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Evaluating the Performance of Free Space Optical Link in Tropical Climate

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ABSTRACT
Free space optical communication systems are the future of the communication systems which can meet the needs of the end users who are demanding high bandwidths to support high speed communication. Due to its huge number of advantages and its better performance many researchers are including it in their research activity. This technology would revolutionize the field of communications if it is implemented on a real-time basis. So, a deep qualitative study is necessary to realize the systems performance under any worse climatic conditions. In this paper, we estimated the link margin of a free space optical link by simulating it and incorporating the losses into it as per ITU-R recommendations and some other models which resemble the worst climatic conditions prevailing in the tropical region.

Keywords- *Free space, end users, communication link, ITU-R, Tropical region.*

I.INTRODUCTION

Free space optics is one of the most advanced and efficient wireless communication which resolves the problem of the existing RF bottle neck and the necessity for high speed communications. Free space optics is a perfect line of sight communicationin which the transmitter and the receiver are placed along a straight line facing each other without any misalignment [1]. Free space optics provides many advantages compared to the existing RF communication such as license free communication, low interference, high bandwidth, greater speed, less cost, greater ease of deployment, low bit error rates, improved security of information etc. Free space optics is capable of providing a bandwidth of up to 2.5 Gbps which is very much greater than that of the existing microwave communication [3].

The basic construction of a free space optical system includes a transmitter, a free space channel and an receiver. The schematic diagram can be given as

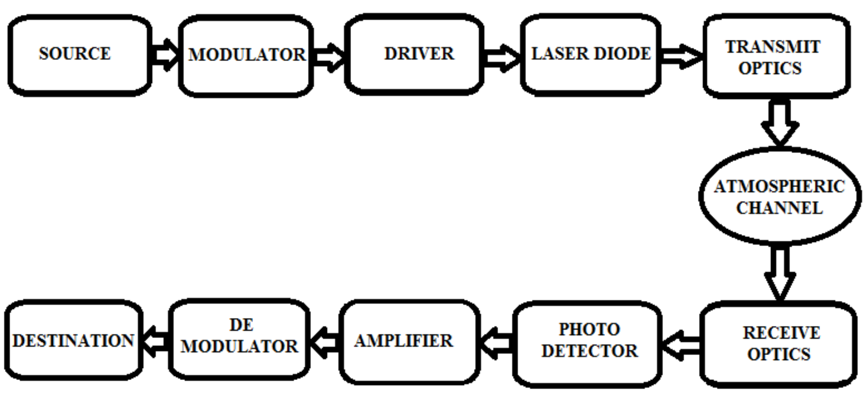

Figure 1: Schematic Diagram of Free Space Optics

Here the source is the information that we want to transmit to the destination. Now the information is to be modulated along with the carrier and then it sent through the driver circuit. In the next stage, the laser carrier which carries the information is given to the transmitter circuitry i.e. the laser emitter which emits the laser light into the free space. The signal now travels in the free space and reaches the destination (receiver) to deliver the information [7]. The receiver consisting of the photo detector detects the optical signal and down converts it and amplifies the essential part of the signal and then separates the message from the carrier and then it is stored or displayed according to the requirement based on the application [8]. As the signal travels in free space it degrades due to the effects in the atmosphere such as rain, fog, haze, scintillation and many other depending upon the region in which they are installed. So, the performance of the system may depend on the climatic condition prevailing in that region. It is necessary to calculate the link margin for a particular region before establishing a wireless link in any region. The equation for estimating the link margin is given as

$$\text{Link margin (dB)} = P_e - S_r - A_{geo} - A_{atm} - A_{scin} - A_{system} .$$

II. SYSTEM MODELLING

The system which is used for estimating the link margin is designed in software called as Optisystem developed by Optiwave. Individual blocks are taken based on the design or on the application and then joined together to form a complete optical communication system. The schematic of the system designed in Optisystem is given as

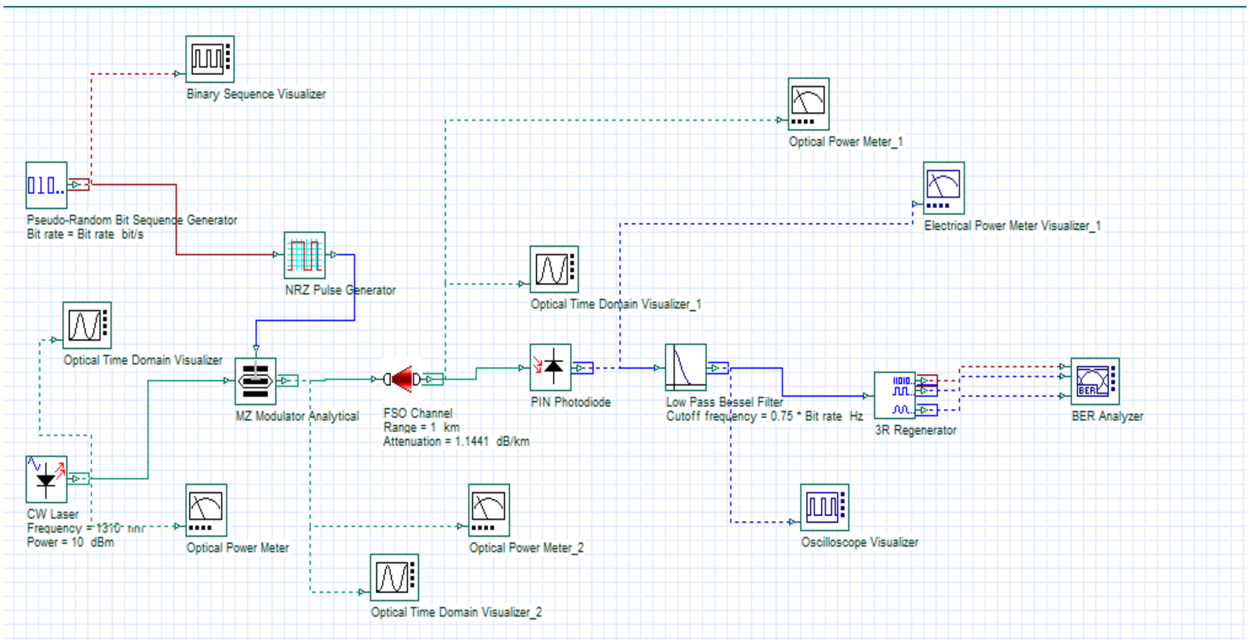

Figure 2: Free space optical system

The construction of the system initially begins with the PRBS generator for generating the bit sequence. In this stage, the bit rate is set for the system as 1.25Gbps and then it is given to the NRZ pulse generator for encoding the information. The next stage is the crucial stage which is the modulator stage where the carrier signal is modulated according to the information signal. Here the carrier signal is that is the continuous wave laser signal is generated with a power of 10dBm and the frequency of the carrier is also decided here that is around 1310nm. Now the information signal and the carrier are modulated together at the Mach Zender Modulator stage. Now a free space channel is placed in between the transmitter and the receiver stages i.e. before the photo detector stage. At this stage, all the atmospheric effects can be introduced into the simulation and can be tested for all the best and worst conditions. In this paper, the climatic conditions prevailing in the testing region are taken and the specific attenuation that occurs is calculated and incorporated into this simulation. After the FSO channel stage the signal is detected at the photo detector stage and the optical energy is converted into electrical energy and then the signal is given into the low pass Bessel filter to eliminate the unwanted frequencies and then the 3R generator is taken for generating all the reference signal for giving it to the BER analyzer for analyzing the bit error rate [10].

III. ESTIMATING THE SPECIFIC ATTENUATION FOR DIFFERENT CLIMATIC CONDITIONS

Some of the most important atmospheric effects that interfere with the free space optical signal are rain, fog, scintillation [4]etc.

A.Rain

The effect of rain is very much significant on the optical frequencies as they are of the higher order compared to the microwave frequencies [11]. In order to obtain the effect of rainfall on the optical link we need to estimate the specific attenuation due to the rain. In this paper four models like Japan model, Carbonneau model, Samir and Suriza models were used in estimating the specific attenuation. The raw data required for this is derived from the reading of the disdrometer kept at the testing location. The equations for different models are given as [5]

$$A_{rain} = k.R^{\alpha}$$

Where R indicates rain intensity in mm/hr and k, α are called the power law parameters. The power law parameters are temperature and frequency dependent which is modeled based on the climate of a region. The power law parameters for the above models are given a

Table 1: Power Law Parameters of different model

MODEL	k	α
1.CARBONNEA	1.076	0.67
2.JAPAN	1.58	0.63
3.SAMIR	2.03	0.74
4.SURIZA	0.4195	0.8486

The rain events are collected from the disdrometer their specific attenuations were estimated and incorporated into Optisystem and eye diagrams were obtained reflecting the characteristics of the transmission. The eye diagrams generated after the simulation for the lower and higher rainy conditions are

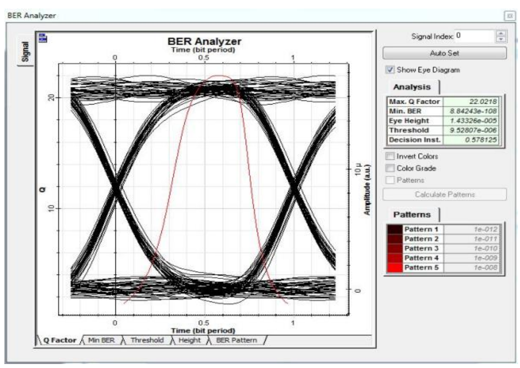

Figure 3: Eye Diagram for R= 0.583mm/hr

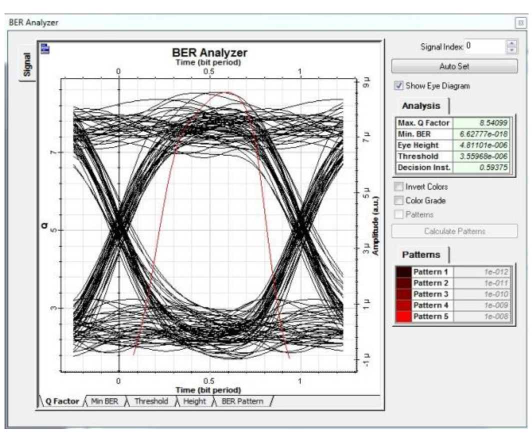

Figure 4: Eye Diagram for R=3.262mm/hr.

By observing the eye diagrams it is clear that as the rain intensity is increasing the opening of the eye diagram is decreasing which means it cannot allow more number of frequencies through it which means its performance is decreased. The corresponding power received in both the cases is also decreased.

B.Fog

Fog is also one of the contributing factors which degrade the performance of the optical signal. Generally fog attenuation is characterized by measurement of visibility at the test site. For estimating specific attenuation due to fog, three models are used which are Kruse model, Kim model and the Al Naboulsi model. The specific attenuation(dB/km) due to Kruse model is given as[6]

$$\text{Specific Attenuation} = \frac{3.91}{v}\left[\frac{\lambda}{550nm}\right]^{-q}$$

Where

v=Visibility in km

λ=Wavelength in nm

q=a coefficient dependent on the size distribution of the scattering particles.

For Kruse model

$$q = \begin{cases} 1.6 \rightarrow v > 50km \\ 1.3 \rightarrow 6km < v < 50km \\ 0.585v^{1/3} \rightarrow v < 6km \end{cases}$$

For Kim model

$$q = \begin{cases} 1.6 \rightarrow v > 50km \\ 1.3 \rightarrow 6km < v < 50km \\ 0.16v + 0.34 \rightarrow 1km < v < 6km \\ v - 0.5 \rightarrow 0.5 < v < 1km \\ 0 \rightarrow v < 0.5km \end{cases}$$

For Al Naboulsi model

$$\text{Specific Attenuation (dB/km)} = \frac{10}{\ln(10)}\left(\frac{0.11478\lambda + 3.8367}{v}\right)$$

The eye diagrams generated in these cases also show the same pattern in the best (19.417km) and worst (0.678 km) cases of visibility conditions. The specific attenuation in the worst case is given as 2.41dB.

C.Scintillation

Scintillation is mainly caused due to the turbulences that occur in the atmosphere. The variation in the refractive index of the atmosphere due to rapid fluctuations in the temperature results in scintillation [2]. In optical range the refractive index structure parameter can be given as

$$Cn2 = \begin{cases} 10^{-16} \quad for\ weak\ Turbulance \\ 10^{-14}\ for\ moderate\ Turbulance \\ 10^{-13}\ for\ strong\ Turbulance \end{cases}$$

The scintillation attenuation can be given as

$$\sigma_{scin} = |10\log(1 - \sqrt{\sigma_{scin}{}^2})| \ \text{dB}$$

D. Geometrical Attenuation

Geometrical attenuation is predictable attenuation .Geometrical attenuation is a fixed value for a specific FSO system since it does not vary with time [9]. Geometrical attenuation occurred when the light beam is diverged as it moves throughout its propagation path. As a result not the entire light beam hits the receiver. Geometrical attenuation is given by the formula [5]:

$$Att_{geo}(dB) = \frac{S_d}{S_{Capture}} = \frac{\frac{\pi}{4}(d\theta)^2}{S_{capture}}$$

Where

S_d is spot surface at distance d, θ is beam divergence, d is the distance between transmitter and receiver and $S_{capture}$ is the capture area of the receiver.

IV.RESULTS AND CONCLUSION

The pre requisites for estimating the link margin are derived using the above formulations and after replacing them in the equation we get the link margin as

Link Margin (dB) = 5.3226dB.

The total loss that occurred for a free space optical link designed for a one kilometer distance is 1.55dB under worst climatic conditions for a transmitting power of 6.8751 dBm. The loss of 1.55dB is not a negligible for a small distance of one kilometer. The quality factor obtained in this worst condition is 5.24 and the bit error rate is around $7.64*10^{-8}$.If the value of the bit error rate falls below 10^{-9} the data will be totally corrupted and no message will transferred to the destination. As the above results are confined only to the simulation, practically the losses may be much greater than that of simulation. So there will be a chance of outage in the practical cases. To avoid the case of outage if the input power is raised to 8.5dBm there will be no chance to loose the quality of the signal under any worst conditions.

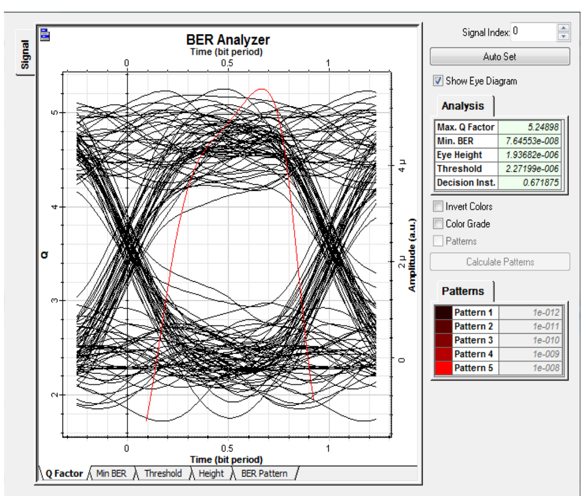

Figure 5: Eye Diagram under worst climatic condition.

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