Mitigation of Atmospheric Attenuation Effects in FSO Communication Link using Amplifier

Mehtab Singh
ECE Department
Satyam Institute of Engineering and Technology
Amritsar, India

Rajveer
ECE Department
Satyam Institute of Engineering and Technology
Amritsar, India

***Abstract*— The performance of Free Space Optical (FSO) communication link depends highly on atmospheric attenuation and environmental conditions through which the information signals propagate. The attenuation suffered by the information signal while travelling through the free space results in loss of information content of the signal. These factors resulting in the degradation of the performance of FSO communication link leads to the application of amplifiers in the link in order to enhance the link performance. The application of an amplifier can result in mitigation of the degradation effect in the link to a great extent. In this paper, an FSO communication link has been modeled and its performance has been analyzed with and without the application of an amplifier. The results show that the application of an amplifier in a FSO link not only enhances the performance of the transmission system but also increases the link distance. This paper investigates the performance and effectiveness of application of Erbium Doped Fiber Amplifier (EDFA) in FSO link. The performance of the link has been analyzed on the basis of Q Factor, BER, and total power of the received signal using OPTISYSTEM simulation software.**

Keywords*— *Free Space Optics (FSO), atmospheric attenuation, Erbium Doped Fiber Amplifier (EDFA), Bit Error Rate (BER), Q Factor, received power

I. INTRODUCTION

The increase in the demand of channel capacity, high data transmission rates, channel bandwidth and the development of different optoelectronic devices have played a crucial role in the development of FSO links in the past few years. FSO is a communication technology in which the information is transferred from source to destination over free space using light signals. FSO technology requires a line of sight (LOS) in order to transfer information between two source and destination [1]. FSO technology has many advantages over the previously existing wireless communication and microwave communication technologies such as availability of license free spectrum, high channel bandwidth, high data transmission rates, low implementation cost, and negligible electromagnetic interference. As the channel bandwidth of FSO technology is very large, it is capable of supporting a large number of subscribers thus mitigating the issue of data traffic [2], [4].

FSO communication link is an attractive solution to last mile problem. Research has been carried out by different institutions, organizations and researchers in the field of FSO link and it has been proved that FSO technology has numerous merits in point-to-point, point-to-multipoint and inter-satellite communication links.

Although, FSO communication links have great potential, but the widespread implementation of FSO communication links have been discouraged by attenuation due to different atmospheric conditions. The process of data transmission in FSO link is very similar to that in optical fiber communication system, but the major difference is the free space propagation medium in FSO link through which the information signal travels. Therefore, the information signal travelling through the free space is affected by various degradation factors such as atmospheric attenuation, scattering, scintillations, absorption and fading [3]. It has been shown in different researches that atmospheric attenuation can reach as high as up to 120 dB/Km in case if heavy fog weather condition which restricts the availability of FSO links in such weather conditions [5], [8]. The application of EDFA amplifier in the FSO link can result in overall link reliability and accuracy. In this paper, the performance of FSO link has been analyzed with and without the implementation of EDFA amplifier under different values of link distance and data transmission power levels. The performance has been analyzed on the basis of BER, Q Factor, SNR, and total power of the received signals. Rest of the paper is organized as follows – in Section II, FSO link model is discussed and different simulation parameters used in this investigation are presented, results are presented and discussed in Section III, and conclusions are drawn in Section IV.

II. SYSTEM MODEL AND DESCRIPTION

The FSO communication link consists of three main sections: the transmitter section, the propagation channel and the receiver section. The generalized block diagram of FSO communication link is presented in Fig. 1 and the different simulation parameters used in this paper are given in Table. 1.

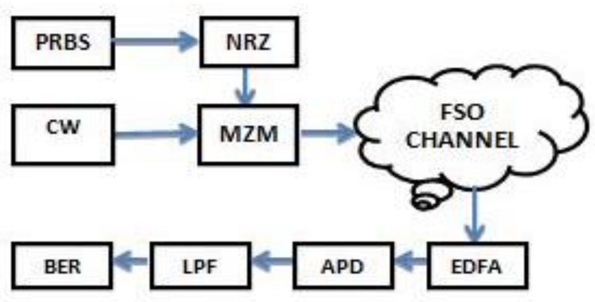

Fig.1: Block Diagram of FSO Link

The most important challenge faced by FSO communication link is the degradation of received information signal due to different atmospheric conditions that result in absorption, scattering and scintillations. The atmospheric conditions and scintillation effect greatly affect the performance of the data transmission link [6], [7]. In order to reduce the degradation effect of atmospheric attenuation, EDFA amplifier can be used in the FSO link. The FSO link model proposed in this paper consists of a Pseudo-Random Bit Sequence Generator (PRBS) which generates information signal in the form of binary data. The binary data from the output of PRBS is then directed towards non return to zero (NRZ) generator which converts the binary signal into an electrical signal. The electrical signal from the output of NRZ generator is then modulated by a Mach-Zender modulator (MZM) and a continuous laser operating at 1550 nm wavelength. The information signal in the form of light pulses is then directed towards the free space with the help of transmitting antenna. The information signal travels from source to destination free space as propagation medium. The light signal propagating in the free air suffers many losses due to atmospheric conditions. At the receiver end, the information signal is then collected by the receiver antenna and then is coupled to an optical fiber and amplifier by EDFA. The amplified information signal is then directed towards Avalanche Photodiode (APD) which converts the optical signal to electrical signal. The electrical signal from the APD is then directed towards Bessel Low pass filter (LPF) to remove and high-frequency noise present in the signal. The quality of the receiver signal is analyzed by BER analyzer.

Table.1 Simulation parameters

S. No.	Simulation Parameter	Value/Type
1.	Operating Wavelength (nm)	1550
2.	Link Distance (m)	500-1000
3.	Transmission Power (dB)	6-12
4.	Atmospheric Attenuation (dB/Km)	22.5
5.	Transmitter antenna diameter (cm)	20
6.	Receiver antenna diameter (cm)	20
7.	Amplifier	EDFA

III. RESULTS AND DISCUSSIONS

In this paper, the performance of FSO link has been analyzed with and without the implementation of EDFA amplifier in FSO link. The results have been analyzed on the basis of Q Factor, BER, received power and SNR of the received signal.

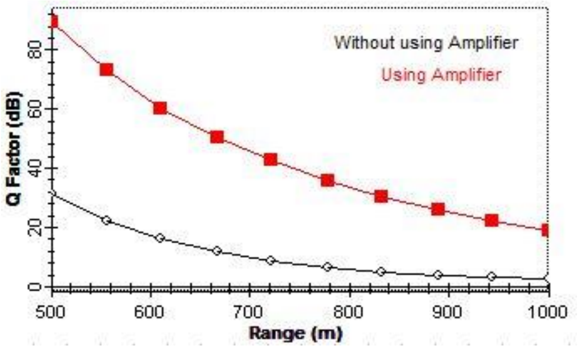

Fig.2: Q Factor v/s Link Distance

Figure.2, 3, and 4 depicts the Q Factor, SNR, and total power of received signal with and without using amplifier in FSO link in link distance of 500 m to 1000m for transmission power level of 6 dBm. From Fig. 2 it can be seen that Q Factor lies in the range [87, 31] dB to [21, 6] dB in the link distance from 500 m to 1000 m with and without the implementation of EDFA amplifier in FSO communication link respectively. From Fig. 3 it can be seen that the SNR values of received signal lies in the range [49, 31] dB to [38, 5] dB in the link distance from 500 m to 1000 m with and without the implementation of EDFA amplifier in FSO communication link respectively. From Fig. 4 it can be seen that the total power of received signal lies in the range[-2, -68] dBm to [-19, -79] dBm in the link distance from 500 m to 1000 m with and without the implementation of EDFA amplifier in FSO communication link respectively. Fig. 5 and Fig. 6 depict the eye diagram of received signal at 1000 m link distance and transmission power level of 6 dB with and without the implementation of EDFA amplifier in FSO communication link respectively.

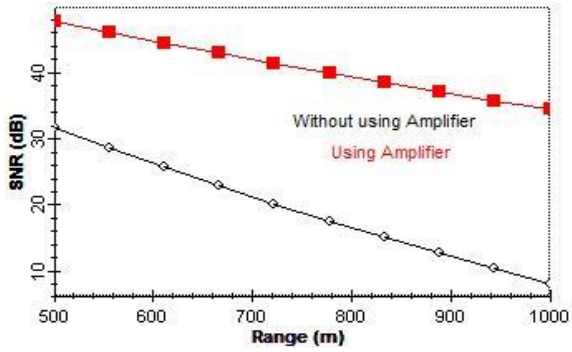

Fig.3: SNR v/s Link Distance

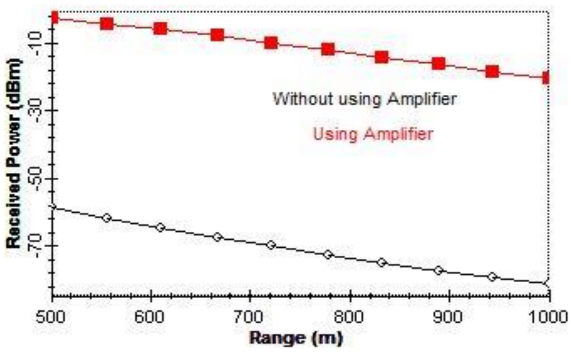

Fig.4: SNR v/s Link Distance

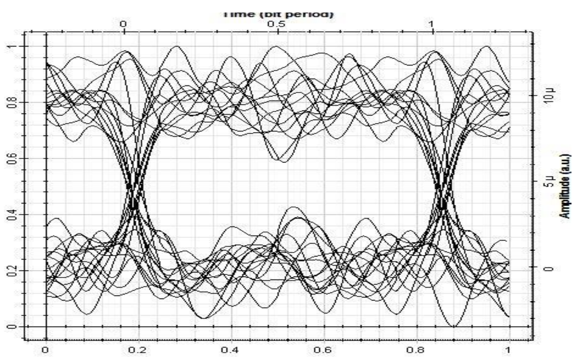

Fig.5: Eye Diagram of received signal at 1000 m link distance with implementation of amplifier in FSO Link

Table.2 presents the values of Q Factor and BER of received signal in the link distance from 500 m to 1000 m with and without the implementation of EDFA amplifier in FSO communication link.

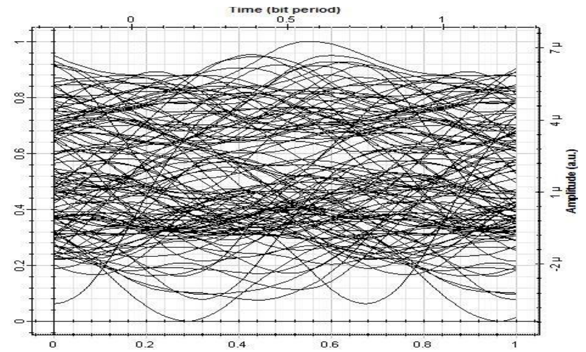

Fig.6: Eye Diagram of received signal at 1000 m link distance without implementation of amplifier in FSO Link

Table-2: Comparison of Q factor and BER of received signal for link distance of 500 m to 1000 m

Link Distance	Without using amplifier in FSO link		With using amplifier in FSO link	
	Q Factor	BER	Q Factor	BER
500 m	20.05	8.91 e-090	89.60	0
600 m	10.88	6.89 e-028	63.78	6.24 e-243
700 m	6.29	1.56 e-010	45.21	3.74 e-179
800 m	3.84	6.09 e-005	33.64	1.31 e- 141
900 m	2.47	6.70 e-002	25.13	6.81 e- 107
1000 m	1.67	4.66 e-002	18.74	8.33 e- 079

Figure.7, 8, and 9 depicts the Q Factor, SNR, and total power of received signal with and without using amplifier in FSO link respectively for transmission power levels of 6 dB to 12 dB.

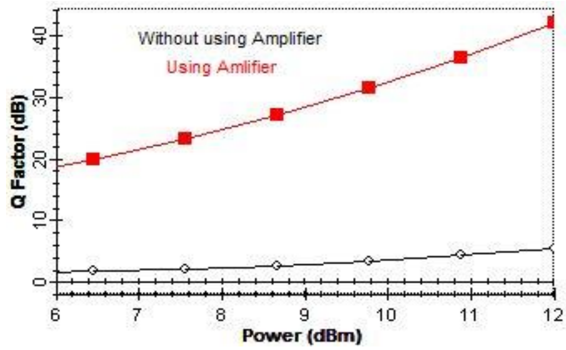

Fig.7: Q Factor v/s Transmission Power Levels

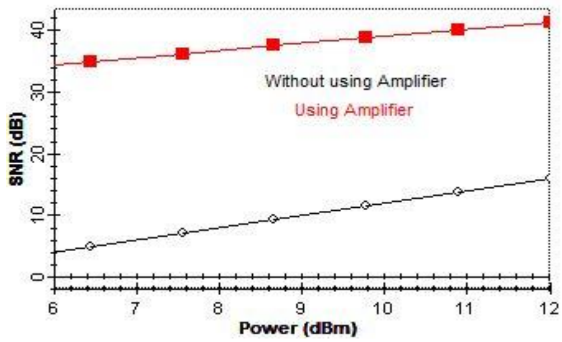

Fig.8: SNR v/s Transmission Power Levels

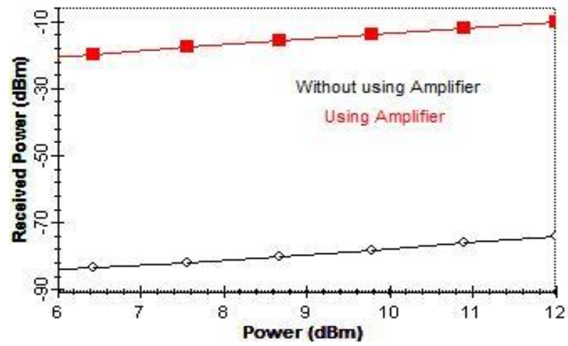

Fig.9: Received Power v/s Transmission Power Level

From Fig. 7 it can be seen that the Q Factor lies in the range [19, 1] dB to [43, 6] dB for transmission power levels varying from 6 dB to 12 dB with and without the implementation of EDFA amplifier in FSO communication link respectively. From Fig. 8 it can be seen that SNR values lies in the range [33, 4] dB to [40, 16] dB for transmission power levels varying from 6 dB to 12 dB with and without the implementation of EDFA amplifier in FSO communication link respectively. From Fig. 9 it can be seen that total received power lies in the range [-21, -86] dBm to [-10, -72] dBm for transmission power levels varying from 6 dB to 12 dB with and without the implementation of EDFA amplifier in FSO communication link respectively. Fig. 10 and Fig. 11 show the eye diagram of received signal for transmission power level of 8 dBm at link distance of 1000 m with and without using EDFA amplifier respectively.

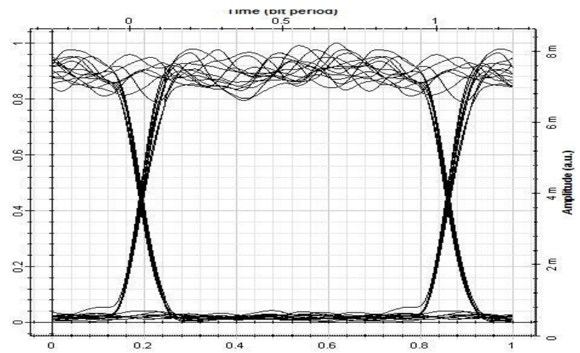

Fig.10: Eye Diagram of Received signal at 8 dB transmission power level with implementation of amplifier in FSO Link

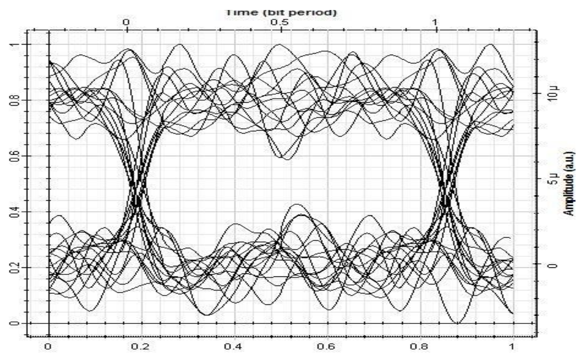

Fig.11: Eye Diagram of Received signal at 8 dB transmission power level without implementation of amplifier in FSO Link

Table.3 presents the values of Q Factor and BER of received signal for transmission power level of 6 dB to 12 dB with and without the implementation of EDFA amplifier in FSO communication link.

Table-3: Comparison of Q factor and BER of received signal for transmission power levels of 6 dBm to 12 dBm

Trans-mitted Power	Without using amplifier in FSO link		With using amplifier in FSO link	
	Q Factor	BER	Q Factor	BER
6 dB	1.67	4.66 e-002	18.74	8.33 e-079
8 dB	2.42	7.56 e-003	24.82	1.72 e-136
10 dB	3.62	1.45 e-004	32.38	1.56 e-230
12 dB	5.51	1.71 e-005	42.13	0

IV. CONCLUSION

This paper investigates the performance of FSO communication system with and without the presence of EDFA amplifier in the FSO link. The performance of FSO link has been analyzed on the basis of Q Factor, total power of received signal, SNR values and BER values of received. The results show a significant improvement of Q Factor and reduction in BER values of received signal with the deployment of EDFA amplifier in the communication link. It can thus be concluded that the deployment of amplifiers in FSO link increases the channel capacity, link distance, link accuracy and reliability in presence of atmospheric attenuation.

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