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Impact of Erbium Doped Fiber Amplifier on WDM-FSO System under Rain Attenuations

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ABSTRACT: Free-space optical (FSO) communication offers the potential to send large amounts of data securely through free space without the expense of laying fiber-optic cable. The primary limitation of FSO system is atmospheric attenuations that may lead to high bit error rate (BER) of the system and makes the communication link impractical. This work is focused to reduce the effect of different rain attenuations (heavy, medium and light rain) on combined WDM-FSO system. The effort in this paper is to propose a solution to this problem by the addition of Erbium doped fiber amplifier with WDM-FSO system and thus improves the strength of weak signal. Also, comparison is done in the presence and absence of Erbium doped fiber amplifier (EDFA) on the WDM-FSO system under different rain attenuations through the evaluation of Q factor and bit error rate (BER).

KEYWORDS: Bit Error Rate,Erbium Doped Fiber Amplifier, Free Space Optics,Q factor, Wavelength Division Multiplexing(WDM).

I.INTRODUCTION

Free-space optical (FSO) communication is a line of sight (LOS) technology in which modulated beam of visible or infrared (IR)light is transmitted over free space for telecommunications or computer networking. It enables optical transmission of voice, data and video communications upto 2.5 Gbpswithout deploying optical fiber cable[1]. FSO bring many advantages to moderncommunications including large bandwidth, license free spectrum, high data rate, low power, higher safety of transmission due to narrow optical beams etc. The increasing demand for high-capacity telecommunication links and the speed limitation of single-wavelength links has resulted in a remarkable increase in the use of Wavelength Division Multiplexing (WDM) in advanced lightwave networks. So WDM network can be applied in FSO systems to improve the system performance with high speed and long distance [2].

Quality of FSO system is greatly affected by atmospheric attenuations. Attenuation is one of the primary parameter that limits the performance of FSO system. It results in the reduction in the strength of signal when it propagates through atmosphere due to different weather conditions. So it is necessary for FSO system to take weather conditions into considerations such as rain, fog,haze etc [3]. Rain is the major attenuation factor in environment for light ray. Rain intensity factor affects the performance of FSO communication system as the attenuation linearly increases with rainfall rate. Attenuation due to rainfall is called non-selective scattering because the radius of raindrops is significantly larger than the wavelength of FSO light sources.Large drops of rain scattered the optical beam and results in reflection and refraction.

The goal of this paper is to reduce the effects of rain attenuations on WDM-FSO system and proposes an appropriate way to mitigate the rain attenuation through the addition of Erbium doped fiber amplifier with the system architecture.

II.LITERATURE SURVEY

The fundamental problem related to FSO system is effect of attenuation under different atmospheric conditions which depends upon temperature and pressure of the atmospheric region through which the signal has to pass.Itaffects the quality of received signal and can result in high bit error rates, scattering and absorption of visible and IR optical beams, thus lowering and degrading the FSO system performance.

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Atmospheric attenuation is described by the Beer's Law as:

$$\tau = e^{-(\beta abs+\beta scat)\ R}(1)$$

where τ is the atmospheric attenuation, R is the link distance and β_{abs} and β_{scat} is the absorption and scattering coefficient respectively.

Snow, rain and fogcause scattering of the signal and are the most critical weather conditions. Fog is composed of fine droplets of water, smoke, ice or combination of these suspended in the airnear the Earth's surface.Fog being microns in diameter, hinder the passage oflight by absorption, scattering and reflection. Absorption occurs when there is an interaction between the propagatingphotons and molecules along its path. This causes a decrease in the power densityof the FSO beam and affects the availability of a system. However,theuse of suitable power based on atmospheric conditions, and use of multiple beams within an FSO-based unit maintain the required level of networkavailability [4].
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III. RAIN ATTENUATION PREDICTION MODEL

Rain attenuation prediction is referred as "specific attenuation" which means attenuation per unit length.The specific attenuationdue to rainin dB/km is given by Carbonneau model [4] as:

$$\alpha_{\ rain}=1.076\ R^{0.67}(2)$$

where $\alpha_{\ rain}$is attenuation due to rain andR is rainfall rate in mm/hr.

Rain can be categorized as heavy, medium and light rain [5] depending on the intensity with which it is falling is shown in Table 1.

Table 1: Attenuation values of different rain attenuations based on rainfall rate

TYPE	RAINFALL RATE (mm/hr)	ATTENUATION VALUES (dB/km)
HEAVY RAIN	80	19.27
MEDIUM RAIN	40	12.27
LIGHT RAIN	26	9.23

IV.SYSTEM ARCHITECTURE

The block diagram for WDM-FSO system with EDFA is shown in Fig. 1. Here TX and RX represents transmitter and receiver section respectively.Transmitter section consist of Pseudo Random Binary Sequence (PRBS) generator that generates a random sequence of binary numbers for the system to transmit. Then Non return to zero (NRZ) pulse generator shapes the input digital signal to the electrical signal. The Continuous wave (CW) laser generates optical signal and each optical signal is modulated by Mach-ZehnderModulator (MZM).These optical signals are multiplexed into one optical signal by a multiplexer and propagates through the atmosphere, which act as FSO channel.At the receiving side, a demultiplexer is required to separate optical signal and each of the optical signals is detected by photodetector.A low pass filter is used to filter the signal from noise. BER analyzer automatically calculate the BER value,Q factor and display eye diagram.

When the signal propagates through FSO channel, the strength of the received signal becomes weak due to atmospheric attenuation. Therefore, the system requires an optical amplifier after the FSO channel to amplify the weak signal.In this simulation,signal attenuation has been considered as 19.27 dB/km, 12.27 dB/km and 9.23 dB/km for heavy, medium and light rain attenuations respectively.Here, Erbium doped fiber amplifier is used to amplify thedistorted signal caused by rain attenuations as it gives better performance than the usual electronic amplification. In EDFA, amplification occurs when the pump laser excites the erbium ions, which reaches to a higher energy level and then decays to lower

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state and releases its energy [6]. Wide bandwidth, high gain, high saturation output, and low noise are the characteristics of Erbium doped fiber amplifier.

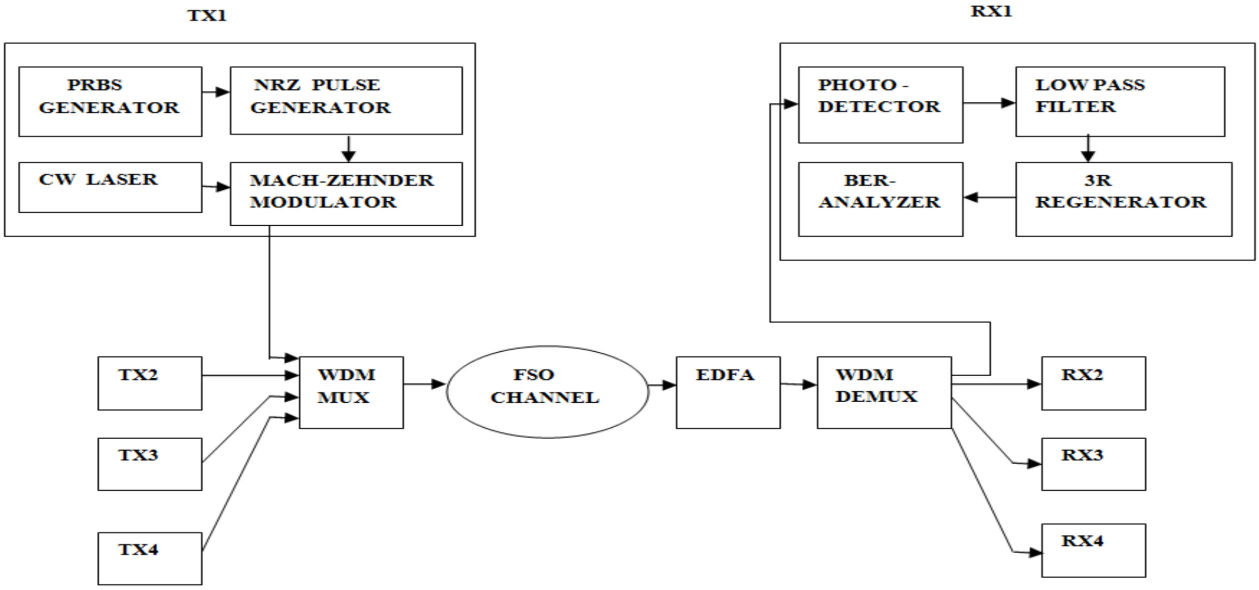

Fig.1 Block diagram of WDM-FSO system in presence of EDFA.

V. SIMULATION MODELLING

The simulation set up for WDM-FSO system with EDFA is modeled using Optisystem version 12 simulation software is shown in the Fig. 2. In this system, each Pseudo Random Bit Sequence (PRBS) generator generates 2.5 Gbps bit rate data. These signals are then light modulated using Mach-Zehnder Modulator (MZM) using laser source of power 10 dBm.100 GHz channel spacing is given to the system. These modulated signals are multiplexed using WDM multiplexer having 4 input ports. The multiplexed signals are then propagated through FSO channel, which is considered under heavy, medium and light rain attenuations. Here the attenuation value is taken as 19.27 dB/km (heavy rain), 12.27 dB/km (medium rain) and 9.23 dB/km (light rain). So, EDFA offiber length 5 m is inserted after the FSO channel to a range of 1 km.The forward pump power of EDFA is set to 100 mW. The apertures of transmitter and receiver of FSO channel are set to 5 cm and 20 cm respectively. At the receiver end, the signals from FSO channelare demultiplexed and converted to electrical signals using Avalanche photodiode (APD). Then it is fed to low pass Bessel filter for filtering the signal from noise. Regenerator regenerates the distorted signals and displays it on the BER analyzer.

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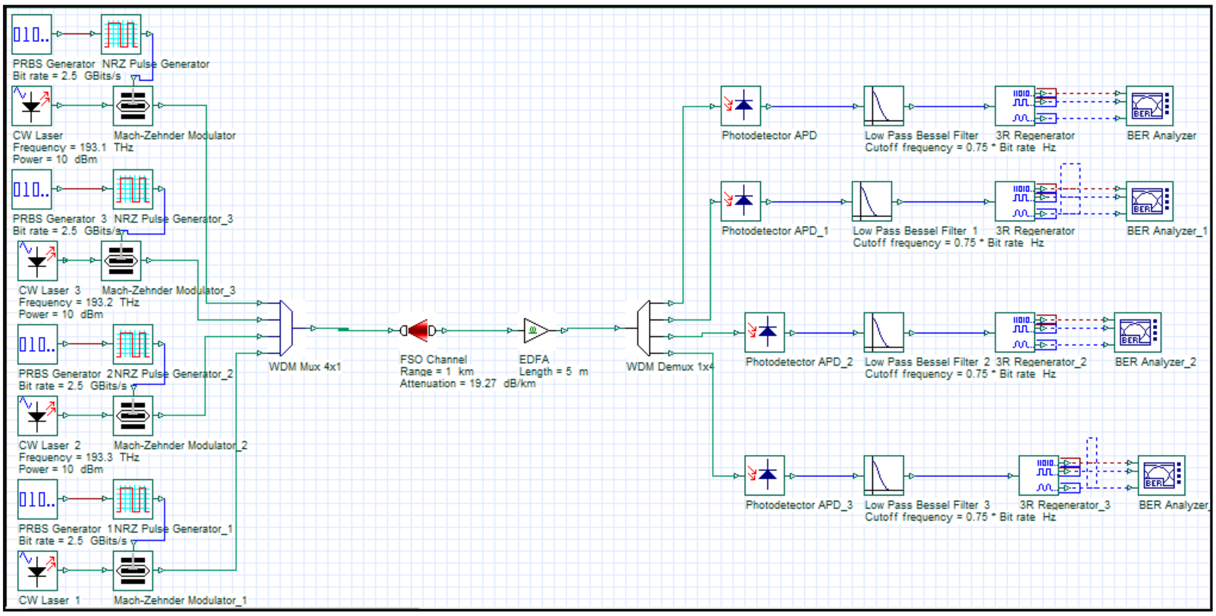
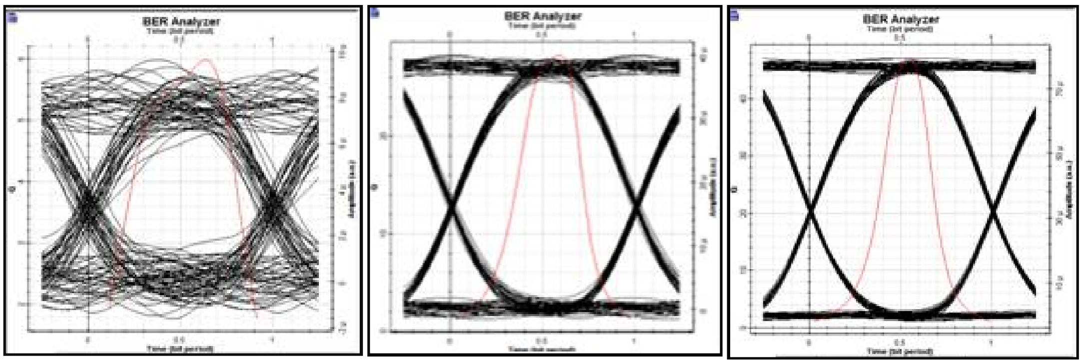


Fig. 2 Simulation model of WDM-FSO system with EDFA under rain attenuations.

VI. RESULTS AND DISCUSSION

The performance of WDM-FSO system in the absence and presence of EDFA is analyzed in this section.

WDM-FSO system without EDFA



(a) (b) (c)

Fig.3 Eye diagram analysis of WDM –FSO system without EDFA under (a) heavy rain (b)medium rain and(c)light rainattenuations.

Eye diagram of WDM-FSO system under heavy, medium and light rain attenuations in absence of EDFA is shown in Fig. 3.In the absence of EDFA,the received power of the signal is very less under rain attenuations. This can be improvedby the insertion of EDFA in the system.

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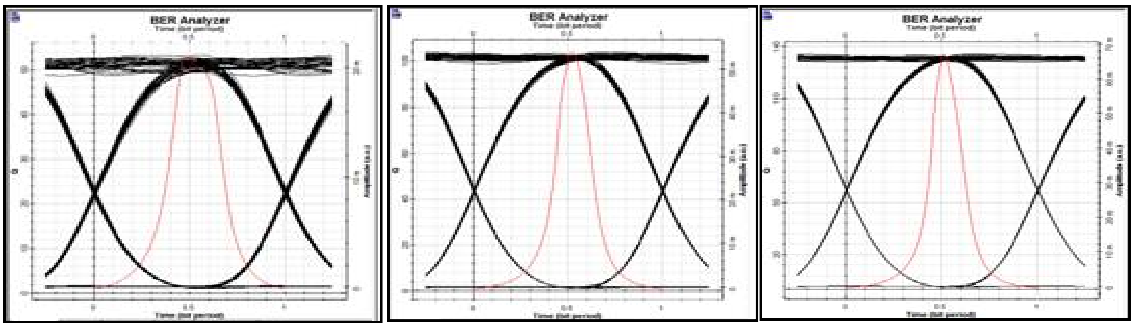
WDM-FSO system with EDFA



(a) (b) (c)

Fig.4 Eye diagram analysis of WDM –FSO system with EDFA under (a) heavy rain (b)medium rain and(c)light rain attenuations.

Eye diagram of WDM-FSO system under heavy, medium and light rain attenuations in the presence of EDFA is shown in Fig. 4.It is found that after the insertion of EDFA in WDM-FSO system, the system performance is improved under different rain attenuations.

Table 2: Simulation output of WDM-FSO system in absence and presence of EDFA under rain attenuations.

Rain Attenuations	WDM-FSO system without EDFA		WDM-FSO system with EDFA	
	Minimum BER	Q factor	Minimum BER	Q factor
HEAVY RAIN	1.06616e-009	5.98687	0	53.318
MEDIUM RAIN	1.148e-176	28.3143	0	103.95
LIGHT RAIN	0	47.0489	0	135.867

The comparison among the parameters of WDM-FSO system in the absence and presence of EDFA under rain attenuations is shown in Table 2.BER appears to decrease and Q-factor appears to increase after the insertion of EDFA in the system configuration. Addition of EDFA produces better eye diagram with Q factor 53.318,103.95 and 135.867 for heavy, medium and light rain respectively. It is noticed that the received signal strength of WDM- FSO system is enhanced after incorporating the EDFA at the receiver side when compared with system without EDFA.

VII.CONCLUSION

Free Space Optical Communication provides wide applications in all fields.Fasterinstallation, license free spectrum, no need of digging in FSO communications.In this paper, the simulation results in absence and presence of EDFA in the receiver side of WDM-FSO system is investigated.The results of simulations has been observed in terms of Q factor and minimum bit error rate. A significant reduction in the values of BER and increase in the value of Q factor is observed with presence of EDFA in WDM-FSO system. It is concluded that the introduction of EDFA increases the accuracy and reliability of the system under rain attenuations which will be useful for real time applications.

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BIOGRAPHY

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