensate for such path effects have been codified so that standard statistical based analyses are available to estimate the probability that the link will fail due to the atmospheric and rain effects.

For path distances greater than about 10km or where there are any obstacles close to or within the Fresnel zone, EM Clarity can provide a complete path analysis.

5.0 Difficult Paths

“Difficult” paths are those where large reflections may occur mainly due to smooth flat surfaces that intercept a significant proportion of the energy propagating between the two antennas. Such paths typically occur where there are longer distances of 40km or more and flat surfaces such as lakes, flat bare ground or the sea along some or all of the path. The path is then subject to multipath fading which may vary greatly with the time of day as the atmospheric variations move the reflections in an out of phase with the main signal.

Such effects can also happen over much shorter paths where one or both antennas may be relatively close to a reflecting surface such as the roof of a building or only several metres above the sea level.

There are a number of ways to improve the link availability of such paths by proper positioning and alignment of the antennas, adding antenna nulling along the direction of the reflected signal, increasing the transmit power levels, adding redundancy by using extra frequencies or extra antennas or some combination of the above.

EM Clarity can assist with deciding on the optimum configuration for any such path subject to cost and availability constraints.