Simulative Analysis of Inter-Satellite Optical Wireless Communication Link using Amplifier

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***Abstract*—Optical Wireless Communication (OWC) systems are considered as an attractive solution to meet the demands of higher data transmission speeds and channel bandwidth over longer link distances. Optical wireless communication links can be deployed for terrestrial communication links and also for inter-satellite communication links (IsOWC). Optical wireless communication is considered as an important communication technique for future inter-satellite communication links. In this paper, an inter-satellite communication link has been designed and its performance has been analyzed with and without the application of an amplifier. The results show that the application of an amplifier in an IsOWC link not only improves the performance of the transmission system but also increases the link range. This paper investigates the performance and effectiveness of application of Erbium Doped Fiber Amplifier (EDFA) in IsOWC link. The performance of the IsOWC link has been analyzed on the basis of Q Factor, BER, SNR, and total power of the received signal using OPTISYSTEM simulation software.**

Keywords*— *IsOWC, EDFA, BER, SNR, Q Factor, received power

I. INTRODUCTION

The demand for higher data transmission speed and highly secure inter-satellite communication links is increasing day by day in present world. Optical Wireless Communication (OWC) links have emerged as an attractive alternative to the existing microwave communication technology for inter-satellite communication links. Higher data transmission rates and secure communication links make OWC technology a promising one for the purpose of inter-satellite communication links [1]. The operating wavelength in IsOWC technology is very low, which results in transmitting the information in form of very narrow beam of light signal. The most important and necessary conditions for an effective IsOWC transmission link is Line of Sight (LOS) and synchronization between transmitter and receiver terminals. Also, the optical terminals used in IsOWC links are smaller in size, have lighter weight and also consume lower power as compared to microwave terminals [2]. In order to achieve data transmission with higher bit rates at low Bit Error Rates (BER) over a longer link distance in IsOWC system, it is recommended that a high input transmission power level or amplification of the information signal within the IsOWC link should be implemented [3]. For the purpose of amplification of information signal, EDFA amplifier plays an important role in satellite communication. EDFA tends to introduce very negligible amount of noise in the communication system which are also not responsive to the state of polarization f the information signal [4]. On the other hand, the increase in input transmission power levels can lead to many issues such as increase in cost, size, weight, complexity, and power consumption in IsOWC links [5]. In earlier work, the comparison of performance of NRZ modulation and RZ modulation format for IsOWC system is simulated and results show that RZ modulation format is a better choice in case for long haul IsOWC links [6]. RZ modulation format is better for long haul communication links but NRZ modulation format is preferred for short distance communication links as it is much cheaper and also is less complex as compared to that of RZ modulation format [7]. In this paper, an inter-satellite communication link has been simulated and its performance has been analyzed with and without the implementation of an EDFA amplifier within IsOWC link. The performance of the IsOWC link has been analyzed on the basis of Q Factor, BER, SNR, and total power of the received signal using OPTISYSTEM simulation software. Rest of the paper is organized as follows- In Section II, the proposed system model and design are discussed and simulation parameters used in the study are also presented. Results are resented and discussed in Section III and conclusion to this investigative study is given in Section IV.

II. SYSTEM MODEL AND DESIGN

In this paper, an inter-satellite optical wireless communication (IsOWC) link is designed and simulated using OPTISYSTEM simulation software. The main sections in an IsOWC link are the transmitter section, the propagation channel, and the receiver section. The model used performance analysis of IsOWC link used in this paper is presented in Fig. 1and the simulation parameters are given in TABLE 1

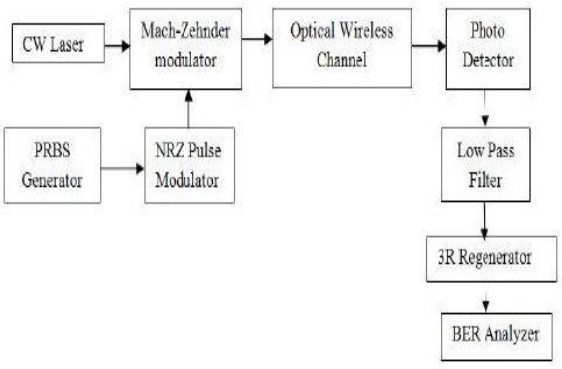

Fig.1: Model of Inter-satellite communication link

The IsOWC link model proposed in this investigative study consists of a Pseudo-Random Bit Sequence (PRBS) generator which produces information in the form of binary data. The binary data from the output port of the PRBS generator is then directed towards non return to zero (NRZ) modulator which converts the binary information signal into an electrical signal. The electrical signal from the output of NRZ modulator is then modulated by a Mach-Zender modulator and a continuous laser having operating wavelength of 1550 nm. The information signal in the form of optical pulses is then directed towards the free space/vacuum with the help of transmitting antenna. The information signal travels from source to destination free space/vacuum as propagation medium. The optical signal propagating in the free air suffers many losses due to atmospheric conditions. At the receiver terminal, the information signal is then collected by the receiving antenna and then is coupled to an optical fiber and amplifier by EDFA. The amplified information signal is then directed towards PIN Photodiode which converts the optical signal to electrical signal. The electrical signal from the PIN photodiode is then directed towards Bessel Low pass filter to remove and high-frequency noise present in the information signal. The quality of the receiver signal is analyzed by BER tester.

Table.1: simulation parameters

Serial No.	Simulation Parameter	Value/Type
1.	Operating Wavelength (nm)	1550
2.	Link Distance (Km)	200-1000
3.	Transmission Power (dB)	6-12
4.	Transmitter antenna diameter (cm)	20
5.	Receiver antenna diameter (cm)	20
6.	Amplifier	EDFA

III. RESULTS AND DISCUSSIONS

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

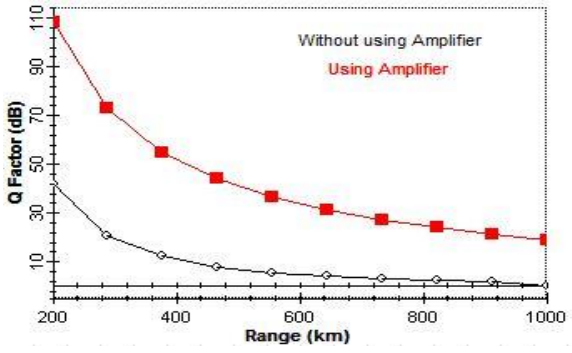

Fig.2: Q Factor v/s Transmission Distance

Figure.2, 3, and 4 depicts the Q Factor, SNR, and total power of received signal with and without using amplifier in IsOWC link in link distance of 200 Km to 1000 Km for transmission power level of 6 dBm. From Fig. 2 it can be seen that Q Factor lies in the range [110, 41] dB to [25, 0] dB in the link distance from 200 Km to 1000 Km with and without the implementation of EDFA amplifier in IsOWC communication link respectively. From Fig. 3 it can be seen that the SNR values of received signal lies in the range [42, 33] dB to [31, 4] dB in the link distance from 200 km to 1000 km with and without the implementation of EDFA amplifier in IsOWC communication link respectively. From Fig. 4 it can be seen that the total power of received signal lies in the range[-2, -57] dBm to [-19, -80] dBm in the link distance from 200 Km to 1000 Km with and without the implementation of EDFA amplifier in IsOWC communication link respectively. Fig. 5 and Fig. 6 depict the eye diagram of received signal at 1000 Km link distance and transmission power level of 6 dB with and without the implementation of EDFA amplifier in IsOWC communication link respectively.

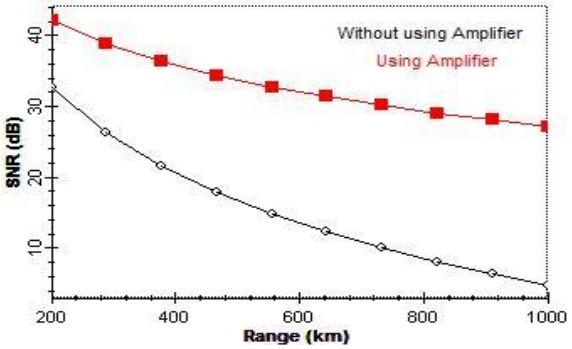

Fig.3: SNR v/s Transmission Distance

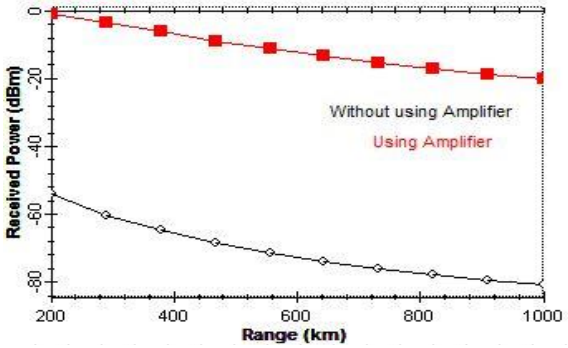

Fig.4: Received Power v/s Transmission Distance

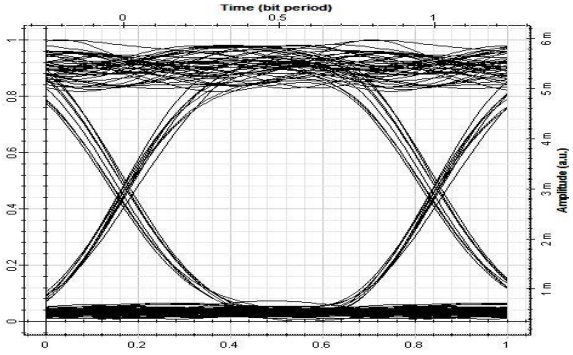

Fig.5: Eye Diagram of received signal at 1000 Km link distance with implementation of amplifier in IsOWC Link

TABLE.2 presents the values of Q Factor and BER of received signal in the link distance from 200 Km to 1000 Km with and without the implementation of EDFA amplifier in IsOWC communication link.

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

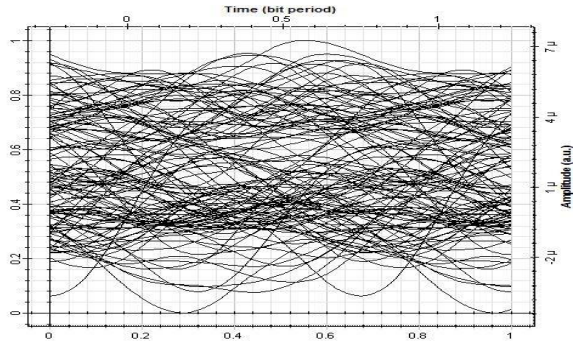

Fig.6: Eye Diagram of received signal at 1000 Km link distance without implementation of amplifier in IsOWC Link

Table.2: Comparison of Q factor and BER of received signal for link distance of 200 Km to 1000 Km

Trans-mission Distance	With implementation of amplifier in IsOWC Link		Without implementation of amplifier in IsOWC Link	
	Q Factor	BER	Q Factor	BER
200 Km	110.16	0	41.96	41.96 e-189
400 Km	65.86	0	10.93	3.65 e-028
600 Km	43.15	4.67 e-225	5.26	4.19 e-007
800 Km	32.01	3.54 e-179	2.81	2.44 e-003
1000 Km	25.04	7.61 e-138	0	1

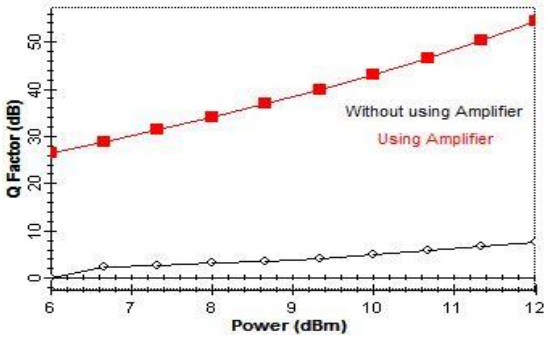

Fig.7: Q Factor v/s Transmission Power Levels

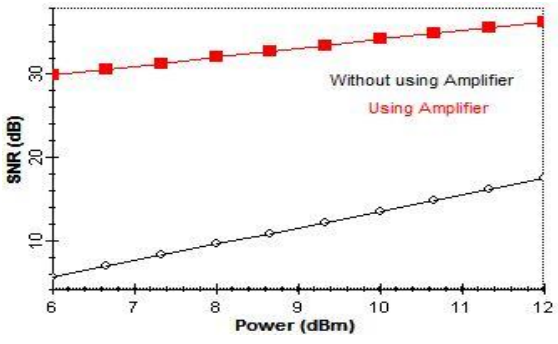

Fig.8: SNR v/s Transmission Power Levels

From Fig. 7 it can be seen that the Q Factor lies in the range [26, 0] dB to [54, 8] dB for transmission power levels varying from 6 dBm to 12 dBm with and without the implementation of EDFA amplifier in IsOWC communication link respectively. From Fig. 8 it can be seen that SNR values lies in the range [30, 8] dB to [38, 19] dB for transmission power levels varying from 6 dBm to 12 dBm with and without the implementation of EDFA amplifier in IsOWC communication link respectively. From Fig. 9 it can be seen that total received power lies in the range [-19, -80] dBm to [-11, -71] dBm for transmission power levels varying from 6 dBm to 12 dBm with and without the implementation of EDFA amplifier in IsOWC communication link respectively. Fig. 10 and Fig. 11 show the eye diagram of received signal for transmission power level of 12 dBm at link distance of 1000 Km with and without using EDFA amplifier respectively.

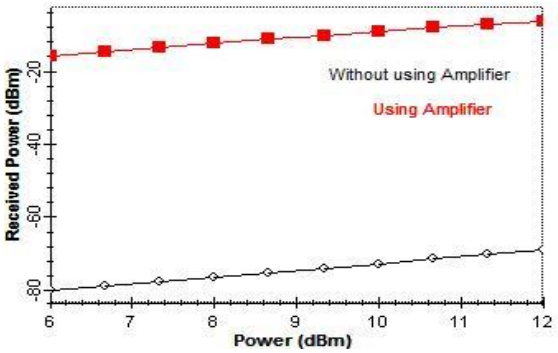

Fig.9: Received Power v/s Transmission Power Levels

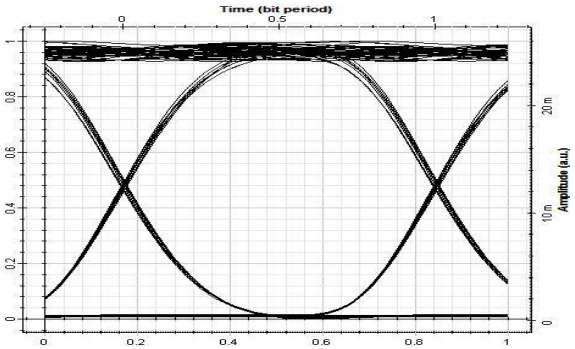

Fig.10: Eye Diagram of Received signal at 12 dBm transmission power level with implementation of amplifier in IsOWC Link

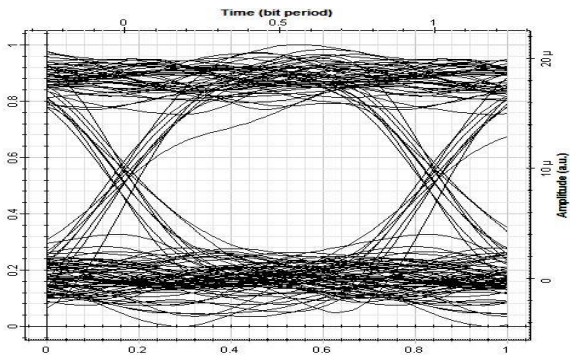

Fig.11: Eye Diagram of Received signal at 12 dBm transmission power level without implementation of amplifier in IsOWC Link

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

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

Trans-mission Power	With implementation of amplifier in IsOWC Link		Without implementation of amplifier in IsOWC Link	
	Q Factor	BER	Q Factor	BER
6 dBm	26.49	3.85 e-155	0	1
8 dBm	34.01	1.65 e-254	3.14	8.22 e-005
10 dBm	43.15	0	4.92	4.19 e-007
12 dBm	54.46	0	7.74	4.72 e-015

IV. CONCLUSION

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

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