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Design & investigation of 32 Channel WDM-FSO Link under Different Weather condition at 5 & 10 Gb/s

Jaskaran Kaur[1], Manpreet Kaur[2]

[1]M.Tech scholar/Department of Electronics & Communication Engg. SBBS University, Punjab, India

[2]Assistant Professor /Department of Electronics & Communication Engg. SBBS University, Punjab, India

Abstract

FSO communication system use Free Space as a communication channel, where free space introducing several effect on FSO communication system mainly atmospheric attenuation effects. The attenuation offered by different atmospheric conditions can degrade the system performance. By using appropriate optical amplifier, the system's performance can be enhanced. WDM over FSO link can increased the information carrying capacity of the system. Hybrid amplifier (EDFA + SOA) is used to overcome the effect of attenuation. In this paper, 32channel WDM-FSO system is simulated at bit rates 5Gb/s & 10Gb/s under different weather conditions using NRZ modulation technique. The Performance of WDM-FSO system is investigated in terms of Bit Error Rate (BER) and Q-factor. The simulation results shows that, the maximum link range of 434km is achieved at data rate 5Gbps and 412km at data rate 10Gbps for very clear weather conditions & 6.2 km & 5 km at 5Gb/s & 10Gb/s respectively under heavy rain condition.

Keywords: APD (Avalanche photodiode), FSO, BER (Bit Error Rate), Atmospheric attenuation, WDM (Wavelength division multiplexing), Hybrid amplifier.

1. INTRODUCTION

Free Space Optical communication is a technology where free space is used as a communication medium/channel. 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 basic block diagram of FSO (Free Space Optic) communication system is shown in Figure 1. [1]

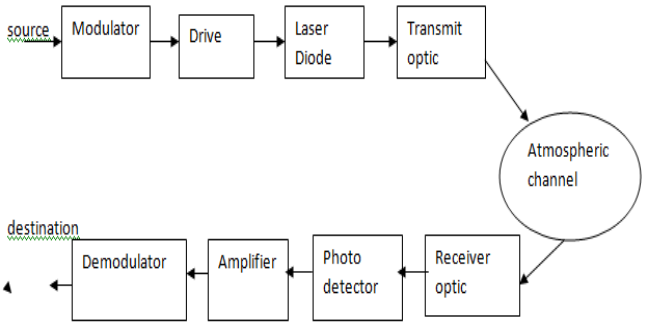


Figure 1. Block Diagram of Free Space Optical Communication system

The major challenges for FSO communication system is Atmospheric conditions such as: Haze, Fog, Snow, Dust and Rain. These Atmospheric conditions case higher attenuation in system. The attenuation present in the system reduced the performance of system. The particles which effect the most on FSO communication link are discuss below:

Haze—Atmospheric attenuation present in FSO system leads to the reduction of its performance. The Atmospheric attenuation effect the particles presents in the air such as fog, rain, dust haze etc. Performance of FSO system depends on the attenuation value at different level of visibility. Haze particle stay long time in air rather than any others. Haze mainly effect the visibility of the link. Because due to Haze more particles stay longer in atmosphere compared to Rain, it presents more degradation on FSO system.[2]

Rain—Rain intensity factor is capable of attenuating laser power or rain is distance- reducing impact of free space optical communication system. Rain is formed by water vapor contained in the weather. The rain impact is slightly less than that of other atmospheric conditions. Scattering due to rain is called non- selective scattering, because the radius of raindrop is larger than the wavelength of typically FSO laser sources. Rain attenuation value are moderate in nature. There are two conditions of Rain i,e light rain and heavy rain. The haze particles are small and stay longer in atmosphere but the rain particles are very large and stay shorter in atmosphere. [3]

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

2. SIMULATION SETUP

32-channel WDM-FSO communication system is designed and simulated in Optisim simulator software. The block diagram of simulation setup is shown in Figure 2. In this simulation setup, the WDM-FSO system is divided into three sections as

(a) Transmitter section
(b) FSO channel
(c) Receiver section

On the transmitter side, the Pseudo-Random Bit Generator, NRZ Pulse Generator, CW Laser, Mach-Zehnder Modulator WDM-MUX and EDFA+SOA amplifier are used. Each input signal is modulated by NRZ format. The transmitter transmit the optical signal over FSO link under different weather attenuation conditions as shown in diagram.[4]

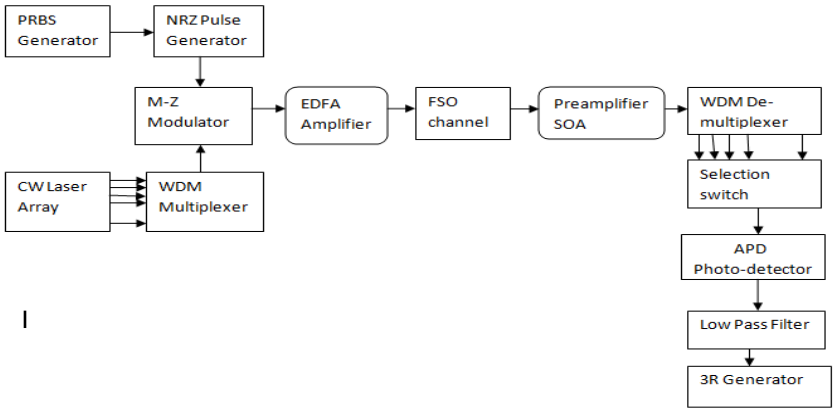


Figure 2 Simulation setup of 32 Channel WDM based FSO system.

On the receiver side firstly the SOA pre-amplification is connect to raise the signal strength after that 1x32 WDM De-multiplexer is used to separate the different signals. These signals separated by WDM De-multiplexer are detected by APD photo-detector . Filtering of the signal is achieved by Bessel Low pass filter. Visualizer tool such as BER analyzer is used to visualize the signal. The quality of the received signal is mainly depends on the conditions of the FSO channel and the WDM system design.

Table 1: Simulation parameters

Parameter	Value
Bit rate	5 &10 Gb/s
Laser wavelength (λ)	1552 nm
CW array laser frequency	193.1-196.2THz

Transmitter aperture diameter	10 cm
Receiver aperture	20cm
Beam divergence	1.5 Mrad

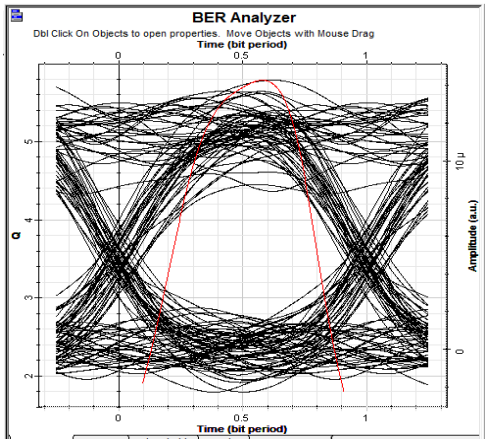
3. RESULT & DISCUSSION

This paper presents the simulated results for analyzing the performance of 32 channel WDM-FSO communication link under different weather conditions. This system is running at maximum link range with high speed data rate up to 5 & 10Gb/s. The performance evaluation of the system under heavy rain, light rain, heavy haze, light haze, clear sky and very clear conditions are shown in Table 2. It can be seen that 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 achieved up to 434 km & 412 km at 5 & 10Gb/s respectively while under heavy rain condition it get reduced to 6.2 km & 5km at data rate 5 & 10Gbps. The eye diagram for the very clear sky, clear, light haze, heavy haze, light rain and heavy rain are shown in Figure 3 & 4. Table 2 & 3 demonstrate the performance of the 32 channel WDM-FSO communication link under different weather conditions at 5 Gb/s & 10 Gb/s respectively.

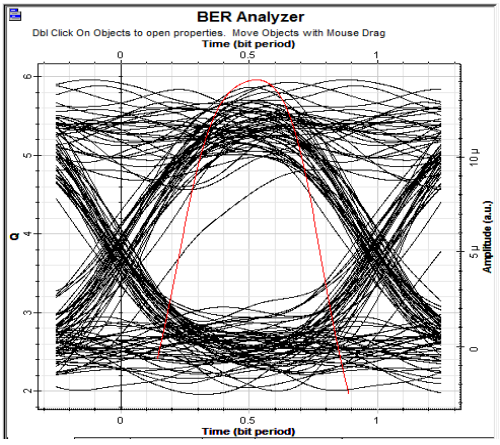
Table 2: Performance analysis of 32x5 Gb/s system under different weather conditions.

Weather Condition	Attenuation (dB/km)	Power (dBm)	Max. Link Range (Km)	BER	Q-Factor
Very clear sky	0.18	-10	434	$3.5684e^{-009}$	5.78632
Clear	0.36	-10	323	$1.24696e^{-009}$	5.96147
Light haze	0.61	5	151	$1.30887e^{-010}$	6.31979
Heavy haze	2.7	10	39.5	$2.16908e^{-010}$	6.24087
Light rain	6.8	10	16.7	$1.30779e^{-009}$	5.94626
Heavy rain	19.8	10	6.2	$4.22688e^{-009}$	5.75844

Eye diagrams under different weather conditions for 32x5 Gb/s WDM-FSO system are shown below:



(a)



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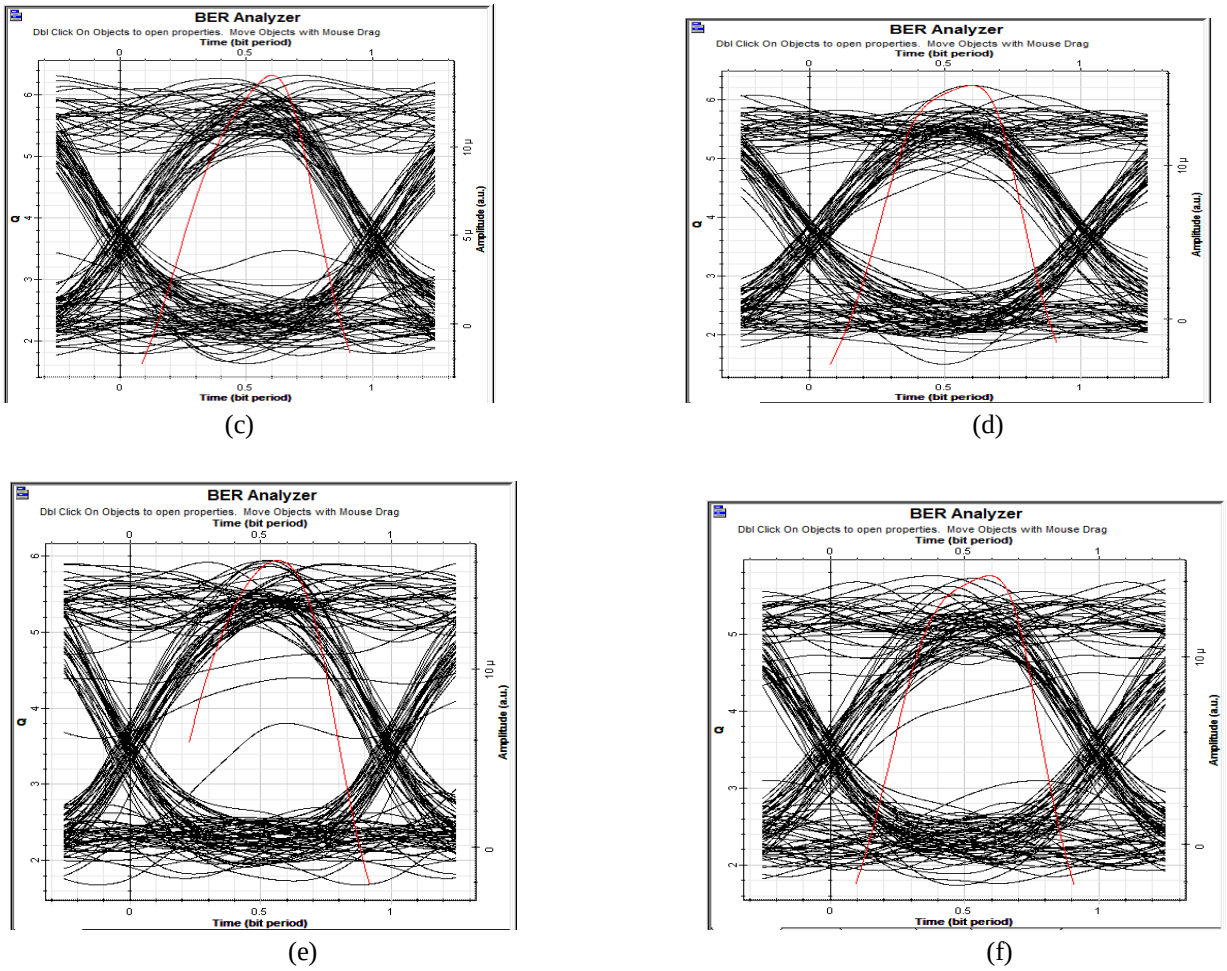


Figure 3 Eye diagrams under different conditions for 32x5 Gb/s WDM-FSO system: (a) very clear sky, (b) clear sky, (c) light haze, (d) heavy haze, (e) light rain& (f) heavy rain

Table 3: Performance analysis of 32x10 Gb/s system under different weather conditions

Weather conditions	Attenuation (dB/km)	Power (dBm)	Link range (km)	BER	Q-factor
Very clear sky	0.18	-10	412	$4.02774e^{-009}$	5.75991
Clear sky	0.36	-10	220	$2.71905e^{-010}$	6.18656
Light haze	0.61	5	141	$1.5715e^{-009}$	5.92264
Heavy haze	2.7	10	36.5	$6.8009e^{-010}$	6.00468
Light rain	6.8	10	16.1	$4.94265e^{-09}$	5.70449
Heavy rain	19.8	10	5	$3.43109e^{-009}$	5.7395

Eye diagrams under different conditions for 32x10Gb/s WDM-FSO system are shown below:

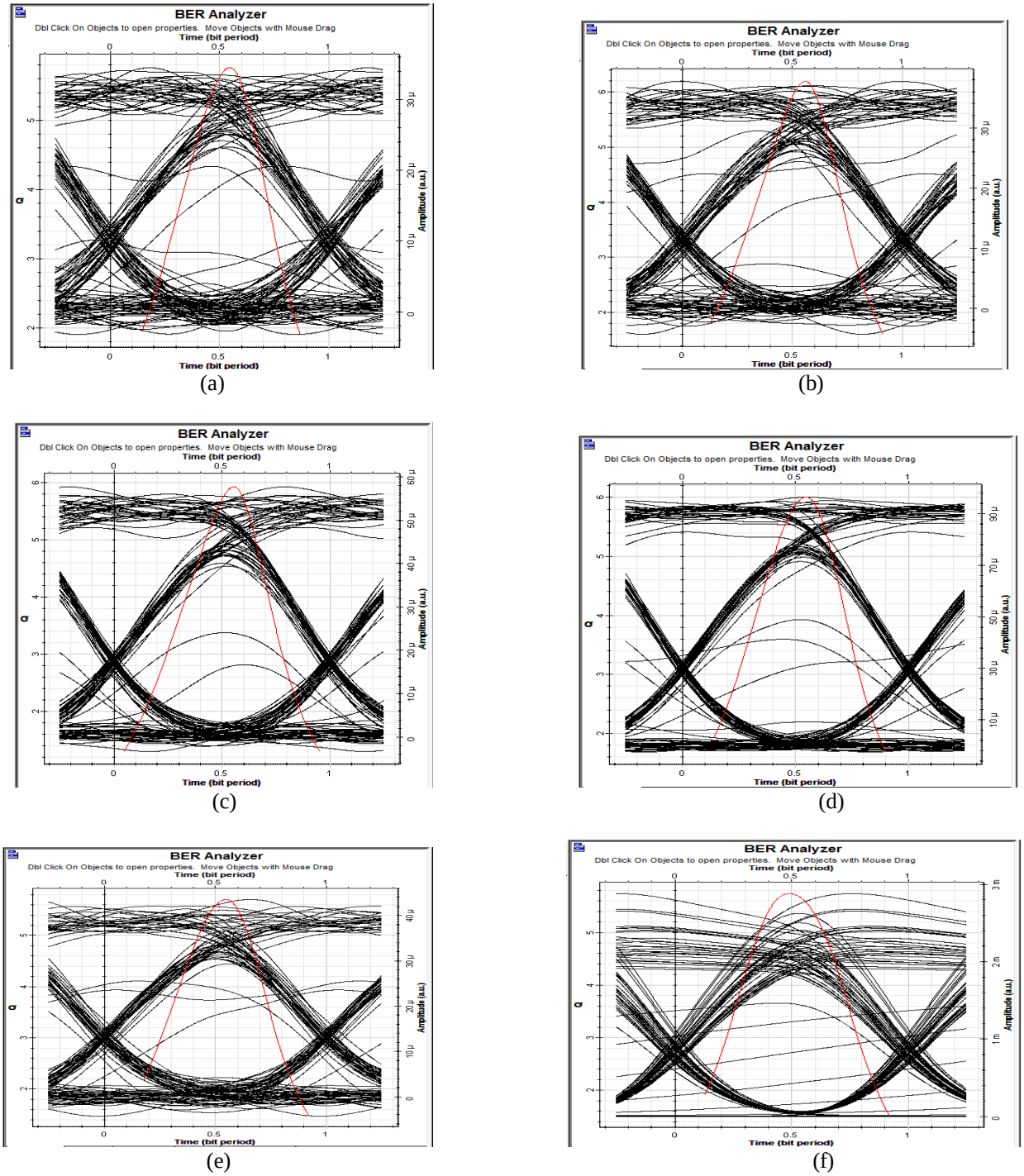
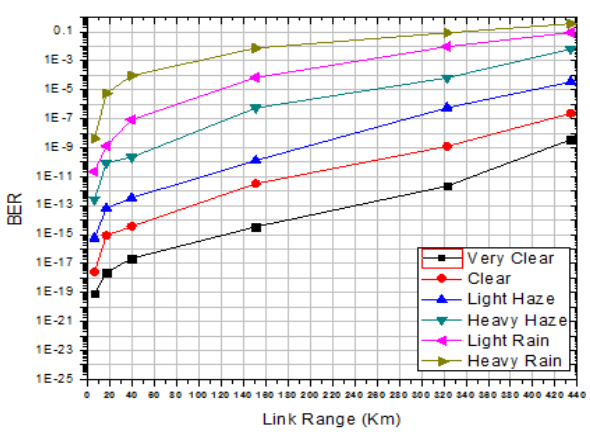
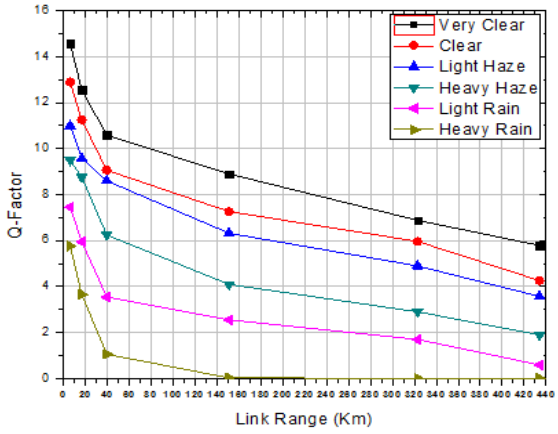


Figure 4 Eye diagrams under different conditions for 32x10 Gb/s WDM-FSO system: (a) very clear sky, (b) clear sky, (c) light haze, (d) heavy haze, (e) light rain& (f) heavy rain

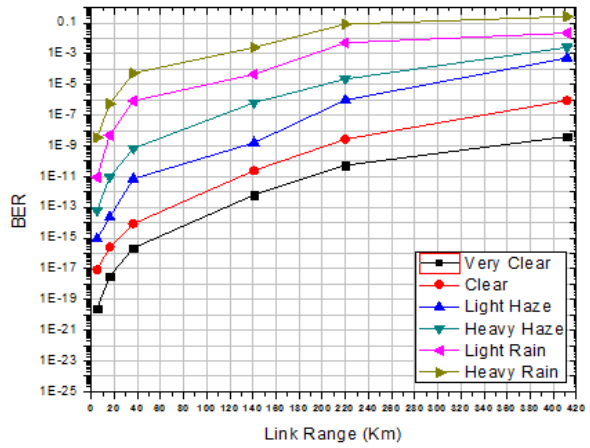


(a)

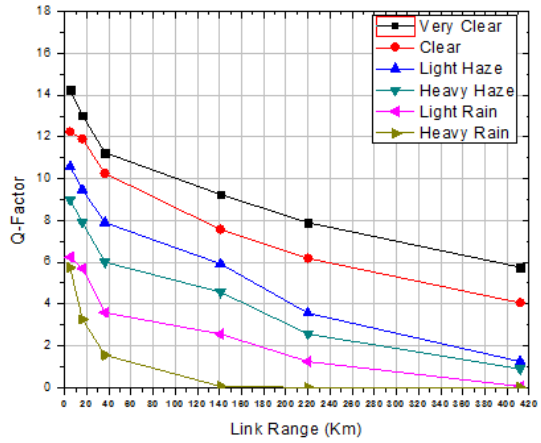


(b)

Figure 5 (a) BER v/s Link Range for 32x5Gb/s WDM-FSO system (b) Q-Factor v/s Link Range for 32x5Gbps WDM-FSO system



(a)



(b)

Figure 6 (a) BER v/s Link Range for 32x10Gb/s WDM-FSO system (b) Q-Factor v/s Link Range for 32x5Gbps WDM-FSO system

4. CONCLUSION

This paper demonstrated the design and investigation of 32 channel WDM based FSO link at 5Gb/s & 10Gb/s data rates & NRZ modulation format under different weather conditions. The attenuation of different weather conditions has very large impact on system's performance. To overcome the impact of attenuation, the Hybrid amplifier (EDFA + SOA) & APD (Avalanche photodiode) are used in this paper. The maximum range under heavy rain is 6.2 km at bit rate 5Gb/s & 5km at bit rate 10Gb/s achieved at acceptable BER of 10^{-9}. For very clear sky link distance is reached up to 434 km at bit rate 5Gb/s and 412 km at bit rate 10Gb/s with acceptable BER of 10^{-9}.

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