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Simulative Investigation of WDM-FSO Link under Different Atmospheric Conditions

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***Abstract*— Free space optics (FSO) technology has various advantages over different communication systems such as higher data rates/speed, bandwidth and capacity despite of these advantages, it has attenuation problem which can degrade the system performance. So by using Wavelength Division Multiplexing (WDM) over FSO link, the system capacity can be increased. In this paper, 8channels WDM-FSO system has been designed and analyzed in worst weather conditions at 1550 nm wavelength using NRZ modulation. The performance of the simulated system has been investigated in terms of quality (Q) factor, bit error rate (BER) and maximum link distance. The simulation work reports a minimum value of Bit Error Rate (BER) attained is greater or equal to 10^{-11} for optimized link range. The optimized link range for heavy rain, light rain, heavy haze, light haze, clear and very clear sky is achieved as 4km, 10km, 16km, 50km, 150km and 190km respectively.**

Keywords*— Free Space Optics, Bit Error Rate, semiconductor optical amplifier, wavelength division multiplexing.

I. Introduction

FSO systems offer excellent automatic power-level control, and eliminate short-distance optical saturation [1].Free Space Optics (FSO) is a communication technology that uses light as carrier and free space as medium to transfer information from one point to other point.The data which has to be transmitted is modulated on the intensity, phase and frequency of the carrier signal [2]. In FSO system different modulation techniques are used to modulate information signal at source. Each FSO system uses a high-power optical transmitter for transmit source signal towards destination and receiving side high sensitivity receiver used. But the atmospheric attenuation is major challenge for faced by FSO systems which affect the performance of the link. The other factors which can affect the FSO are humidity, water-vapors, signals absorption, smoke, beam scintillation, spreading and wandering are some of the factors [3]. It desires an unobstructed line-of-sight between the transmitter and receiver for proper operation of an FSO system. FSO systems operates around 850 and 1550 nm wavelengths and the frequencies corresponding to this range of wavelengths is around 200 THz.1550nm wavelength is preferred because of more eye safety and reduced solar background radiation[4].

The main objective of any communication system is to increase the link distance and speed. In the field of FSO communication, the wavelength division multiplexing (WDM) is one of the most popular technique used to provide long distance transmission. So WDM approach can be applied in FSO systems to enlarge the bandwidth usage in cheaper way [5]. WDM system is designed to conquer the problem of FSO signal degradation due to atmospheric disorder [6]. WDM system has high capacity so that it has ability to achieve high data rate and longer link distance due to more laser power [7]. There has been studied lot of different works reported in the literatures on the contact of weather attenuation on (FSO) link. Most of the works based on theoretical [8, 9], simulation and experimental [10].

Rest of the paper organized as follows: Section II describes the simulation setup. In Section III simulation results and discussion have been reported and conclusions are given in IV.

II. Simulation Setup

The simulation setup of 8-channel WDM-FSO communication system with 100 GHz channel spacing is shown in "Fig. 1". On the transmitter side we have used Pseudo-Random Bit Generator, NRZ Pulse Generator, CW Laser, Mach-Zehnder Modulator and WDM-MUX. Each input signal is modulated by NRZ format. The transmitter optical signal is the transmitted over FSO link under different weather attenuation conditions. On the receiver side firstly the SOA preamplification is done to raise the signal strength then WDM-DEMUX is used to separate the different signals, APD photo detector is used to detect the signal, then filtering of the signal is achieved by Bessel filter and then to visualize the signal a visualizer tool is used. With appropriate parameters, the WDM based FSO system can be optimized to achieve a maximum link range of operation. These system design parameters are given in Table I. The quality of the received signal is considerably depends on the conditions of the FSO channel and the WDM system design.

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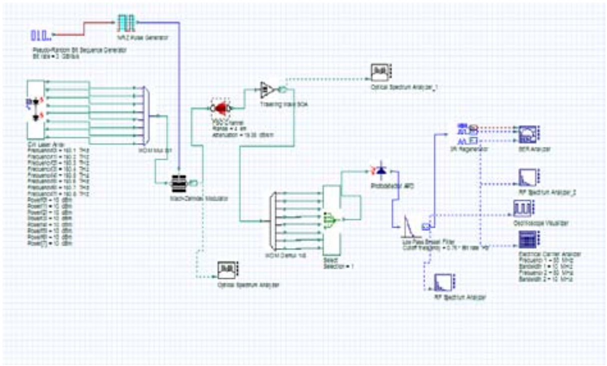


Fig. 1. Simulation setup of 8-channel WDM -FSO communication link

Table I. Simulation parameters

Parameter	Value
Bit rate	3 Gbps
Power	10 dBm
CW array laser frequency	193.1-193.8 THz
Transmitter aperture diameter	10 cm
Receiver aperture	20cm
Beam divergence	1 mrad

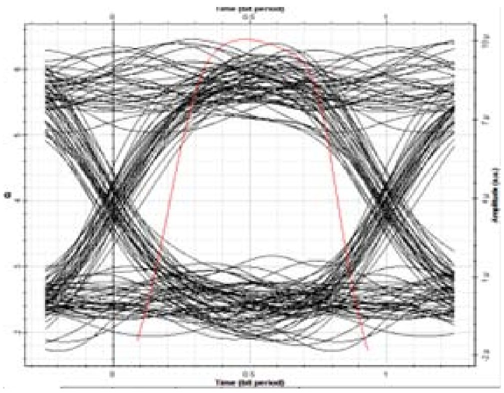
III. SIMULATION RESULTS AND DISCUSSIONS

This paper presents simulated results for analyzing the performance of 8 channel WDM-FSO communication link under different weather conditions. This system is running at maximum link range. The performance analysis of the system under heavy rain, medium rain, light rain, heavy haze, light haze, clear sky and very clear conditions are shown in Table (2). It can be seen that under optimized conditions of laser power and data rate, the increase in the attenuation causes reduce in the maximum transmission link with acceptable BER and Q-factor. It can be seen that for clear weather condition the maximum link can be carried out up to 190 km while it get reduced to 4 km for heavy rain condition. The eye opening and BER for the clear, heavy haze, light rain and heavy rain are seen in “Fig.2”.

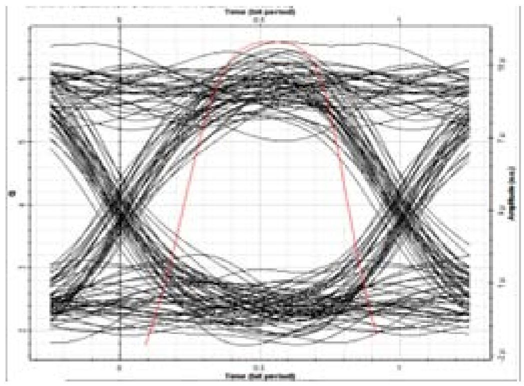
Table II. Performance analysis of system under different atmospheric conditions

Weather Condition	Attenuation (dB/km)	Max. Link Range (Km)	BER	Q. Factor
Heavy rain	19.30	4	5.53963e-11	6.45143
Medium rain	12.0	6	2.19225e-11	6.58931
Light rain	7.0	10	1.77301e-11	6.62166
Heavy haze	4.0	16	1.03874e-11	6.70006
Medium haze	2.0	30	2.05813e-11	6.59876
Light haze	1.4	50	9.42434e-11	6.37043
Clear	0.31	150	9.78491e-11	6.36372
Very clear	0.233	190	2.00113e-10	6.25393

Eye diagrams at different atmospheric conditions are shown below:



(a)



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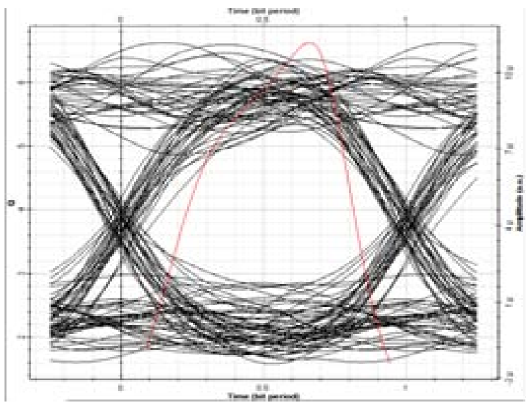

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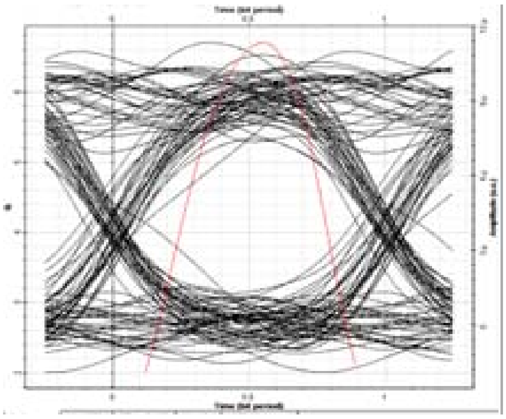

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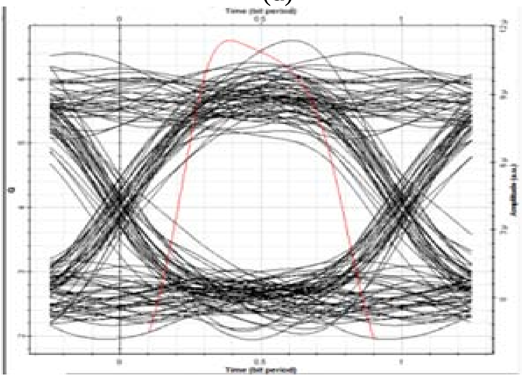

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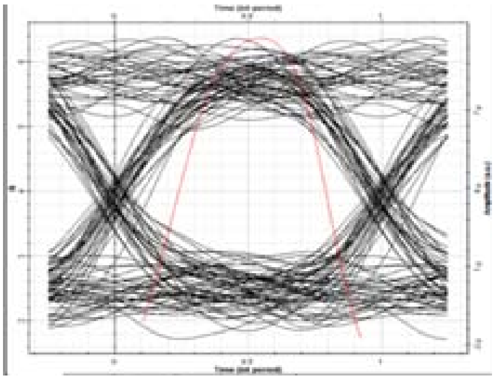

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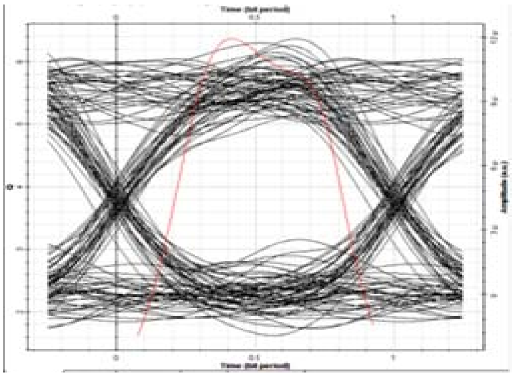
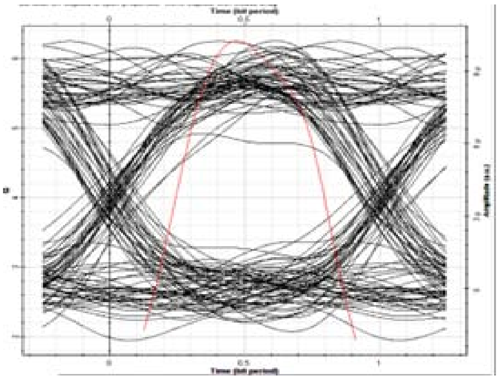


(g)



(h)

Fig.2. Eye diagrams for different conditions: (a) heavy rain (4km), (b) moderate rain(6km), (c) light rain(10km) (d) heavy haze (16km), (e) moderate haze(30km), (f) light haze(50km), (g) clear (150km) & (h) very clear sky(190km).

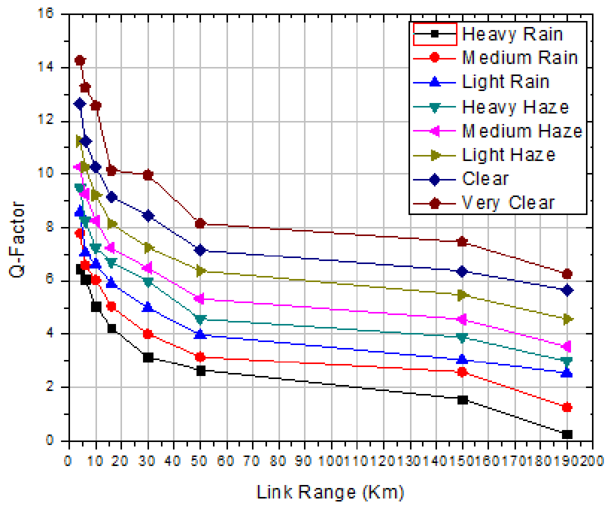


Fig. 3. Q-factor v/s range

Fig. 3 shows that max. Q. factor with respect to link distance under different weather conditions. The increase in the attenuation leads to decreasing in the distance link. The acceptable Q- factor was about 6.45143 and 6.25393 for heavy rain and very clear weather at the maximum link range.

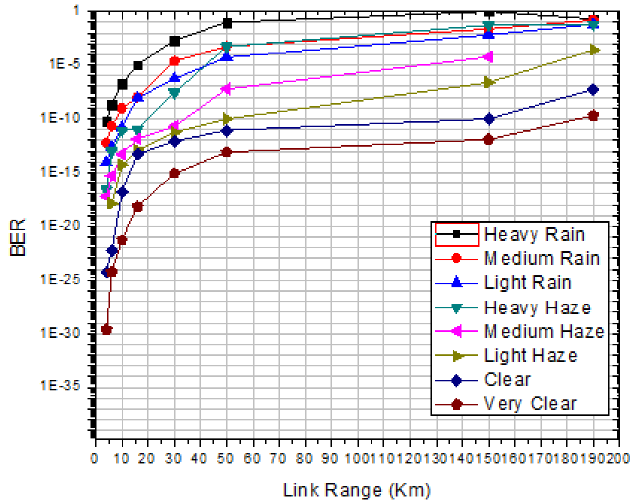


Fig.4. BER v/s range

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Fig. 4 shows the curves of the BER v/s link range for different weather conditions. In this case, it is noticed that for BER e10-11, the distance transmission is limited to 150 km, 50km and 16 km for clear, light haze and heavy haze, respectively as shown in Table (2). It can be seen that the BER curves decreases with increase in the distance of transmission. In this case, for strong attenuation the data transmission does not exceed 10 km, 6 km and 4 km for light rain, medium rain and heavy rain respectively. This decrease in distance of data transmission comes from increase in attenuation coefficient.

IV. Conclusion

This paper emphasizes on the simulation analysis of WDM-FSO communication link using digital data format (NRZ modulation technique) and TWT-SOA optical amplifier is used for amplification. The performance of the system is explored under improved optimized parameters. In this paper, maximum link range for the heavy rain condition about 4 km at BER 10^{-11} and for heavy haze condition about 16 km at BER 10^{-11}, also for very clear sky the distance reached up to 190km at BER 10^{-10} is concluded.

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