Apéndice

Simulation of Fresnel Zones for Microwave Terrestrial Links

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ABSTRACT

This project is based on software that analyzes and plots the different Fresnel Zones in every terrestrial link by giving the carrier frequency and the transmitting power. The software is able to calculate the power at the receiver and it can give suggestions to the link in order to obtain the biggest receiving power .possible.

I.-INTRODUCCTION

The fundamental objective of this project is to perform a simulator for radio links, so that, every link could be simulated before its implementation. Therefore, the performance of the link would be known in advance. The success or failure of the link is evaluated according the Fresnel zones that librates the obstacle as well as the received power. In case that less than 55% of the first Fresnel zone is librated, the link is considerate as a failure and suggestions would be displayed. These suggestions are focused in the antennas height. As higher the antennas are located the clearance of the Fresnel zones will be more.

II.- MICROWAVE PROPAGATION

Microwaves can propagate through free space in a way of wave-fronts and there are several mechanisms behind electromagnetic wave propagation and they are generally attributed to reflection, diffraction and scattering. In some cases the electromagnetic waves do not travel in a line-of-sight propagation, so that they can take several paths to get the receiver antenna. Propagation models have traditionally focused on predicting the average received signal strength at a given distance from the transmitter, as well as the variability of the signal strength in close spatial proximity to a particular location.

III.- DIFFRACTION AND THE HUYGEN´S PRINCIPLE

Diffraction is considerate a natural phenomenon that every wave front has. Diffraction allows radio signals to propagate around obstacles and they can travel from the transmitter antenna to the receiver even if they do not have a line-of-sight or there are obstacles between them.
Although the received field decreases rapidly as a receiver moves deeper into the obstructed region, the diffraction field still exists and often has sufficient strength to produce a useful signal.

The diffraction phenomenon is explained by the Huygen´s principle that explains that all points on a wave front can be considered as a point of sources because each point produces secondary wavelets that when they mix, produce a new wave front in the propagation direction showed in figure 1.1. Therefore, diffraction is caused by the propagation of all these secondary wavelets into a shadowed region. After this, Fresnel followed the Huygen`s principle in order to generated the analysis of the Fresnel Zones.

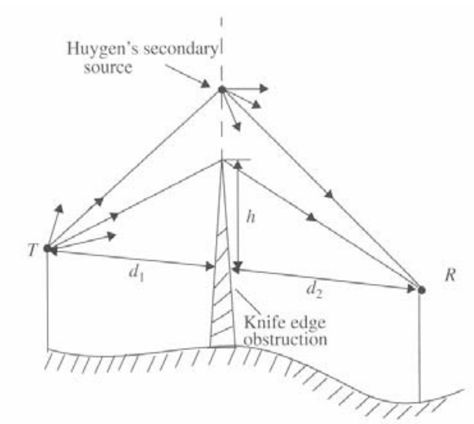

Figure 1.1 Illustration of Huygen´s secondary source [2]

IV.-FRESNEL ZONE CONSTRUCTION

The first problem studied by Fresnel after perfecting Huygens` Principle was to prove more precisely the rectilinear propagation of light. He solved this problem by considering the mutual interference of the secondary waves at the receiver antenna. If the transmitter and receiver are considered separated in the free space and there is an obstructing screen of effective height *h* with infinite width placed between them at distance *d1* from the transmitter and *d2* from the receiver. It is apparent that the waves propagating from the transmitter to the receiver via the top of the screen travels a longer distance that if a direct line of sight path existed. The difference between the direct path and the diffracted path, called the excess path length (Δ) is defined by

$$\Delta \cong \frac{h^2}{2}\frac{(d1+d2)}{d1d2}$$

The corresponding phase difference is given by

$$\phi = \frac{2\pi\Delta}{\lambda}$$

The Fresnel zones represent successive regions where secondary waves have a path length from the transmitter to receiver which are nλ/2 grater than the total path length of a line-of-sight path. when a transparent plane represent the loci of the origins of secondary wavelets which propagate to the receiver such tat the total path length increases by λ/2 for successive circles These circles showed in figure 1.2, are called Fresnel zones.

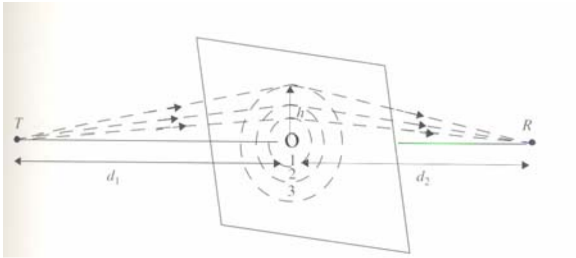

Figure 1.2.- Concentric circles which define the boundaries of successive Fresnel zones [3]

The successive Fresnel zones have the effect of alternately providing constructive and destructive interference to the total received signal. The radius if the nth Fresnel zone circle is given by

$$r_n = \sqrt{\frac{n\lambda d1d2}{d1+d2}}$$

V.- RECEIVED POWER CALCULATION

In order to calculate the power at the receiver antenna the software makes use of two different models

- Free Space Propagation model
- Knife edge Diffraction Model

In this way, the simulator is able to calculate the received power with the free space propagation model and calculate the losses that the obstacle produces with the knife edge diffraction model in case of non line-of-sight propagation.

The first model is function of the distance between the antennas and is used to predict the received signal strength when the transmitter and the receiver have a clear line-of-sight path between them so most of microwave systems undergo free space propagation. The free space power received by a receiver antenna which is separated from a radiating transmitter antenna by a distance d, is given by

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

Where Pt is the transmitted power, P(d) is the received power which is function of the separation between the antennas, Gt is the transmitter antenna gain, Gr is the receiver antenna gain, d is the distance between the antennas in meters, L is the system loss factor not related to propagation and λ is the wavelength in meters.

The knife edge diffraction Model estimates the signal attenuation caused by diffraction of radio waves over obstacles and it is essential in predicting the field strength in a given service area. Generally, it is impossible to make very precise estimates of diffraction losses, and in practice prediction is a process of theoretical approximation modified by necessary empirical correction. The knife edge diffraction Model is given by the dimensionless *Fresnel-Kirchoff* diffraction parameter *v*.

$$v = h\sqrt{\frac{2(d_1 + d_2)}{\lambda d_1 d_2}}$$

The using of this parameter perform the calculation of the looses that the obstacles gives to the system given by the figure 1.3

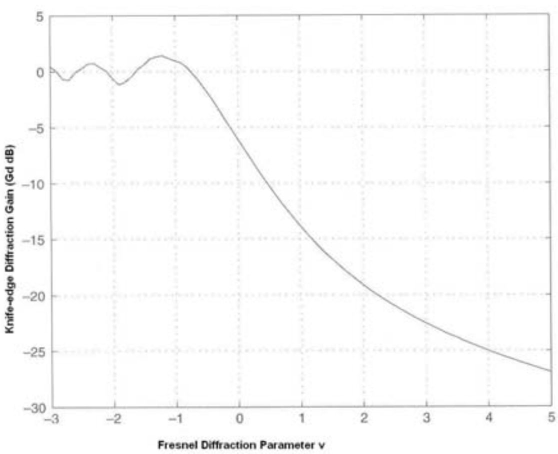

Figure 1.3 Diffraction gain vs Fresnel diffraction parameter *v* [1]

The chart represented in figure 1.3 can be calculated by the next equations that are function of the Fresnel diffraction parameter *v*.

$$G_d(dB) = 0$$
$$v \le -1$$

$$G_d(dB) = 20\log(0.5 - 0.62v)$$
$$-1 \le v \le 0$$

$$G_d(dB) = 20\log(0.5\exp(-0.95v))$$
$$0 \le v \le 1$$

$$G_d(dB) = 20\log(0.4 - \sqrt{0.1184 - (0.38 - 0.1v)^2})$$
$$1 \le v \le 2.4$$

$$G_d(dB) = 20\log\left(\frac{0.225}{v}\right)$$
$$v > 2.4$$

In this way, the using of the two models allows the simulator to calculate the received power of the radio link.

VI.- SIMULATOR PERFORMANCE

The simulator is done in MATLAB and can chart the Fresnel zones by asking to the user different features of the radio link like

-Carrier Frequency
-Distance between Tx and Rx
-Distance between Tx and Obstacle
-Height of the Rx
-Height of the Tx
-Height of the obstacle
-Receiver antenna gain
-Transmitter antenna gain
-Transmitting power

All these features are mixed up as showed in figure 1.4 so that the real Fresnel zones and the total receive power is calculated and evaluated in order to display the corresponded suggestions to the terrestrial link.

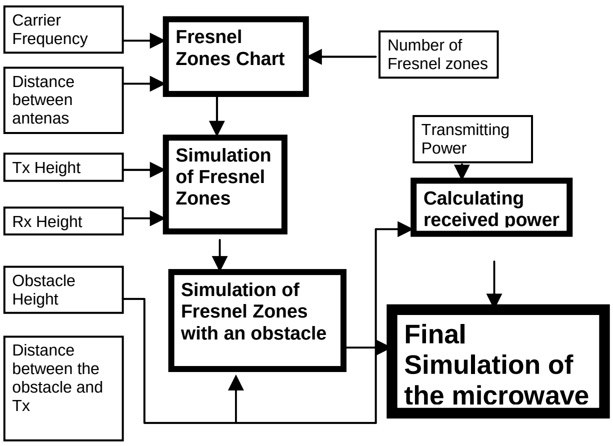

Figure 1.4.- Diagram of the software that chart the Fresnel zones

As showed in figure 1.4, the carrier frequency in combination of the link distance and the number of Fresnel zones the Fresnel zones can be charted. In order to have a real simulation, the antennas' heights are evaluated and calculated for a real char. Besides these, an obstacle is taken in the simulation in case it exists and it would be charted in the graphic. Finally, the received power is calculated due to the transmitting power and the losses that the obstacle adds to the communication system.

VII.- SIMULATOR PROBES

The figure 1.5 shows the simulator with a 2 GHz carrier frequency, 2 kilometers distance between transmitter and receiver that have 60 and 2 meters height respectably. There is an obstacle at 1.5 kilometers from the transmitter and 25 meters height. By the way, the antennas have 25 dBi of gain.

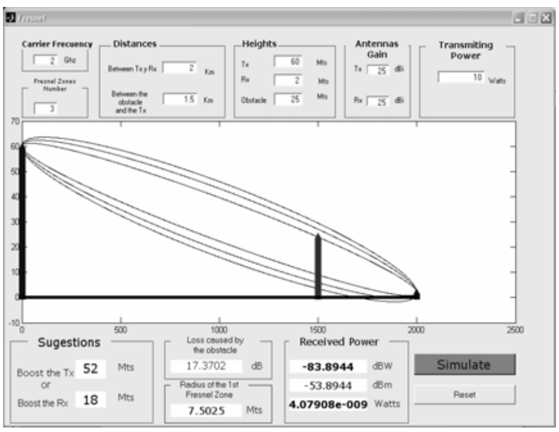

Figure 1.5.- Simulation of a terrestrial link with the first Fresnel zone obstructed.

The simulation ends with the First Fresnel zone obstructed but there is still power at the receiver. The obstacle adds to the system a 17.37 dB loss. Because of these, there are just -83.89 dB at the receiver.

This link can be improved following the suggestions showed at the simulator. These suggestions are either boosting the transmitter 52 meters or 18 the receiver.

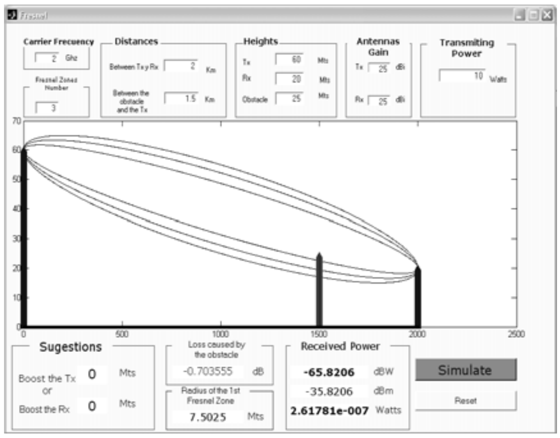

Figure 1.6 Simulation of a terrestrial link with the first Fresnel zone unobstructed

If we follow the second suggestion as showed in Figure 1.6 the Fresnel zone is liberated successfully and the receiver power is improved by 18.07 dB.

The simulator was also compared with the software Hertz Mapper. Hertz Mapper is able to simulate terrestrial links too and it can plot the first Fresnel zone and calculate the received power as well. In this case there were used exampled to validate the software was done for this project.

At first, a 18.5 kilometers link was simulated in both software, Hertz Mapper and the own. The carrier frequency was 1.7 GHz and the receiver and transmitter were at 150 and 90 meters each one. The most relevant obstacle was of 99 metes height and 7.3 kilometers from the transmitter.

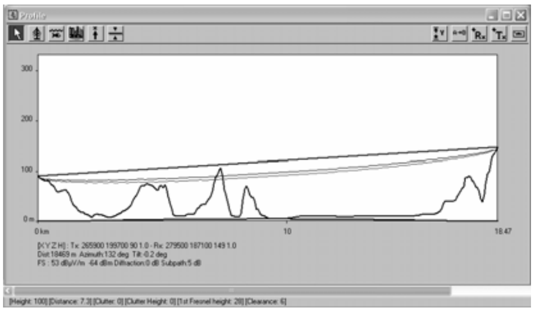

Figure 1.7.- Real environment link simulated in Hertz Mapper

The figure 1.7 shows the link simulated on Hertz Mapper with a real environment. As it is seen, the link is seriously obstructed by the most relevant obstacle almost obstructing the line-of-sight between the antennas. The first Fresnel zone has a radius of 28 meters on the place of the obstacle.

In the other hand, the figure 1.8 shows the same link simulation but the software used is the one developed for this project.

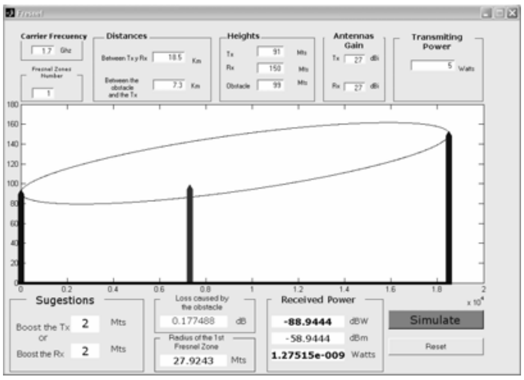

Figure 1.8 Link simulation for the own software.

The software on the figure 1.8 displays the same link than figure 1.7 but it gives suggestions in order to improve the terrestrial link and it recommend raising 2 meters any of the antennas

If the transmitter is raised by two meters as suggested in the software of the project, the link is improved tremendously and the received power goes up as showed on figure 1.9.

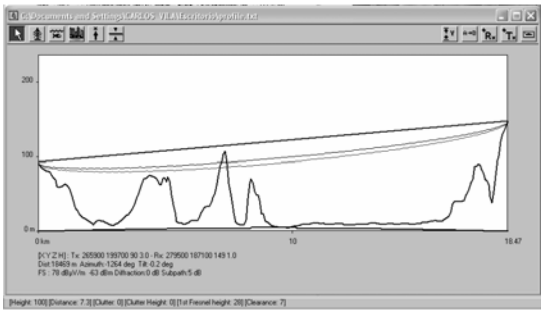

Figure 1.9 Real environment link simulated in Hertz Mapper getting the this project software suggestions

The received power goes up from -102 dB to -88 dB and this can be crucial to any terrestrial link and it is so important to always simulate the terrestrial links before their implementations.

VIII.- CONCLUSION

As conclusion, The Fresnel zones are really important because even at the Gigahertz frequencies. The Fresnel zones can reach various metes of radius that can interrupt with the link behavior lowering the receiver power significantly.

Using the simulator, the link can be easily evaluated if the Fresnel zone is going to be obstructed or not. In case this happens, it can be known how much the obstruction is going to affect the link reflected in the receiver power.

The Hertz Mapper software can be used but it is not able to deliver suggestion as well as to calculate the received power when there are obstacles on the terrestrial link because Hertz Mapper takes the link as free of obstacle even if they are and that's why this project is really important.

If the affectation is acceptable, the link could be hold in this way. In the other hand, if the receiver power is not enough, the receiver power can be raised by following the suggestions showed in the simulator.

Finally, running the simulator is fundamental in any terrestrial link because the probability of the link success is significantly better if the link is probed in advance.

IX. REFERENCES

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