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Study of Factors which affect the Calculation of Co-Channel Interference in a Radio Link

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Abstract

The frequency spectrum lower than 10 GHz is already congested in most of countries. Therefore the telecommunication engineers are forced to look forward for frequencies above 10 GHz. The environmental effects on these frequencies are severe especially in tropical countries. Some of the factors which severely affect a Radio link are discussed here. Keeping these points under consideration a successful link can be planned.

Keywords: Fresnel Zone, Multipath fading, Effective isotropic radiated power, Rain Attenuation

I. INTRODUCTION

Here we use Microwaves in planning of a good, stable and reliable microwave network. The basic motive of communication system is to ensure the exchange of information in between the people. Now a days this wireless communication get more attention from the communication industry and provide better quality information transfer between portable devices. Microwave radio offers a number of compelling advantages over cable/fiber based transmission. They offer rapid deployment, more reliability. There is no right of way issues in installing microwave radios. It easily crosses city terrain.

II. FACTORS

A. Interference Angle

We considered a plane of 50 km square. We arranged the given latitude-longitude data from left to right. Latitude and longitude data is giving the positions of Microwave Radios. The data was arranged according to longitude.

Consider Fig.1 where Interference angle is calculated by considering all possible links for a given set of points. A particular link would get affected by other links around it.

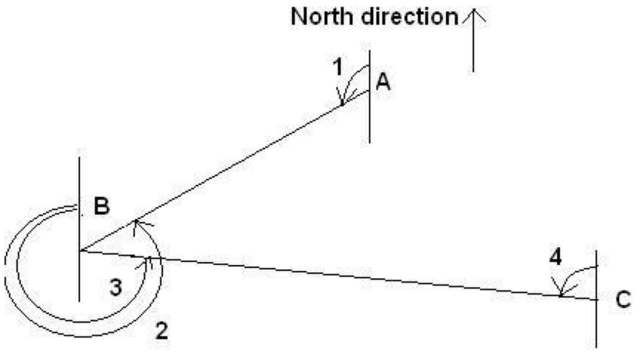

Fig.1

Considering above example, power of link BC would produce interference in link AB. Hence, overall performance of link AB would get disturbed. We considered N no. of nodes or stations given in Fig.2. Then total no. of possible links was N(N-1) in both direction[1]. Thus each link would get interference from (N-1) links.

In matrix form we got N X N matrix for each link. Hence, for N nodes we get N^2 matrices.

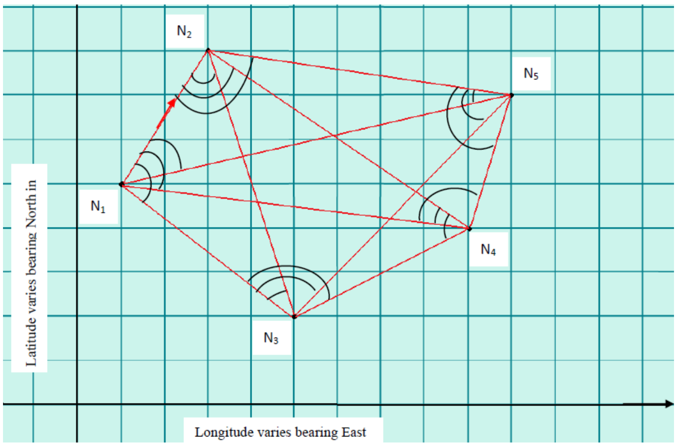

Fig.2

If $N_1 - N_2$ was desired link, we calculated the interference angle from other links on receiver node.

B. Gain due to Interference Angle

It was calculated by using following formulas[2]:

For parabolic antenna the gain is given by:

$$G = \frac{\pi^2 D^2}{\lambda^2}$$

Where,
G = power gain over isotropic
D = reflector diameter in same unit as wavelength.

a) If D/λ is greater than 100:

$$G(\theta) = G_{max} - 2.5 * 10^{-3} (\frac{D*\theta}{\lambda})^2 \text{for } 0 \leq \theta \leq \theta_m$$

$$G(\theta) = G_1 \text{for} \theta_m \leq \theta \leq \theta_r$$

$$G(\theta) = 32 - 25 \log (\theta) \text{for} \theta_r \leq \theta \leq 48^o$$

$$G(\theta) = -10 \text{for} 48^o \leq \theta \leq 180^o$$

Where,
θ = off-axis angle
G_{max}= main lobe antenna gain = $7.7 * 20 \log \frac{D}{\lambda}$ (dB)
G_1 = gain of first side lobe = $2 + 15 \log \frac{D}{\lambda}$ (dB)
θ_m= $20 \frac{\lambda}{D} \sqrt{G_{max} - G_1}$ (deg)
θ_r= $15.85 \, (\frac{D}{\lambda})^{-0.6}$ (deg)

b) If D/λ is less than 100:

$$G(\theta) = G_{max} - 2.5 * 10^{-3} (\frac{D*\theta}{\lambda})^2 \text{for } 0 \leq \theta \leq \theta_m$$

$$G(\theta) = G_1 \text{for} \theta_m \leq \theta \leq 100(\frac{\lambda}{D})$$

$$G(\theta) = 52 - 10 \log \frac{D}{\lambda} - 25 \log \theta \text{for} 100(\frac{\lambda}{D}) \leq \theta \leq 48^o$$

$$G(\theta) = 10 - 10 \log \frac{D}{\lambda} \text{for} 48^o \leq \theta \leq 180^o$$

C. 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”. The area that the signal spreads out into is called 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. This refraction will reduce the amount of RF energy reaching the receive antenna.

For a given frequency in the microwave frequency range, they require line-of-sight (LOS)[4] propagation. They also need clearance for what is referred to as the 1st Fresnel Zone, whose boundary vary with the frequency and wavelength of the specific system.

The first zone must be kept largely free from obstructions to avoid interfering with the radio reception. Maximum obstruction allowed in Fresnel zone is 40%, but the recommended obstruction is 20% or less.

In telecommunication, Free-space path loss (FSPL) measured in dB and it specifies how much the signal has weakened over a given distance.

$$FSPL = (\frac{4\pi d}{\lambda})^2 = (\frac{4\pi d f}{c})^2$$

where,
λ is the signal wavelength (in meters)
f is signal frequency (in Hz)
d is distance from the transmitter (in meters)
c is speed of light in vacuum

Above equation is only accurate in far field; it does not hold close to the transmitter. A convenient way to express FSPL is in terms of dB

$$FSPL(dB) = 20\log_{10} d + 20\log_{10} f - 147.55$$

where units are as before.

If f is measured in MHz and d in km, in which case FSPL equation becomes

$$FSPL(dB) = 20\log_{10} d + 20\log_{10} f + 32.45$$

$$FSPL(dB) = 20\log_{10} d + 20\log_{10} f + 92.4$$

where, d is in km and f is in GHz.

The general equation for calculating Fresnel zone radius at any point P (Fig.3.) in between the endpoints of the link is the following:

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

where,
F_n = the nth Fresnel Zone radius in meters
d_1 = the distance of P from one end in meters
d_2 = the distance of P from the other end in meters
λ = the wavelength of the transmitted signal in meters

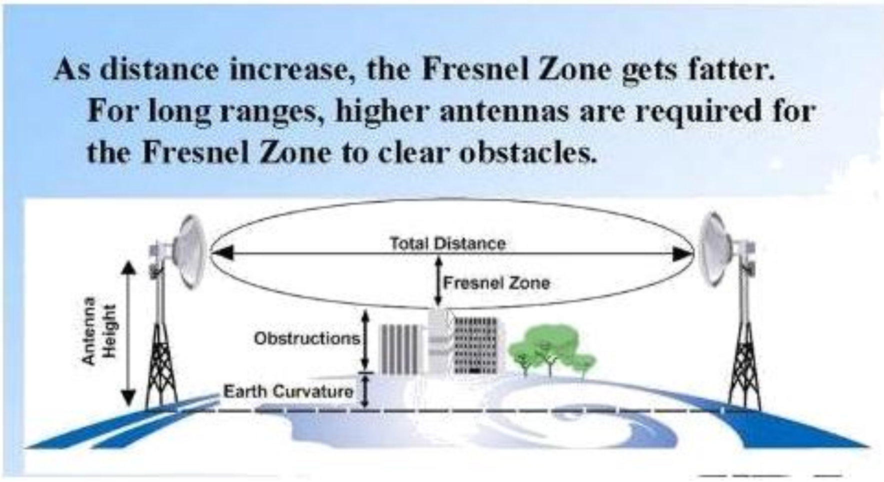

Fig.3

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

$$r = 17.32\sqrt{\frac{D}{4f}}$$

where
r = radius in meters
D = total distance in kilometers
f = frequency transmitted in GHz

D.Antenna gain

It is the ratio of how much an antenna boosts the RF signal over a specified low-gain radiator. Antennas achieve gain simply by focusing RF energy.

A parabolic antenna is a high-gain reflector antenna used for radio, television and data communications, and also for radiolocation (radar), on the UHF and SHF parts of the electromagnetic spectrum.

Gain of parabolic antenna in dB is as follows:

$$G(dB) = 17.5 + 20\log_{10} D + 20\ \log_{10} f$$

where,
D = diameter of parabolic antenna in meters,
f = frequency is in GHz.

E. Multipath Fading

It can be minimized by practices called SPACE DIVERSITY and FREQUENCY DIVERSITY. SelectiveFading resulting from multipath propagation varies withfrequency since each frequency arrives at the receiving point via a different radio path. When a wide band of frequencies is transmitted simultaneously, each frequency will vary in the amount of fading. This variation is called SELECTIVE FADING. When selective fading occurs, all frequencies of the transmitted signal do not retain their original phases and relative amplitudes.

This fading causes severe distortion of the signal and limits the total signal transmitted. Frequency shifts and distance changes because of daily variations of the different ionosphere.

F. Effective isotropic radiated power (EIRP)

It is the actual RF power as measured in the main lobe (or focal point) of an antenna. It is equal to the sum of the transmit power into the antenna (in dBm) added to the dBi gain of the antenna. Since it is a power level, the result is measured in dBm.

G. System operating margin (SOM)

SOM[3] is the difference (measured in dB) between the nominal signal level received at one end of a radio link and the signal level required by that radio to assure that a packet of data is decoded without error.

H. Rain Attenuation

It is main reason of signal loss or attenuation. It is generally significant over longer hops (> 10 Km).It starts increasing at about 10 GHz and for frequencies above 15 GHz rain attenuation become the dominant fading mechanism. Rain attenuation increases dramatically with frequency and then with path length. Therefore, microwave path lengths must be reduced in areas where rain outage is severe.

Hence a margin is included to compensate for rain attenuation at a given level of availability. Increased Fade Margin (margins as high as 45 dB to 60 dB) is of some help in rainfall attenuation. To calculate Attenuation gradient, A dB/km, we use Prediction Methods[5]. The prediction method may be roughly divided into two groups.

1) Direct conversion method
2) Parametric method

Here we are using ―Direct conversion method of predicting attenuationdue to precipitation**.** This prediction method is based on reductioncoefficients to determine the effective path length, so that the attenuation exceeded for 0.01 % of the time can be determined.

- Obtain the rain rate exceeded for 0.01 percent of the time, measured at the ground in the location of interest.
- The initial calculation is to determine, from the rain rate exceeded for 0.01 percent of the time with an integration time of 1 min, the specific attenuation γ_R . This is determined from a power law relationship, given by:

$$\gamma_R = k.R^{\alpha} dB/km$$

where, R is rain rate in mm/h averaged with an integration time t_i and the parameters k and α are functions of radio frequency and wave polarization, given by:

$$k = [k_H + k_V + (k_H - k_V)(cos\theta)^2.cos2\tau]/2$$

$$\alpha = [k_H.\alpha_H + k_V.\alpha_V + (k_H.\alpha_H - k_V.\alpha_V)(cos\theta)^2.cos2\tau]/2$$

Where θ is the path elevation angle and τ is the polarization tilt angle relative to the horizontal ($\tau = 45^o$ for circular polarization, 0^o for horizontal polarization and 90^o for vertical polarization)

Table 1 :Regression coefficients for estimating specific attenuations

freq(GHz)	***kH***	***kV***	***aH***	***aV***
1	3.87E-05	3.52E-05	0.9116	0.8802
2	0.000154	0.000138	0.9632	0.9234
4	0.00065	0.000591	1.121	1.075
6	0.00175	0.00155	1.308	1.265
7	0.00301	0.00265	1.332	1.312
8	0.00454	0.00395	1.327	1.31
10	0.0101	0.00887	1.276	1.264
12	0.0188	0.0168	1.217	1.2
15	0.0367	0.0335	1.154	1.128
20	0.0751	0.0691	1.099	1.065
25	0.124	0.113	1.061	1.03
30	0.187	0.167	1.021	1
35	0.263	0.233	0.979	0.963
40	0.35	0.31	0.939	0.929
45	0.4424	0.3932	0.9032	0.8965
50	0.5362	0.4793	0.8725	0.8683
60	0.7069	0.6419	0.8621	0.8243
70	0.8514	0.7836	0.793	0.7925
80	0.9753	0.9063	0.7687	0.7693
90	1.064	0.9992	0.7529	0.7537
100	1.12	1.06	0.743	0.744
120	1.18	1.13	0.731	0.732
150	1.31	1.27	0.71	0.711
200	1.45	1.42	0.689	0.69
300	1.36	1.35	0.688	0.689
400	1.32	1.31	0.683	0.684

- The effective path length d_e of the link is defined as the length of a fictitious path along which a constant specific attenuation would cause the same attenuation as that exceeded for 0.01 percent of the time on the actual path. It depends on the model assumed for the spatial structure of rainfall and is computed by multiplying the actual path length d by a reduction factor r. the value of r is given by:

$$r = (1 + 0.045d)^{-1}$$

- An estimate of the path attenuation exceeded for 0.01 percent of the time is given by:

$$A_{0.01} = \gamma_R . d_e = \gamma_R . r . d \text{dB}$$

- Attenuations exceeded for 1,0.1,0.01,0.001 and 0.0001 percent give the factors 0.12,0.39,1,2.14 and 3.76 respectively, by using the formula mentioned below, which is valid in the range 0.001 to 1 percent ;

$$A_p = 0.12(A_{0.01}) . p^{[-(0.546+0.043 log p)]} \text{dB}$$

Where ,A_p is the attenuation (dB), exceeded for p percent of the time.

The International Telecommunication Union(ITU) has created a statistical model in which earth is divided into different "rain zones"(Fig.4.), where each zone corresponds to a certain level of rain rate.

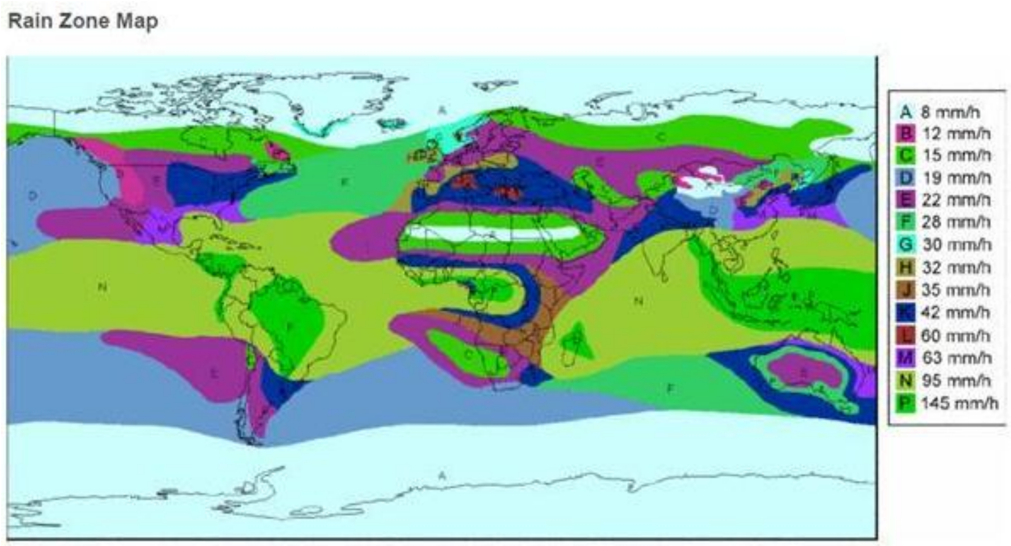

Fig.4

I. Signal to noise ratio (SNR or S/N)

It is also measured to know how much a signal has been corrupted by noise. Another factor is System Operating Margin (SOM). By doing SOM calculation, we can test various system designs and scenarios to see how much fade margin or safety cushion our link will theoretically have. Regarding minimum SOM needed, there is no absolute answer to this question, but the higher it is, the better.

In practice, the SOM is not the only determining factor. It's the actual CNR at the receiver that makes a link reliable. If we are getting **noise** or **interference** on our channel, our CNR will deteriorate. This could be anissue if we are co-locating at a site with other radios operating in the same band. We need to find out what frequency spectrum these radios are occupying. If these transmitter have energy or sideband noise on our receive channel and their antennas are close to ours, we will likely get interference from them, perhaps to the point where our link will not work.

III. CONCLUSION

In this work, factors are given which helps a designer to design and analyze multi hop links at any desired location. Considering these we can design a software to calculate carrier to interference ratio to check the reliability of Radio link.

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