Network microwave link

Microwave Communications Link Design And Implementation Gert Brits

Abstract Internet and network access from any location is a requirement in most businesses around the world today. This paper outlines the procedure necessary to plan, install and commission a 5. 8 GHz un-licensed point-to-point microwave link. The link will serve as a connection between two office buildings to provide internet and network access to the employees. The planning stages of the project presents the various environmental influences on a microwave link, as well as the considerations that must be made to select the appropriate sites, hardware and configuration settings for the link. These parameters are used to calculate the expected performance data and install a microwave link that would operate reliably at five nines (99. 999%) of availability.

Index Terms attenuation, losses, fading, line-of-site, received signal level,

Introduction

DIGITAL microwave systems are used all over the world for a wide variety of applications. The majority is point-to-point systems; a single link connecting two sites together.

For most businesses, having access to the local area network and the internet is essential. The challenge for many is the occupation of more than one office building and how multiple buildings can gain access to the same network.

Harris Stratex Networks (HSTX) in San Jose, California occupies an office building in San Jose as well as an equipment warehouse in Milpitas, two miles from the office building. Since the company manufactures digital point-to-point microwave radios and has access to such equipment, an effective method was researched to utilize a point-to-point radio link as a connection between the two buildings.

The purpose of this paper is to demonstrate how a digital point-to-point microwave link can be used to link two office buildings together, in this case the main office building of HSTX in San Jose and the warehouse in Milpitas, and provide internet and local area network access to the employees at the warehouse.

The various aspects involved in the design, installation and commissioning of a digital point-to-point microwave system is described to highlight the procedures and planning required from microwave engineering before, during and after a microwave link is installed.

attenuating influences on a microwave link

Almost all components involved in a microwave link will cause the signal to be attenuated at some stage during transmission. In microwave engineering, attenuation plays a major role in the design and planning of such a link to ensure reliability and availability regardless of the surrounding conditions. Whether it’s in the cables, connectors, antennas or free space; attenuation on a link can not be avoided and provision needs to be made, during the design stage, for the degree of expected attenuation to occur.

Propagation losses

Propagation losses such as attenuation caused by reflection, free space losses, attenuation caused by rain and by atmospheric gasses have a negative influence on a microwave link.

Reflection

Line-of-Sight Microwave links are designed to have enough clearance over any object or terrain along the path to avoid the signal grazing or scraping across obstacles. The Fresnel zone is known as the area around the visual line-of-sight that radio waves spread out into after they leave the antenna [1] and where obstacles would cause in phase or out of phase reflection of the radio wave. This area must be clear of any obstructions to avoid an undesired affect on signal strength. Fig. 1 illustrates the typical Fresnel zones associated with a microwave link.

Microwave signals which are reflected or refracted could lead to multiple copies of the same transmitted signal to arrive at the receiving antenna at different times and out of phase. The reflected and refracted signals will experience differences in attenuation, delay and phase shifts which will result in either constructive (amplifying the signal) or destructive (attenuating the signal) interference.

There are an infinite number of Fresnel zones. Obstacles in the first Fresnel zone will create signals that will be 0 to 90 degrees out of phase. The second Fresnel zone will cause signals to be 90 to 270 degrees out of phase. In the third, the signals will be 270 to 450 degrees out of phase and so forth. Odd numbered zones (1, 3, 5 etc.) have a negative effect on the signal power while even numbered zones have a positive effect since these signals actually add to the signal power.

The phase canceling effect is strongest in zone 1 and decreases in each successive zone, hence the need to eliminate as many obstacles from the first zone as possible. These clearance requirements also include the sides of the path and not only the top and bottom.

Free space loss

Free space loss is defined as the loss that would obtain between two isotropic antennas in free space, where there are no ground influences or obstructions [2]; in other words, the loss where no obstacles nearby can cause blocking, refraction, diffraction or absorption.

This loss increases with an increase in frequency and distance and the formula for calculating free space loss [3] using the frequency of operation (f) and the distance (in miles) between the two antennas (D) is given by:

(1)

Attenuation caused by atmospheric gasses

Attenuation caused by atmospheric gases is mainly caused by oxygen and water vapor in the air. The small amount of attenuation caused by oxygen stays relatively constant across all operating frequency bands. Attenuation caused by water vapor absorption however is highly dependent on the frequency of operation as well as the density of the water vapor and will have a deep impact on the links operating above 14 GHz.

Attenuation caused by rain

Furthermore, fading can be the distortion a microwave signal experiences due to changes in the atmosphere or rain. The total amount of rain that falls is not as important as the intensity of the rainfall. For example, an area which gets lite rain for most of the year would be less affected by rain attenuation than an area that gets a storm of rain during the rainy season, even for a short period of time. Microwave links operating below 8 GHz remain largely unaffected by rain attenuation but at 10 GHz and above, rain has a big impact on the network's reliability.

Availability for modern day high reliability systems varies. The annual outage objective for high reliability systems could be as little as 0. 01% to 0. 0001% of the total operating time which translates to 53 minutes of down time per year for 99. 99% reliability and only 30 seconds of downtime per year for 99. 9999% reliability.

Fading can degrade the bit error rate (BER) performance of a microwave link resulting in loss of data. Parameters such as the radio frequency, path length, humidity, temperature, smoothness of the terrain, calmness of the wind, fog and the number of thunderstorms per year can all increase the probability of fading.

Branching losses

Branching losses are introduced by the hardware used to carry the microwave signal and is generally specified by the equipment manufacturer.

Other losses

Other losses associated with a microwave link include losses from feeders, connectors, antennas, radomes and TX line losses. These losses are specified by the manufacturers at different frequencies of operation.

Microwave link Planning

Sufficient microwave path engineering ensures a link performs according to the requirements set by the owner or user. In a perfect world, any microwave beam would travel in a straight line from start to finish. In reality however, everything surrounding the microwave beam and equipment can cause the signal to be attenuated, amplified or interfered with. The challenge for any microwave engineer is to know what these factors are and how to design around it.

Site selection

An essential part of planning a microwave link is the selection of appropriate sites. The office and warehouse roof of HSTX provided a line of sight which was clear of any surrounding buildings and obstructions that could block or cause the microwave signal to be diffracted. There was no possibility of additional floors being added to either of the two buildings and the absence of other towers and microwave systems in the area, which could interfere with this link, made these sites ideal for the antenna installation. In addition to this, the sites already had access roads, ac power and telephone services which were other requirements considered when choosing the appropriate sites.

Frequency and equipment selection

Industry standards and licensing for microwave radios are, in the USA, governed by the Federal Communications Commission (FCC). Radios operating in the license-free 2. 4 GHz and 5. 8 GHz bands are considered un-licensed radios and require no licensing from any governing body. Un-licensed radios, such as the Velox LE 5850 manufactured by Harris Stratex Networks, can be installed and operated without any approval from the FCC.

The Velox 5850 series is capable of providing up to 45 Mbps of Ethernet throughput (Full-duplex) which was sufficient for the purpose of this link. The output power of the radio can be software adjusted up to +22 dBm and with a receiver sensitivity of -78 dBm; enough fade margin can be achieved to ensure link availability of 99. 999%.

The radio hardware is available in a split-mount configuration; a radio frequency unit (RFU) which is connected to a digital unit (DU) using shielded CAT5e cable. The RFU is installed on the tower or mounted below the antenna and the DU is installed inside an equipment building or enclosure. Management software to configure the radio and monitor the performance of the radio link is available for this product.

A 4. 940-5. 580 GHz Grid Antenna (model no GS2-58N), manufactured by mWAVE Industries, LLC was selected for the project. The antenna provided a gain of +27 dBi, a VSWR of 1. 5: 1, a return loss of 14 dB and could be mounted for horizontal or vertical polarization as illustrated in Fig. 2.

Microwave link calculations

The microwave link design was started by doing a link budget analysis; a calculation that involves all the gains and losses associated with the antennas, cables, connectors, radio hardware and environment. The link budget was used to determine the expected received signal levels at each end of the link. Once this has been done, minor adjustments were made to the sites and hardware selections to achieve the desired link availability.

Path calculations

The receiver threshold value is a measure of the lowest possible signal level the radio can receive and still operate at an acceptable level of performance. This level was specified by the equipment manufacturer as -78 dBm. The difference between the received signal level and the receiver threshold indicates the fade margin (the amount of fading a microwave radio can experience before having the signal degraded enough to cause BER errors or framing errors) of the link. To calculate the expected receive signal level and the fade margin, the propagation losses, branching losses and other losses had to be subtracted from the radio output power and antenna gain.

The attenuation caused by atmospheric gasses for links below 14 GHz was negligible. The free space loss given by (1) and therefore the total propagation loss was calculated as 114. 32 dB. Transmit and receive branching losses associated with the Velox 5850 radio was specified by the equipment manufacturer as 1. 5 dB respectively. Other losses, all of which were specified by the various manufacturers, included the TX line losses of 3. 72 dB (1. 24 dB per 100ft of cable used) for each site and an N-Type connector loss of 0. 3 dB per connector (four connectors used).

Output Power = + 22 dBm

TX Branching Loss = – 1. 5 dBm

Antenna Gain = + 27 dBm

Propagation Losses = – 114. 341 dBm

Other Losses = – 8. 34 dBm

Antenna Gain = + 27 dBm

RX Branching Los = – 1. 5 dBm

Received Power = – 49. 68 dBm

Receiver Threshold = – 78 dBm

Fade Margin = + 28. 32 dB

Fading and interference calculations

The amount of attenuation expected on the link due to rain was calculated using the formula in (2)[4], where $R_{0.\ 01\%}$ represents the rain rate exceeded 0. 01% of the time in mm/hour and D the path length in kilometers. Multiplier *a* and exponent *b* are values taken from the North American and ITU-R rain attenuation coefficients chart, while *d* represents the effective path length in kilometers. The link operating at 5. 8 GHz over two miles can thus expect 0. 106 dB of additional attenuation during the heaviest rainfall.

(2)

The possibility of the radio signal being diffracted was investigated by observing the structures surrounding the microwave beam and calculating the first and second Fresnel zones using (3)[5]. The distance from the antenna to any possible obstruction is given by d_1 while d_2 represents the remaining distance to the other end of the link.

(3)

Since the Fresnel zones consist of a series of concentric circles, the areas to the side, above and below the microwave beam had to be clear of obstructions. The height of the two buildings where the antennas were to be installed provided enough clearance to ensure no obstructions within the first two Fresnel zones. With a mere 0. 106 dB of additional attenuation from rain and no possibility of the signal being diffracted or reflected, only 3 dB of variation on the calculated receive level was expected. The 3 dB of variation is due to component tolerance and is specified by the equipment manufacturer.

Microwave link installation

The antenna and radio frequency unit were installed on a mounting pole on the roof of both buildings, in accordance with the manufacturers recommended installation procedures. A high quality 5/8 coaxial cable was used to connect the antenna to the RFU. The digital units were installed in 19 racks inside the buildings while Belden 7921A Shielded CAT5e cable was used to connect the DU to the RFU. All the hardware was grounded to the various grounding points at the sites and the recommended impedance of less than one ohm measured on all ground connections.

The antennas were aligned using a digital voltmeter connected to the back of each RFU. The DC voltage reading from the voltmeter was compared to the received signal level (RSL) chart shown in Fig. 3 [6] which was supplied by the radio manufacturer.

[1] Fresnel Zone

http://www. webopedia. com/TERM/F/Fresnel_Zone. htm

[16 June 2000]

[2], [4]-[5] GTE Lenkurt. 1970. *Engineering Considerations for Microwave Communications Systems*

[3] Harvey Lehpamer. 2004. *Microwave Transmission Network:, Planning, Design and Deployment*

[6] Harris Stratex Networks. July 2004. *Velox LE Installation and Operation Manual.*