Research Article

Performance Enhancement In WDM – FSO System Using Semiconductor Optical Amplifier Under Different Rain Conditions

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Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 28 April 2021

Abstract

The free space optics (FSO) is considered as an attractive technology of telecommunication networks, due to several benefits as compared to other communication systems. However, signal degradation due to various weather conditions caused by wave attenuation can distort the performance of (FSO) connection link. The optimum performance is achieved by connecting a 5 Gbps optical amplifier at different places within the system. A laser source of 35 dBm power was transmitted at different weather conditions. Two systems were compared and analyzed. Results represented by both parameters (Q-factor, BER).

Keywords: DWDM, SOA, Q Factor, Channel spacing, Bit Error Rate (BER)

1. Introduction

The extending demand of high quality signal and high bandwidth in telecommunication technology field lead to using laser in free space optics (FSO) instead of the classic radio frequency (RF). FSO can provide a viable point-to-point technique to satisfy the requirements of designing optical networks [1].

There are three main parts of the basic (FSO) communications system construction, transmission part, link (medium), and reception part. A correct configuration of the line of sight (LOS) is a requirement for FSO for sending and detecting signals. There are two choices of optical sources for sending signals in FSO, light emitting and laser diodes. Laser diodes are more effective due to high transmitted power and high signal directivity compared to LED [2,3].

Air is the transmission channel used to send data between transmitter and receiver. Receiver part includes a photo-detector of either (PIN) or (APD). APD is preferred in bad weather conditions due to its high sensitivity. Various parameters of FSO need to be optimized in order to provide high data rate transmission with secure and reliable link, as well as low power consumption, and lower cost of installation. Hence, FSO is used in several critical applications such as military communications and navigation. Although the features and deployment of FSO are attractive, however, difficult weather conditions limits the effectiveness of the system. As the performance would be changing according to the attenuation value based on refractive index of transmission channel due to atmosphere fluctuations.

Absorption, distortion, scattering and scintillation parameters are used to observe the effects of environment variation on transmission data rate of laser beam transmission [4,5]. The performance degrades depending on a variety of weather conditions such as (fog, rain, haze, snow). In this paper, the effects of rain are discussed. The boundary of rainfall rate changes in a range of about (85 – 100) mm/h. Maximum value of rain attenuation is 150 dB/km for FSO systems, while at microwave channel is 50 dB/km [6,7]. $\alpha\_specific = 1.076\ R^{0.67}$ [dB/km]

The variable R illustrates the boundary of rainfall rate in (mm/h), while specific attenuation is expressed by the rain amount.

The WDM system is a technology that includes a number of photonic carriers of information which are multiplexed within an optical laser beam that have various wavelengths. WDM is a unidirectional data transmission technology. It, also, enhances the speed of data transmission and system capacity, by utilizing optical amplifiers to reach high performance levels [8]. The circuits' complexity is reduced by the help of an optical amplifier, that works to amplify the optical wave signal directly without needing an electrical signal conversion. The laser beam uses line of sight (LOS) in free space as a communication link without optical channel cavity in the system. This paper includes the design of two systems, both have an array of 16 continuous wave (CW) laser sources, taking in account the performance under rain conditions changing among three cases: light, medium and heavy [9,10].

The results have been obtained and analyzed. All CW laser sources are passing through an optical amplifier in transmitter side. While in system II an additional optical amplifier has been added to the receiver side improving over system I. The evaluation of performance is done and compared in terms of bit error rate (BER), Q-factor and eye diagrams. For example, [11] studied and demonstrated the 3×2.5 Gbps WDM system of FSO module to compare between two systems with SOA optical amplifier, likewise, [12] studied and estimated the optimal performance of 16×2.5 Gbps WDM-FSO system under different weather conditions (clear, haze, rain, and fog). The maximum link range obtained was 3.3 Km at moderate rain. This paper provides 16×5 Gbps WDM-FSO system using channel spacing of 5 GHz (corresponding to 0.4 nm), with SOA optical amplifier being used, the transmission distance is varied to get an optimum Q-factor range of about 10, providing better data transmission.

2. WDM System Design:

There are three main parts in the construction of this system, transmitter, medium and receiver. The transmission part consists of (pseudo random bit sequence generator) at data rate 5Gb/s flow through NRZ pulse generator, CW laser, Mach Zehnder modulator that produce the optiwave modulated signal. The medium part is represented by FSO channel. An APD photodetector diode and Gaussian filter (LPF) are used in the receiver part. The quality of performance is evaluated by utilizing eye diagram analyzer which obtains information about Q-factor, BER, OSNR, and eye diagram.

Table (1) shows all system parameters. At the minimum attenuation window for 1550 nm wave length, the communication system is evaluated to give BER equal to 1E-9. The Opti-system software v12 is used for the design and simulation to show the specification of the system. While results graphs were prepared using Matlab. Both system I and system II have the same parameters.

The optimum performance was obtained in the construction of FSO and WDM system by utilizing (SOA) optical amplifier at both sides: transmitter and receiver parts as shown in Figure (1) (system II). The configuration values of the optical amplifier (SOA) was optimized to achieve best results for both systems.

Table 1: System Parameters.

Parameter	Value
Beam Divergence	2.5 (mrad)
Laser Power Level	30 (dBm)
Receiver Aperture	30 (cm)
Amplification Gain	30 (db)
Attenuation Level	Clear 0.233 (dB/km)
	Light Rain 3 (dB/km)
	Medium Rain 9 (dB/km)
	Heavy Rain 20 (dB/km)

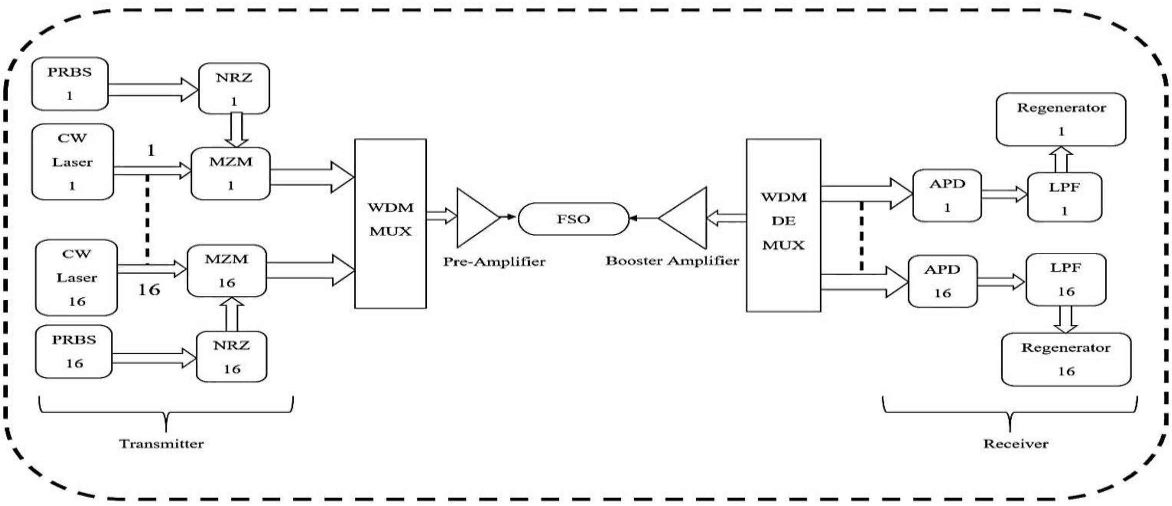

Figure (1): Block Diagram Representation of WDM-FSO

3.Results and Discussions

3.1. Simulation results analysis: This paper shows the influence of the changed parameters in the simulated system under different rain rate conditions (clear, light, medium, and heavy) to give optimized system. The simulation includes geometrical losses under various rain conditions. The longest acceptable transmission distance of system I was recorded in the simulation to be at 67.8Km under clear condition. The distance range is inversely proportional with attenuation and rainfall rate. The distance ranges under various rain conditions (light, medium, and heavy) were 19.3Km, 8.18Km, and 4.9Km respectively. These results, shown in Table (2), correspond to optimum Q-factor and eye diagram's opening. The introduced system II, includes two (SOA) amplifiers, one at each side of the system, i.e. one as a pre optical amplifier after MUX, the other as a post optical amplifier before DMUX (booster). In system II, it can be observed that the distance range increased. Moreover, the measured value of optical signal to noise ratio (OSNR) is greater than that of system I.

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Table 2: performance evaluation for both systems.

Weather Rain Condition	System I				System II			
	Max. link distance (Km)	Min. BER	Max. Q-factor	OSNR (dB)	Max. link distance (Km)	Min. BER	Max. Q-factor	OSNR (dB)
Clear	67.8	7.32E-10	6.23	16.4	89.7	5.23E-26	14.2	20.2
Light rain	19.3	2.43E-9	5.92	15.9	28.6	3.21E-23	10.5	19.3
Medium rain	8.18	3.8E-9	5.96	15.9	13.7	3.3E-23	10.53	19.5
Heavy rain	4.9	6.73E-8	5.64	15.3	6.98	7.31E-21	9.41	18.9

3.2. Comparison between system I and system II: Table (2) illustrates an optimum performance comparison between system I and system II in terms of distance range, BER, OSNR, and Q-factor. For the sake of producing the optimum performance levels, FSO system used a WDM 16-channel utilizing (SOA) optical amplifiers of similar specifications at both systems. However, system II design uses different placement of (SOA) amplifier.

The type of (SOA) used in this paper is gain optical amplifier. In both systems, pre-optical amplifiers after MUX were used, though system II adds a post-optical amplifier before DMUX. Simulation result achieved in system II are superior to those of system I as shown in Table (2) under all rain condition. The transmission distance under clear condition obtained in the simulation is 67.8Km for system I, but in system II it was increased to 89.7Km. Under rainy conditions (light, medium and heavy), system II also achieved better results compared to system I. The observed maximum transmission distance ranges were 28.6Km, 13.7Km, and 6.98Km for light, medium, and heavy rain conditions respectively. Moreover, with help of the eye diagrams opening shown in Figure (2), system II can be observed to be better than system I regarding both Q-factor and BER.

Figure 2.a shows the graph of system I performance in terms of Q-factor of optical transmitted signal increased from 16.9 to 6.18 when the transmission distance was increased from 12 Km to 85 Km, due to variation of attenuation level following weather condition fluctuations.

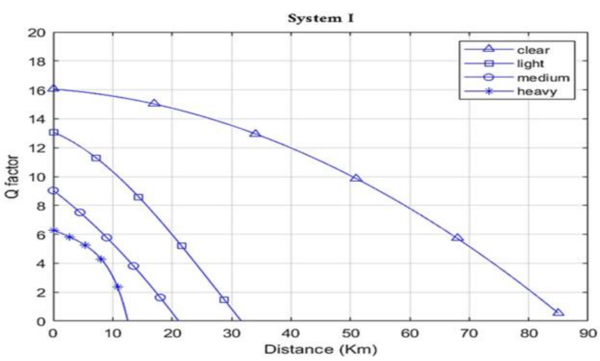

Figure 2.a: Q Factor vs. distance

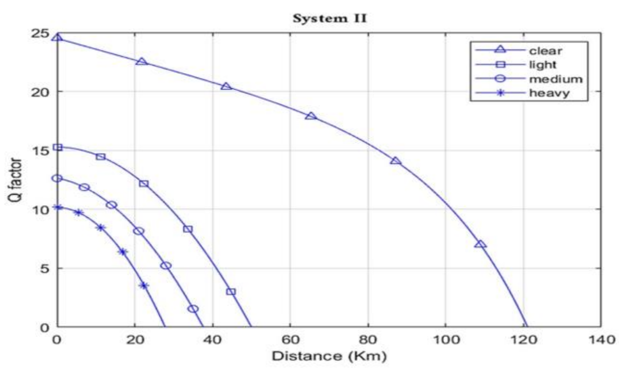

Figure 2.b: Q Factor vs. distance

However, the graph of system II shows the Q-factor value decreased from 24.5 to 11.5 when the transmission distance was increased from 27.6 Km to 120.2 Km for the same reason. So the obtained results of improved optical communication system II shows that higher Q-factor was achieved.

Figure 3.a of system I shows that the measured value of BER decreases from 1E-10 to 1E-40 when the transmission distance was increased from 7 Km to 87 Km. It also shows that the bit error rate increased when the attenuation level increased due to variation of weather conditions.

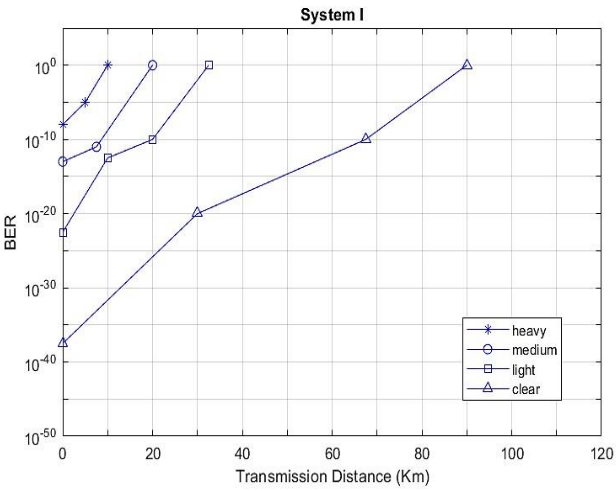

Figure 3.a: BER vs. distance

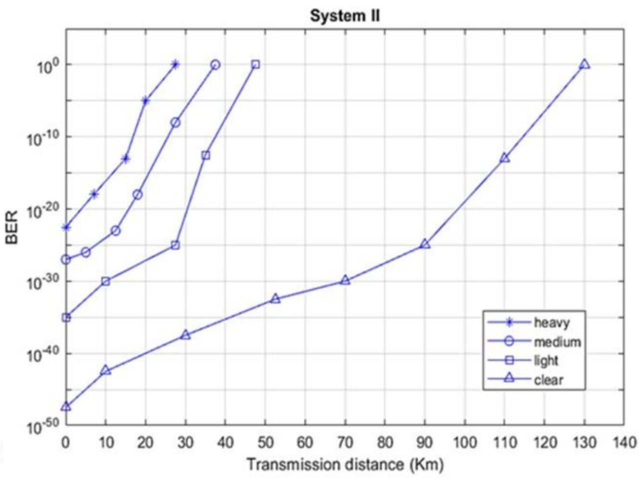

Figure 3.b: BER vs. distance

But figure 3.b of system II illustrates lower BER than in system I under the same optical signal propagation and weather conditions, such as transmission distance increasing from 22 Km to 120 Km. That corresponded with the measured value of BER not exceeding a range between 1E-22 to 1E-52. So a lower BER with higher performance in system II was achieved.

4.Conclusion: FSO technology is applied extensively at the present time in many regions due to easier installation, and higher performance and security compared to other conventional networking technologies. But the bad weather causes signal degradation and reduce the performance. An improved configuration utilizing (SOA) optical amplifier is introduced in this paper. The proposed design was simulated and results were analyzed. Analysis showed an improvement in Q-factor, BER, and OSNR level in terms of transmission distance. This proposed system could help in increasing the data rate and transmission distance.

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