FSO (Free Space Optics) Communication Under Different Weather Conditions and Wavelengths

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***Abstract*—Broadband wireless data transmission system using modulated optical beams is established by using a very recent and emerging technology called Free Space Optical Communication. In cases where it is practically impossible to connect Transmitter and Receiver physically or where bandwidth is really important, we are going to need to use the FSO system. As a result of atmospheric attenuation, which varies from weather condition to weather condition, as well as operating wavelengths, FSO (Free Space Optics) technology performance is impacted by these parameters. In different weather conditions, a point-to-point free space optical link will be discussed in relation to atmospheric attenuation depending on visibility and wavelength. We also discuss the methods to determine the optimal link distance for point-to-point FSO (Free Space Optics) operating in a variety of weather conditions. Upon changing the operating wavelengths as well as the weather conditions, the atmospheric attenuation also changes.**

Keywords -- Atmospheric Attenuation, Free Space Optical Communications, Link Distances, OptiSystem , Visibility.

I.INTRODUCTION

Wireless data transmission for telecommunication and computer networks is accomplished using free space optical communication using the propagation of light in free space. In this communication the channel which we use is free space channel. This is a recent, exciting and upgraded means for short distance broadband communication. Through free space optics, data, video and voice can be transmitted across a distance of up to a few kilometres over a line of sight optical connection with throughput speeds up to 1.5Gbps for frequencies above 300GHz of wavelengths, for ranges, 785nm to 1600nm. It is cheaper to use Free Space Optics wireless networks instead of RF signal solutions since no licensing is required, and fibre optic cable can be laid inexpensively; Essentially, data can be transferred using light just like fibre optics, only with a different medium. Performance of FSO (Free Space Optics) link needed to be studied it is mainly based on the Weather conditions, Weather visibilities, Link distance and different Operating Wavelengths. The different wavelengths are depending on the Atmospheric Attenuation. Free-Space optical networks typically have ranges between 100m and 2km but as the signal strength becomes increasingly dependent on atmospheric conditions as distance increases, the transmission range typically decreases, connecting two units with a shorter distance will pose challenges for FSO(Free Space Optics) as a result of the lower performance and availability. In our study, we considered the effects of different weather conditions on point-to-point FSO link at different visibilities for 850, 1250 and 1550 nm wavelengths of optical signal. Firstly, we identified the level of atmospheric attenuation of (Free Space Optics) FSO channel. Here we are finding the atmospheric attenuations for the operating wavelengths.

II. SYSTEM MODEL

A line of sight, point-to-point wireless link is required

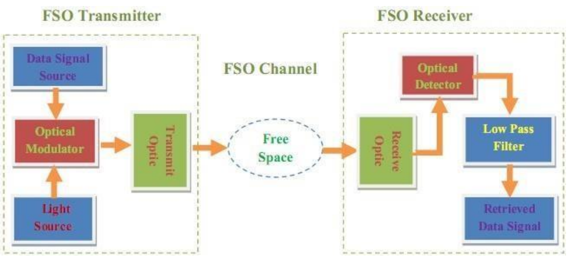

Figure (1): General block diagram of FSO link.

between the transmitter and receiver in Free Space Optical Communication. An optical transmission is used to transmit a modulated signal to the receiver over a free space channel. This signal is detected and filtered by the low pass filter and the optical detector, respectively.

III. MATHEMATICAL ANALYSIS

Atmospheric attenuation is a major factor that affects the performance of a point-to-point FSO (Free Space Optics) link. In addition, weather visibility and the distance between the links also affect atmospheric attenuation. The relation between received signal power (P_R) and transmitted signal power(P_T) can be represented by Beers Lambert Law,

$$P_R = P_T e^{(-\sigma Z)} \quad (1)$$

A point-to-point FSO(Free Space Optics) link has the following link distance (Z) and attenuation coefficient (σ); Z = link distance (distance between transmitter and receiver) in km. Where σ is given by the following equation:

$$\sigma = \frac{3.91}{V}\left(\frac{\lambda_{nm}}{550}\right)^{-q} \quad (2)$$

λ_{nm} is the wavelength at which a transmission can be clearly distinguished in nm, And V is the visibility (the maximum distance at which an object or light can be well perceived) in km. According to the standard Kim Model, q represents the size distribution of the scattering particles and is given by:

attenuation along the free space path can be expressed as follows, based on definition of attenuation and Eq.1 :

$$\sigma_{dB} = 10\log\left(\frac{P_T}{P_R}\right) = 10\log\left(\frac{1}{e^{(-\sigma Z)}}\right) = 10\log\left(e^{(\sigma Z)}\right) \quad (4)$$

So, the atmospheric attenuation (dB/km) can be stated as follows :

$$\alpha_{dB} = \frac{\sigma_{dB}}{Z} = \frac{[10\log(e^{(\sigma Z)})]}{Z} \text{ dB/km} \quad (5)$$

IV. SIMULATION REPRESENTATION

An optical communication system design simulation package called Opti System 7.0 was used to simulate a proposed point-to-point Free Space Optical (FSO) link.

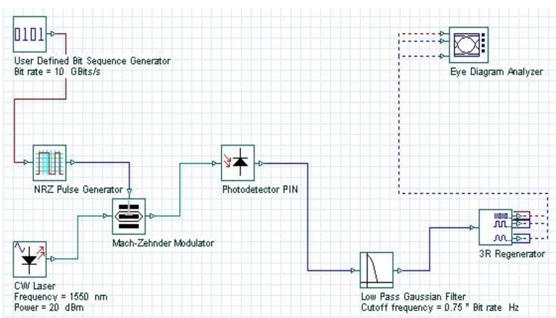

Figure:2(a) Back-to-Back Link.

$$q = \begin{cases} 1.6 & \text{if } V > 50\ km \\ 1.3 & \text{if } 6km < V < 50km \\ 0.16V + 0.34 & \text{if } 1km < V < 6km \\ V - 0.5 & \text{if } 0.5km < V < 1\ km \\ 0 & \text{if } V < 0.5\ km \end{cases}$$

Specifically, a clear area is defined as 6km<V<50km, a hazy area is defined as 1km<V<6km, a foggy area is defined by 0km<V<1km, etc. The fog condition is further classified according to its density, thickness, moderateness, and lightness; visibility ranges are 0 km<V<0.05 km, 0.05 km<V<0.2 km, 0.2 km<V<0.5 km, and 0.5 km<V<1 km, respectively. A total atmospheric

V. EXPECTED RESULTS

There are three of them. They are maximum link distance measurements at different visibility levels with wavelength dependence, atmospheric attenuation effects of free space optical channels, and effect of visibility and wavelength on signal reception. In this study, atmospheric attenuation measurements were made using MATLAB 7.5. OptiSystem 18 is used to measure the Q-factors and eye patterns.

A. MAXIMUM LINK DISTANCE MEASUREMENT

For three weather conditions of clear, hazy, and foggy, the visible range is 50 km, 6 km, and 1 km respectively. The received signal Quality Factor is called Q- factor.

1. CLEAR WEATHER CONDITION: -

We need to find the received signal Q-factor versus the link distance for the 850, 1250, and 1550 nm wavelengths, respectively, with maximum visibility (50 km) at clear weather. Each wavelength receives less quality as the link distance increases, and vice versa. If you calculate the received signal quality with noisy eyes considering the link distance of 5 km, you will notice an obvious degradation in quality. The quality of reception is also satisfactory for 1250 and 1550 nm wavelengths over a distance of 4 km, and significantly degrades over a distance of 5 km. A considerable amount of signal degradation will occur if the quality factor falls below 200-250. According to the above discussion, the received signal quality degrades rapidly over distances greater than 4 km in clear weather conditions for all the wavelengths.

In clear weather conditions for all wavelengths, the maximum link distance is expecting to not to exceed the distance between 4 km to 5 km

2. HAZY WEATHER CONDITION :-

Considering the link distance as 2.5 km, a considerable amount of degradation in the signal quality needs to be calculated with the help of noise eye patterns. The quality of reception is also satisfactory for 1250 and 1550 nm wavelengths over a distance of 2.5 km, and significantly degrades over a distance of 3 km. As the quality factor (Q- factor) may drops below 200-250, a considerable amount of degradation need to be found at distance above 3 km in the received signal. According to the above discussion, the received signal quality degrades rapidly over distances greater than 2.5 km in clear weather conditions for all the wavelengths.

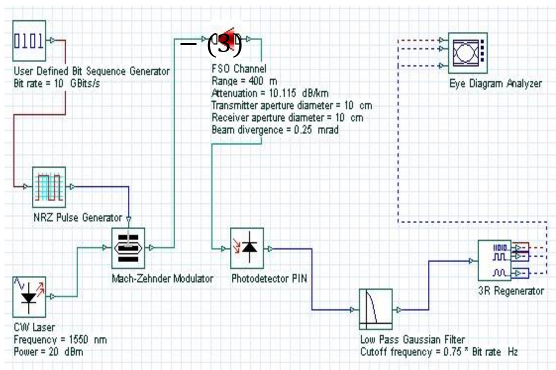

Figure:2(b) Point-to-Point FSO Link

In clear weather conditions for all wavelengths, the maximum link distance is expecting to not to exceed the distance between 2.5 km to 3.5 km

3.FOGGY WEATHER CONDITION :-

It is important to note that with 0.8 km link distance, almost the same eye shape and eye opening as with a back- to-back link may be obtained for an acceptable received signal quality. When the distance between the link and the receiver is 0.9 km, the received signal quality (Q-factor needs to be calculated) with noisy eye patterns is significantly degraded. Similarly, for 1250 and 1550 nm wavelengths, a satisfied quality of received signals (Q-factor need to be obtained and assumed that it may be below 200) are obtained for 0.9, 1 km link distances and significant degradation in the received signal quality (Q-factor: assumed to be below 180) are required to obtained for 1 and 1.1 km link distances sequentially.

Therefore, at foggy weather conditions with visibility of 1 km, the maximum link distance can be obtained. Considering all the wavelengths at this visibility, link distance expecting to not exceed the distance between 0.8 km and 1km for satisfactory operation.

VI. CONCLUSIONS

As operating wavelengths, weather visibility, and link distance changes, the operating performance of Free Space Optical links (FSO) will change as well. FSO link's performance is largely independent of wavelength under clear weather conditions. In hazy or foggy weather conditions, performance is greatly affected by the wavelength. Within the variations in the weather visibility and operating wavelength the maximum link distances varies. Considering the three weather conditions the operating wavelength which in between 1400nm to 1600nm may give better performance with respect to maximum link distance at different visibility levels. An FSO (Free Space Optics) link's performance is strongly controlled by atmospheric attenuation, which depends on the weather and the wavelength of the operating light. As the weather visibility increases, attenuation decreases and it is less in clear weather condition and more in hazy and foggy weather conditions. When the visibility is less than or equal to 0.5km then the attenuation is independent of wavelength. It has been determined that the optimum distance for multiple weather conditions is 400m. We hope that the proposed FSO (Free Space Optics) link and the results of this study will have a greater implications on future work in the field of FSO (Free Space Optics) communication.

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