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Microwave 101

The following is meant to be a simple guide or check list to be reviewed before the creation of a new microwave radio design.

Microwave Radio Problems, Issues, and Concerns

1. Fading and Signal Loss Issues

- Free Space Loss

A free space path is one on which there are no physical obstructions and so the path loss can be calculated precisely. At microwave frequencies the path losses associated with these paths are large, even when little or no obstructions are present. They are however, the paths with the minimum losses.

- Refractive Loss

As microwave paths nearly always involve passages through the lower troposphere, they are usually affected by the air and precipitation that also exist in this region. How much they are affected depends on the atmospheric pressure, humidity and temperature. The effect of these variations is that radio waves are bent or 'refracted' along the curvature of the earth's surface. How much they are bent depends on a number of factors but it is possible under certain conditions for them to be refracted over 1000's of kilometres.

- Multipath and Reflections

Multipathing exists where an out-of-phase signal arrives at the receiving antenna along with the main signal, attenuating the received signal strength. Multipathing can arise due to reflection off the ground, especially a problem over water or desert conditions. Multipathing can also arise due to the refractivity gradients in the atmosphere.

1. Water
2. Flat Terrain
3. Man-made (Buildings)

- Thermal Ducting (Temperature Inversion)



Warm airflows over coldwater bodies can give the effect of anomalous ducting, which causes strange effects to microwave radios operating in the 10-11 GHz regions. In the summer, when there are protracted periods of still air over the cold, water surfaces, ducts can extend for 100's of kilometres.

Evaporation ducting can also occur in similar circumstances. When winds are light and the weather is hot, the sun can cause intense evaporation ducting up to a depth of a few metres. The passage of weather fronts can also lead to short term enhancements but this medium is very uncertain and still being investigated.

- Layering

The atmosphere can refract radio waves. This can result in ways in which they can be very helpful in extending our normal radio coverage and give us 'lift' conditions.

Certain types of air within high-pressure weather systems can become layered with a distinct layer of warm over cold air or vice-versa, cold over warm air. These distinct layers produce areas of high refractivity which act like air-borne waveguides, directing radio waves over 100's to 1000 Km's. These can give rise to periods of extended lift conditions lasting for days.

1. Linear Stratification
2. Non-Linear Stratification

- Rain Fade

1. Rain

Rain fade is a consequence of the fact that microwave signals are absorbed by moisture in the atmosphere. For frequencies below 10GHz, rain fade is not a significant problem. From 10GHz up, the rainfall has an increasingly negative impact on a microwave path as the frequency increases.

2. Mist and Fog

- Mechanical Error (Alignment)

1. Azimuth

Misalignment or mechanical instability on the east-west (left-right) axis of the antenna often caused by improper installation, poor fittings, or the effects of wind.

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2. Elevation

Misalignment or mechanical instability on the north-south (up-down) axis of the antenna often caused by improper installation, poor fittings, or the effects of wind.

3. Polarization

Misalignment or mechanical instability on the rotational axis of the antenna's feed assembly often caused by improper installation or loose fittings. Only applicable for linear polarized signals (vertical and horizontal polarization) and not applicable for circularly (clock-wise and counter clock-wise) polarization signals.

2. Physical Obstructions (Line-of-Sight)

A Line Of Sight (LOS) path is one in which the receiving and transmitting stations antennas are arranged so that there are no obvious physical obstructions between them. The term line of sight does not mean that each station can optically see each other, in fact it is quite possible for the stations to be so remotely located that they cannot see each other. It is worth remembering that LOS paths at microwave frequencies are often beyond optical path lengths. The one problem for LOS paths is that the atmosphere often intrudes in to its operating capabilities. Precipitation in the lower atmosphere is our biggest hurdle. There are occasions when weather effects in the troposphere can actually improve and enhance conditions and increase coverage way beyond LOS ranges

- Terrain
- Curvature of the Earth
- Man-made
- Trees and Foliage
- Site Coordinates
- Fresnel Zone

The area around the visual line-of-sight that radio waves spread out into after they leave the antenna. This area must be clear or else the signal strength will weaken or lost. The Fresnel zones are a series of concentric ellipsoids surrounding the radio path. The *First* Fresnel zone is the surface containing every point for which the sum of the distances from that point to the two ends of the path is exactly 1/2 wavelength longer than the direct end-to-end path.

3. Terrestrial Interference (TI)

The local regulator usually controls interference. Frequency allocation is given when the location of both ends of the link is known and the frequency band has been selected. Then,

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the regulator should assign a channel, which will not cause interference to other microwave radios in the vicinity. For a project requiring many hops, the customer will reuse channels and interference between hops must be considered.

- In-band
 - Out-of-Band
4. Modulation Issues
- Modulation
 - a. Analog
 - b. Digital
 - i. QPSK
 - ii. QAM
 - iii. FSK
 - iv. Spread Spectrum
 - v. COFDM
 - Forward Error Correction
 - Bit Error Rate
5. Interconnection and Signalling Issues
6. Standards and Best Practices
7. EMI / RFI and Safety Code 6



How to make a Microwave Path more Robust

The following list can be considered as insight into some of the planning processes required for microwave radio systems. There will obviously be variations due to specific operating conditions and objectives of different operators, and therefore this should not be considered a definitive list. Also, planning is an iterative process, and the following list does not necessarily follow sequentially in every case.

Produce preliminary network design.

- Determine local frequency availability and regulations relating to frequency management and microwave path availabilities,
- Select sites,
- Establish line-of-sight,
- Calculate path prediction with a software tool,
- Overlay the path on a topographical map.

1. Redundancy (Protected versus Non-Protected Radios)

Microwave terminals are available in non-protected and protected configurations. A protected terminal provides full duplication of all active elements, i.e. both the RF transceiver and the base band components.

2. Path Diversity (Route)

3. Antenna Diversity (Space)

Space diversity requires use of additional antennas, which must be separated vertically in line with engineering calculations.

4. Polarization Diversity

Frequency diversity can be achieved with one antenna per terminal configured with a dual-pole feed

5. Frequency Diversity

Frequency diversity can be achieved with one antenna per terminal configured with a dual-pole feed. Frequency diversity has the disadvantage of requiring two frequency channels per link, and the frequency inefficiency of this technique



6. Margins and the Power / Gain Balance
7. UPS
8. Monitor and Control
9. Filters
10. Grounding
11. Lightning Effects

Other Issues

- Scintillation effects

In electromagnetic wave propagation, “scintillation effects” are a small random fluctuation of the received field strength about its mean value. Scintillation effects become more significant as the frequency of the propagating wave increases

- Bandwidth requirements for digital radio links
- The penalties of not meeting line-of-sight conditions
- Analysis of radio interference
- Coordination contours
- Jitter accumulation
- Forward error correction
- Advanced digital modulation waveforms
- Dispersion on digital paths and its mitigation.