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Effects of attenuation for live video streaming on free-space optics

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ABSTRACT

Free Space Optical Communications (FSO) has become a magnet for a variety of applications in the communication field. Signal attenuation was highlighted in data transfer, particularly in the multimedia e.g. high-speed video camera network requires sufficient throughput. This paper focuses on finding an approach to improve the signal received through the use of bi-directional FSO multiple access channel with high transmission power to avoid signal attenuation in short distances over atmospheric turbulence channels. Comparison of the extracted results proved that the performance of the proposed system is effective in overcome these effects.

Keywords— *Free space optical, Multiple access channel, Atmospheric attenuation*

1. INTRODUCTION

Free Space Optical (FSO) is still not widely used in many Countries. Although it has many advantages e.g. security, the speed of implementation compared with optical cable. Moreover, FSO hardware is also portable and quickly deployable [1]. Despite having a lot of advantages, the system is sensitive to environmental conditions. However, the most prominent of these restrictions that hinder implementation is bad weather conditions such as rain, haze, and fog are able to degrade the quality of FSO transmission. Handling the influencing conditions and selecting the best factors in the installation have an effective role to optimize the final system performance [2]. This paper contains a feasibility study for an optical free-space link intended for Short-range communication below 500 m.

2. ATMOSPHERIC TURBULENCE

Scintillations and beam wandering Turbulence in the atmosphere cause variation in the spatial intensity distribution of the laser beam [3]. Besides that, selection of appropriate wavelength in FSO is also an important issue. In contrast, a wavelength which is greater than 1400 nm is absorbed by cornea and lens. As well as the, higher wavelength beam is able to penetrate haze, smog, and fog [4].

In optical waves, light propagation through the atmosphere is mainly affected by absorption and scattering via air molecules. The transmission of the light in the atmosphere is described by the Beer-Lambert law:

$$\tau(\lambda, R) = -\frac{P(\lambda, L)}{P(\lambda, O)} = e^{[-\gamma(\lambda)L]} \tag{1}$$

- $\tau(\lambda)$ is the total transmittance of the atmosphere at wavelength λ
- $P(\lambda, L)$ is the signal power at distance L from the transmitter,
- $P(\lambda, 0)$ is the emitted power,
-$-\gamma(\lambda)$ is the attenuation or the total extinction coefficient per unit of length

Thus, the attenuation coefficient is approximated by the following relation (Kruse relation):

$$\beta = \frac{3.91}{v}\left(\frac{\lambda}{550\,nm}\right)^{-q} \tag{2}$$

Where: β scattering coefficient, λ= the wavelength in nanometers, v = visibility in kilometers, and q = the size distribution of the scattering particles.

The attenuation of the transmitted signal can be obtained from the previous model to various weather conditions using q [5].

$$q = \begin{cases} 1.6 & v > 50\text{km} \\ 1.3 & 6\text{ km} < v < 50 < \text{km} \\ 0.16v + 0.34 & 1\text{km} < v < 6\text{km} \\ v - 0.5 & 0.5\text{km} < v < 1\text{km} \\ 0 & v < 0.5\text{km} \end{cases} \quad (3)$$

This form of calculation is very handy because, for a given wavelength, the amount of the attenuation only depends on the visibility [5]. The visibility is used in the equation above as in [5, 6]. In this research, more than wavelengths are adapted to compare the attenuation effect on each one of them.

3. DESIGN OF THE BI-DIRECTIONAL FSO SIMULATION

In current experience, more than one Gbps can be used to obtain high speed and reliability in data transmission to satisfy the system's requirements. The FSO transmission part includes a pseudo-random bit generator, a non-return-to-zero (NRZ) pulse generator, continuous wave (CW) laser diodes, and a Mach-Zehnder Modulator. An avalanche photodiode (APD) and a low-pass Gaussian filter were used in the receiver's node component.

The multiple channels are used to improve the quality of free-space optical communication systems. the peak laser output power is 320 mW (2 x 160 mW) with 20 cm diameter receive aperture and operates at data rates more than 2.5 Gbps, has been utilized. High-powered laser transmitters are able to penetrate heavy rain, snow, and for far more effectively and consistently than those with lower power. Figure 1 shows the topology of the FSO system by the utilizing a high-power, the multi-channel transmitter in order to increase the reliability of data transmission during extreme environmental conditions [8]. Table 1 indicates the parameters that were used in the configuration of the FSO channel.

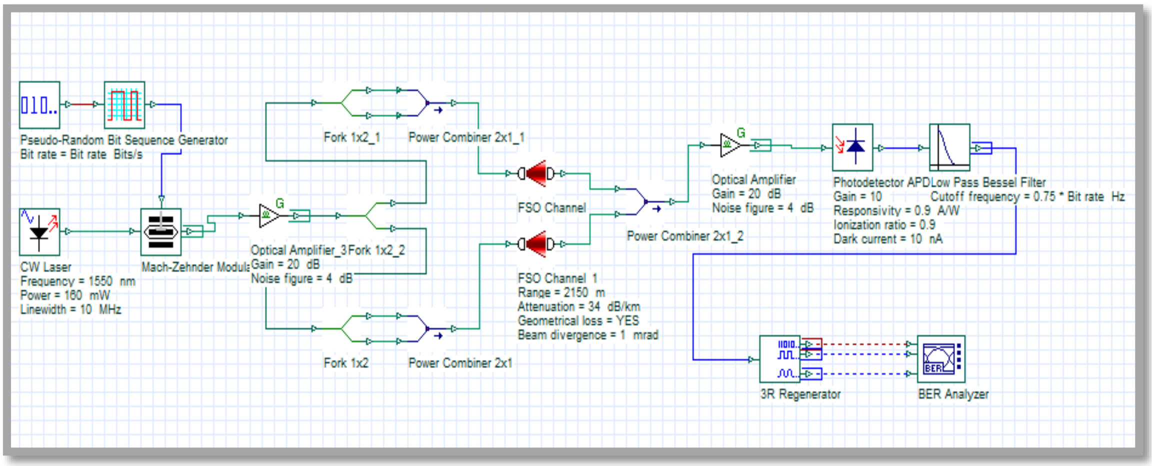

Fig. 1: Layout of Multi-channel Free-Space Optical

Table 1: Parameters of the FSO Link

Channel Configurations	Parameter
The diameter of the Aperture of the Receiver	20 cm
The diameter of the Aperture of the Transmitter	2.5 cm
Transmitter and Receive Loss	1 dB
Transmission Power	160 mv
Wavelength	1550 nm
Beam Divergences/adjustable	1 mrad

4. RESULTS AND DISCUSSION

In order to test the effectiveness of the proposed system, the performance of the system will be compared with some systems for previous ambitious experiment has been conducted. The focus will be on studying the ability to transfer data in variable conditions.

According to [8], running a high-speed video camera network requires sufficient throughput, security, and simplicity, all of which can be best provided by FSO transmission. In using the transmitter, a laser diode with a wavelength of 670 nm and a silicon PIN diode as a photodetector were used for the receiver. Live video was acquired by utilizing a camera at the transmitter, and the video was displayed on a TV monitor at the receiver. The authors used an FSO link with a data rate of 100 Mbps for streaming the live video for a distance of 100 m. The laser's frequency was chosen as 447.451 THz with an input power of 5 mW and a line width of 10 MHz, and the authors used an attenuation value of 1 dB/km. During normal conditions, the input power was4.393 dBm, and the output optical power was -0.710 dBm from which the video was retrieved.

(1) For the purposes of comparing the current system's performance, the existing parameters were changed to the same parameters that were used by other authors. Figure 2 shows the layout response of a single-channel FSO link under normal conditions using the design parameters specified by [8].

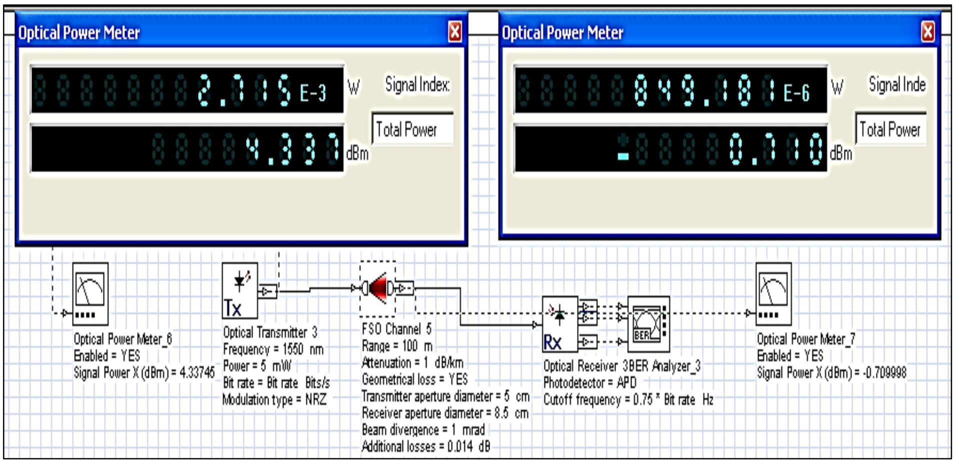

Fig. 2: FSO Link Layout Response at Normal Conditions

According to [8], the output power at the receiver was inadequate to accommodate the clear image. During rain, the FSO channel has attenuated by the impact of rain. The main component was coded in MATLAB and simulated along with Optisystem, and the output optical power was -3.814 dBm. The video signal was distorted, and a pure image could not be attained. To achieve a clearer video, the power of the laser was increased in order to withstand the attenuation that occurred due to the rain. In order to estimate the value of the attenuation coefficient used by [8], changes in the power value were continued in sync with the change in the attenuation coefficient until the same power results were obtained by the receiving side. The test results showed that an attenuation of 32.85 dB/km provided power comparable to the results of the researcher. For this reason, the input power was increased gradually from 5 to 8.565 mW to get the output power at the receiver side up to the -1.557 dBm, which is sufficient to produce a clear video. Figure 3 shows the response of the existing system while it was raining.

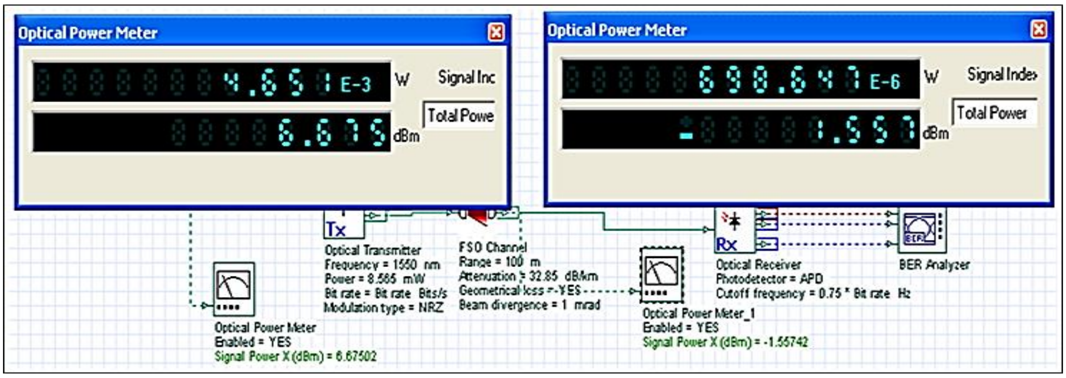

Fig. 3: FSO link Layout Response during Rain

The image from the optical power meter is shown in Figure 3, and the figure shows that the value of the transmitter's power was up to 6.675 dBm with -1.557 dBm at the receiver side at a distance of 100 m.

(2) In the third case, the design parameters of the multi-channel transmitter were used to observe the performance. Figure 4 shows that the value of transmitter power of 160 mV resulted in a value of 18.893 dBm and a value of -1.557 dBm at the receiver side. The same results as the recipient were acquired by increasing the transmission distance from 100 to 414.79 m. The results indicated that transmission distance was increased by ~ 314 m at the same attenuation rate of 32.85 dB/ km, and Figure 5 shows the Q-factor up to 428 at same conditions.

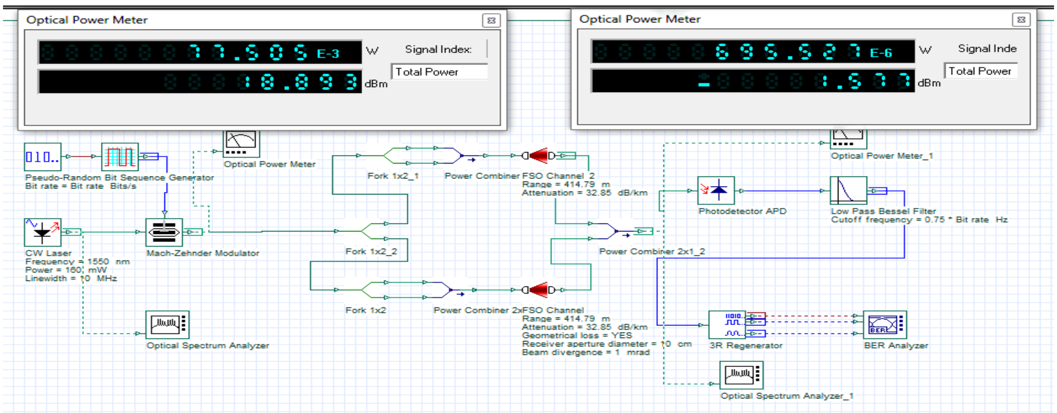

Fig. 4: Multi-Channel transmission for FSO link during rain

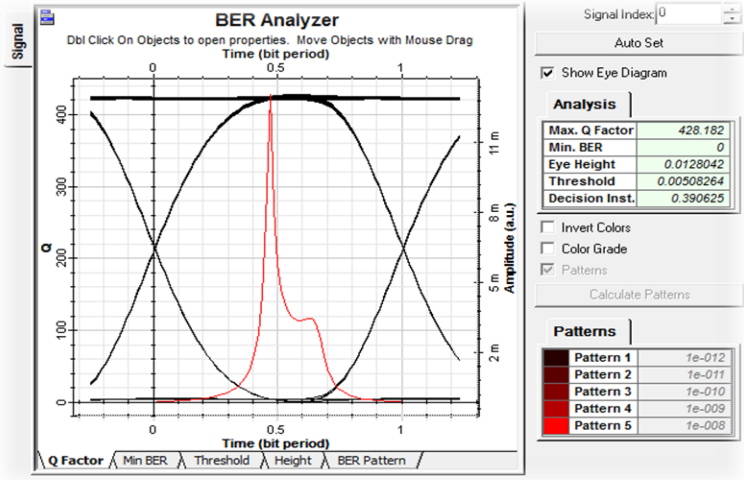

Fig. 5: Q-factor for Multi-Channel at 414m for attenuation of 32.85 dB/km

Table 2 shows the three cases were discussed previously. The first case illustrates the application of the authors' parameters in normal condition, and the second case illustrates the application during attenuation by rain.

Table 2: Comparison of the Performance Results Of the Multi-Channel Transmission

Case	Power Input (mW)	Total Input Power (dBm)	Total Output Power (dBm)	Range (m)	Attenuation (dB/km)
1	5	4.437	-0.701	100	1
2	8.565	6.675	-1.557	100	32.85
3	160	19.389	-1.557	414.79	32.85

(3) The third case shows the ability of a multi-channel transmitter system to function with the same attenuation conditions.

5. CONCLUSION

The results of this experiment have highlighted the efficiency of the Multi-Channel Transmission, and they also were confirmed by comparison with the results of previous studies. That bi-directional FSO multiple access channels utilizing 1550nm it can absorb the attenuation that occurred in the transmission channel and the live streaming video was transferred by free-space optics to distances up to 414m in harsh environmental conditions when compared to the same conditions with a single transmitter channel.

6. REFERENCES

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