DEVELOPMENT OF SOFTWARE FOR THE BASIC LINE-OF-SIGHT PARAMETERS CALCULATION

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Abstract: In this paper we have developed a software by which the general parameter of a line-of-sight (LOS) microwave link can be calculated. We have also put here an overall concept about the link parameters. A Line-of-sight microwave link is designed. For a LOS link implementation there are two steps to follow: at first, we have to make a survey to collect a few data and then we have to calculate some data with the help of survey data. The link parameters which are crucial to the design have been calculated. All important parameters like Fresnel zone, fade margin, effective earth curvature, antenna tower height and the minimum transmitter power for a given BER have been calculated. In the link budget calculation all of the losses like fading loss, absorption loss, feeding loss and noise figure of the receiver are considered. Finally, a computer GUI program has been developed for the enhancement of a complete usable LOS software which original coding was done in C language to be used by any designer.

Key Words— Microwave, Line of Sight (LOS), Link parameter, LOS software.

I. INTRODUCTION

Microwaves are electromagnetic waves with wavelengths ranging from 1 mm to 1 m, or frequencies between 0.3 GHz and 300 GHz. The term microwave refers to electromagnetic energy having a frequency higher than 1 Gigahertz (billions of cycles per second), corresponding to wavelength shorter than 30 centimeters. The microwave range includes Ultra-High Frequency (UHF) (0.3–3 GHz), Super High Frequency (SHF) (3–30 GHz), and Extremely High Frequency (EHF) (30–300 GHz) signals.

A Line-of-Sight microwave link uses highly directional transmitting and receiving antennas to communicate via a narrowly focused radio beam. The transmission path of a Line-of-Sight microwave link can be established between two land-based antennas, between a land-based antenna and a satellite-based antenna, or between two satellite antennas.

A link budget is the accounting of all of the gains and losses from the transmitter, through the medium (free space, cable, waveguide, fiber, etc.) to the receiver in a telecommunication system. It accounts for the attenuation of the transmitted signal due to propagation, as well as the antenna gains, feed line and miscellaneous losses. A simple link budget equation looks like this:

Received Power (dBm) = Transmitted Power (dBm) + Gains (dB) − Losses (dB).

For a line of sight radio system, a link budget equation might look like this:

\[ P_{RX} = P_{TX} + G_{TX} - L_{TX} - L_{FS} - L_M + G_{RX} - L_{RX} \]

Where,

- \( P_{RX} \) = received power (dBm)
- \( P_{TX} \) = transmitter output power (dBm)
- \( G_{TX} \) = transmitter antenna gain (dBi)
- \( L_{TX} \) = transmitter losses (coax, connectors.) (dB)
- \( L_{FS} \) = free space loss or path loss (dB)

Fig 1.1: Radio Path Link Budget [1]
\[ L_M = \text{miscellaneous losses (fading margin, body loss, polarization mismatch, etc)} \ (\text{dB}) \]
\[ G_{RX} = \text{receiver antenna gain (dBi)} \]
\[ L_{RX} = \text{receiver losses (coax, connectors...)} \ (\text{dB}) \]

II. BACKGROUND: FUNDAMENTAL ELEMENTS OF LOS MICROWAVE RADIO SYSTEMS

Frequency

The carrier frequencies of LOS microwave links are usually above 200 MHz. For digital transmission, the frequency range between 1.8 GHz and 7 GHz is utilized. Higher frequency has two main advantages—First, it provides the large bandwidth necessary for high bit rate transmission. Second, high carrier frequencies are less susceptible to atmospheric effects by the transmission path.

The Fresnel Zone

Radio waves travel in a straight line, unless something refracts or reflects them. But the energy of radio waves is not “pencil thin.” They spread out the farther they get from the radiating source — like ripples from a rock thrown into a pond. The area that the signal spreads out into is called the Fresnel zone. If there is an obstacle in the Fresnel zone, part of the radio signal will be diffracted or bent away from the straight-line path. The practical effect is that on a point-to-point radio link, this refraction will reduce the amount of RF energy reaching the receive antenna. The thickness or radius of the Fresnel zone depends on the frequency of the signal — the higher the frequency, the smaller the Fresnel zone. The reflection point offset from a direct signal path, where the length of the reflected path is exactly ½ wavelengths longer than the direct signal path. These boundaries can be calculated with the following formula:

\[ F_n = \sqrt{\frac{n \lambda d_1 d_2}{d_1 + d_2}} \]

Where,
\[ F_n = \text{The nth Fresnel Zone radius in meters.} \]
\[ d_1 = \text{The distance of P from one end in meters} \]
\[ d_2 = \text{The distance of P from the other end in meters.} \]

The cross section radius of the first Fresnel zone is the highest in the center of the RF LOS which can be calculated as:

\[ r = 17.32 \sqrt{\frac{D}{4f}} \]

Absorption

Transmitted EM energy can converts into another form e.g. thermal. The conversion takes place as a result of interaction between the incident energy and the material medium, at the molecular or atomic level. One causes of signal attenuation due to absorption by walls, precipitations (rain, snow, sand) and atmospheric gases.

Fig 1.2: Gas Attenuation vs Frequency [Google image]

Atmospheric Refraction

The atmosphere changes dynamically and is never constant. Keep this principle in mind; we discuss the effects of atmospheric refraction, which significantly affects radio signal propagation. The result is a signal path that normally tends to follow earth curvature, but to a lesser degree. In radio engineering, atmospheric refraction is also referred to as “the K factor,” which describes the type and amount of refraction. A K=1 describes a condition where there is no refraction of the signal, and it propagates in a straight line. A K<1 describes a condition where the refracted signal path deviates from a straight line, and it arcs in the direction opposite the earth curvature. A K>1 describes a condition where the refracted signal path deviates from a straight line, and it arcs in the same direction as the earth curvature.

Fig 1.3: Variation of Ray curvature as a function of k [1]
Effective Earth curvature or Bulge

Effective earth bulge represents the effects of atmospheric refraction, or K, combined with physical earth bulge. The following formula can be used to compute “effective earth bulge,” in meter, at any data point in a path. It includes the effects of the applicable K factor:

\[ h = 0.078 \frac{d^2}{4K} \]

Where,
\( h \) = curvature height in meter,
\( d \) = path length in kilometer

System gain

This parameter incorporates all the gains and losses of the system and also determinates the transmitter power required, based on a pre-established receiver sensitivity for a given Bit Error Rate (BER) or determines receiver sensitivity based on available transmitter power at a given BER.

\[ G_{\text{sys}} = \text{FM} - G_t - G_r + L_p + L_f + L_{\text{br}} \]

Where,
\( G_{\text{sys}} \) = System Gain(dB),
\( \text{FM} \) = Fade Margin(dB),
\( G_t \) = Transmitter antenna gain(dB),
\( G_r \) = Receiver antenna gain(dB),
\( L_p \) = Free space loss or path loss(dB),
\( L_f \) = Feed loss(dB),
\( L_{\text{br}} \) = Branching loss(dB).

Fade margin

Fading is define as the variation of the strength of a received radio career signal due to atmospheric changes and/or ground and water reflections in the propagation path. Fade margin is based on the link power budget. Fade margin of a link is given by-

\[ \text{FM (dB)} = 30 \log (d) + 10 \log (A) + 10 \log (B) + 10 \log (f) – 30 \]

Where,
\( f \) = career frequency (MHz),
\( d \) = path/hop length (km),
\( A \) = factor determining the terrain roughness of the path,
\( B \) = factor determining atmosphere impact on the link.

Free space path loss

Free-space path loss (FSPL) is the loss in signal strength of an electromagnetic wave that would result from a line-of-sight path through free space, with no obstacles nearby to cause reflection or diffraction. It does not include factors such as the gain of the antennas used at the transmitter and receiver, nor any loss associated with hardware imperfections. For typical radio applications, it is common to find frequency (f) measured in units of MHz and distance (d) in km, and thus FSPL equation becomes-

\[ \text{FSPL(dB)} = 20 \log_{10}(d) + 20 \log_{10}(f) + 32.44 \]

III. Calculation

The following parameters need to calculate.

Noise power

The term noise power has the following meanings the measured total noise per bandwidth unit at the input or output of a device when the signal is not present. Noise power of a microwave link is given by-

\[ N(\text{dB}) = 10 \log(K) + 10 \log(T) + 10 \log(BW) + NF(\text{dB}) \]

Where,
\( N \) = Noise power in dB,
\( T \) = Temperature in K,
\( BW \) = Bandwidth in H,
\( NF \) = receiver Noise Figure in dB,
\( K \) = Boltzmann’s constant.

Carrier-to-Noise ratio

The Carrier-to-Noise ratio, often written CNR or C/N, is a measure of the received carrier strength relative to the strength of the received noise. If the incoming carrier strength in microwatts is \( P_c \) and the noise level, also in microwatts, is \( P_n \), then the carrier-to-noise ratio, C/N, in decibels is given by the formula,

\[ C/N = 10 \log(P_c/P_n) \]

Channel capacity

Channel capacity is the tightest upper bound on the amount of information that can be reliably transmitted over a communications channel. In microwave communication link it depends on the spectral efficiency of the selected modulation scheme and the available bandwidth of the link.

\[ f_b = \text{Spectral efficiency} \times \text{Available bandwidth} \]

Modulation scheme

The choice of digital modulation scheme will significantly affect the characteristics, Performance and resulting physical realization of a communication system. In our consideration we prefer the QPSK for our
link design because QPSK is widely used for its attractive power/bandwidth performance for acceptable levels of error.

Antenna tower height

For antenna height calculation in an LOS microwave link, the knowledge of obstacle heights and location along the path, earth curvature and Fresnel zone clearance are absolutely necessary.

![Antenna Tower Height Diagram](Google image)

Fig 1.4: Antenna Tower Height [Google image].

The Minimum antenna tower height \((H)\) equation is

\[
H = h_m + r_m + h_{ph}.
\]

Where,

\(h_{ph}\) = Physical obstacle Height (m).

\(h_m\) = Earth curvature = \(0.078 \frac{d^2}{4K}\)

Where,

\(K\) = k-factor value.

\(d\) = path length in km.

First Fresnel clearance,

\[
r_m = 8.65 \sqrt{\frac{d}{f}}
\]

Where,

\(d\) = path length (km).

\(f\) = carrier frequency (GHz).

Bit Error rate (BER)

Bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission, usually expressed as ten to a negative power. A BERT (bit error rate test or tester) is a procedure or device that measures the BER for a given transmission.

Antenna Gain

Antenna gain is the ratio of how much an antenna boosts the RF signal over a specified low-gain radiator.

![Antenna Gain Diagram](Google image)

Fig 1.5: Summary of the whole process [1]

Antennas achieve gain simply by focusing RF energy. Gain for a parabolic antenna-

\[
G = 10 \log \left( \frac{4 \pi f^2 A_{eff}}{c^2} \right)
\]

Where,

\(A_{eff}\) = Effective Area,

\(f\) = Carrier frequency,

\(c\) = Speed of light.

Effective area, \(A_{eff} = K \left( \frac{\pi D^2}{4} \right)\)

Where,

\(K\) = antenna efficiency factor,

\(D\) = antenna diameter.

Transmitted Power

The transmit power is the RF power coming out of the antenna port of a transmitter. It is measured in dBm, Watts or milliWatt and does not include the signal loss of the coax cable or the gain of the antenna. Equation for the calculation is-

\[
P_t = G_{sys} + 10 \log(P_r)
\]

Number of voice channel

The following equation is used for the calculation of the Number of voice channel.

\[
N = 24 \cdot \frac{f_b}{1.544}
\]

Energy bit-to-noise ratio

Equation for the Energy bit-to-noise ratio is-

\[
\left( \frac{E_b}{N_0} \right) = CNR + 10 \log (BW) - 10 \log (f_b)
\]

Error power (\(P_e\))

Total error power equation is-

\[
P_e = e^{-CNR(sin(450))^2}
\]

The total process can be summarize in fig.1.5 as below
IV. DESIGN SPECIFICATION

A complete digital LOS link design.

Here we design the complete LOS link with the following link parameter and calculated the parameters with the program. The following data can be collect from survey and the link demand.

- Operating frequency, $f = 2.0$ GHz.
- Available bandwidth, $BW = 20$ MHz.
- Path length, $d = 55$ km.
- Antenna diameter, $D = 1.5$ m.
- Receiver noise figure selected, $NF = 5$ dB.
- Modulation scheme selected: QPSK (spectral efficiency = 1.9 b/s/Hz)
- Receiver sensitivity $P_{min} = 10$ pW.

Side characteristics:

- Terrain roughness: Average ($A = 1.00$).
- Atmospheric impact factor: Average ($B = 0.25$).
- Tallest physical obstacle ($h_{ph}$): 30m
- Environmental temperature = 300K.
- K-factor value of the terrain = 1.05.

V. PROGRAM

We developed a software program with C language to calculate the different parameters of a digital line-of-sight microwave link. GUI is given by using dotnet.

Fig-1.6: Introducing Interface of LOS software

Fig-1.7: Input Interface

Fig-1.8: Output Interface
Press Start button
Please enter the following data.
Operating frequency in MHz (2000-60000): 2000
Antenna diameter (in meter): 1.5
Available bandwidth in MHz: 20
Path length in kilometer: 55
Receiver noise figure in db: 5
Environment temperature in K: 300
Tallest physical obstacle in meter: 30
K-factor of the terrain (0.5-1.5): 1.05
Terrain
Very rough          0.25
Average            1.00
Very smooth        4.00
Terrain roughness factor from table (A): 1.00
Atmosphere
Very dry           0.125
Average            0.25
Hot and humid      0.5
Atmospheric impact factor from table (B): 0.25
Receiver sensitivity (min) in miliwatt: 0.00000001

OUTPUT:
(1) Fade margin: 49.200581 dB
(2) Path loss: 133.327850 dB
(3) Antenna gain: 27.342220 dB
(4) System gain: 132.843994 dB
(5) Channel capacity: 38.000000Mb/s
(6) Noise Power: -125.818489 dB
(7) Antenna height (minimum): 131.539551 m
(8) Carrier_to_Noise ratio: 15.818489 dB
(9) Number of voice channels: 590.

VI. CONCLUSION

The parameters of the link may vary on many site characteristics such as environmental temperature, reflectivity, terrain roughness, humidity, snow falling, dense foggy weather and huge rainy weather. So the calculation should be adapted for those sites depending on environmental parameters. The system gain may get changed while flying obstacles (like flying bird, aero plane etc.) come on the path of the beam though it is a transient event. We assumed here the branching loss and fading loss of a value of 2.5 dB but in practice it is a variable parameter and it depends on wave guide and antenna. Here we consider LOS between two fixed height antennas. Further study can be done considering variable tower height.

References
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