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Free Space Optical Communication System under all weather conditions using DWDM

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Abstract: In this paper, the Dense Wavelength Division Multiplexed (DWDM) Free Space Optic (FSO) communication system is proposed in the region of Patiala city, Punjab, India. In this work, it has been investigated its performance in all weather conditions. During this course of work, the possibilities of FSO communication system which links up to 10 km with the wavelength of 1550 nm onwards with different power has been observed. The BER and Quality factor with power variation have been used to observe the performance of system in the summer, winter and rain season respectively. In this paper, to achieve the acceptable results at receiving node, an optical amplifiers or repeater has been used according to the attenuation offered by the weather conditions.

Keywords: **Dense wavelength division multiplexing, free space optics, attenuation, Optical amplifier, Optisystem.**

I. INTRODUCTION

Optical communication system was started in 1970 with working wavelength range of 800nm-1600nm. In this system, the information has been communicated from transmitter to receiver in the form of light. Due to high bandwidth, many users can communicate at the same time. But now days, an optical communication supports bandwidth of 300 THz [1]. Many applications in which optical fiber communication is much better are large distance communication, flexible nature, full duplex mode communication, interference resistive nature and large bandwidth capacity. On the other hand, modern generation has been demanded for more efficient utilization of bandwidth and high data rate, which lead to a new communication known as Free Space Optical (FSO) communication [2]. FSO communication is an optical wireless communication, in which the information has been transmitted through free space in the form of optical carrier [3]. FSO communication has some advantages like ease of establishment, license free (no need of spectrum licensing), communication with high speed and bit rate and more secure. This technology also has some disadvantages like limited distance, Line of Sight (Los) communication and atmospheric effects like scattering, scintillation and turbulence etc [4]. FSO links have been used an atmosphere as the medium of transmission. So, the attenuation has been occurred due to atmospheric weather conditions.

For example, fog, heavy snow, heavy rain and haze are the primary weather conditions which have major effect on the availability of FSO link [5]. Different techniques like OFDM-FSO, WDM-FSO based system are new research approaches which have been used to improve the performance of system with high data rate and longer distance [6]. Signal modulation format is used in order to increase capacity of optical transmission link, system design and optimization have to contributed all the relative facts, such as channel bit rate, distance of transmission, signal power, amplifier noise figure, channel wavelength spacing, fiber dispersion and non-linear parameters [7].

On the basis of type of detection, FSO systems have been categorized as direct detection and heterodyne detection systems. Heterodyne receivers are more difficult to implement because the LO field should be spatially and temporally coherent with the received field in comparison to direct detection (DD) systems [8]. The Point to One Point (P2OP) FSO communication in heavy rain weather condition has been carried out in Changsha, China. In this study, they have investigated the possibility of FSO communication link up to 3 km with the power penalty of 0 dBm. In this course of work, they have achieved data rate up to 1.56 Gbps with Spectrum Slicing Wavelength Division Multiplexing (SS-WDM) scheme [9].

This kind of study is very useful to enhance the system capacity to achieve high speed or high data rate transmission facilities. It can work efficiently in any weather condition and able to provide maximum output to maximum number of users. This study is also useful for future use of FSO in any region with any weather condition.

The paper is organized into five sections. Section II describes the working principle of DWDM system with aim and gaps of previous studies have also been discussed in it. The experimental setup has been explained in Section III. In Section IV, simulation results and discussions are described. Finally in section V, conclusions and future work are made.

II. WORKING PRINCIPLE OF DWDM SYSTEM

In a DWDM system, the number of carriers of the different wavelengths has been transmitted into the fiber, and these signals are de-multiplexed at the receiving end. DWDM carries each input signal independently different from the others. This means that each channel has its own dedicated bandwidth/wavelength and all signals arrive at the same time, rather than being broken up and carried in time slots [11].

During present course of study, a point to one point (P2OP) FSO communication has been proposed in the city with link distance of 10 Km between two educational hubs. At receiving node, the better results have been calculated throughout all weather conditions. FSO link with the high data rate of 5 Gbps has been implemented and achieved better and acceptable results than previous researches. Further, it will also be observed that an amplifier is required after maximum distance 5 in clear, after 3 km distance in Fog and 1 km distance in Rain weather condition, respectively. Data rate up to 5 Gbps can be achieved by using DWDM scheme over FSO link under all weather.

In this paper, region of Patiala city, Punjab, India has been taken to propose a FSO communication link. In this study, the weather conditions of the region will be analyzed. The durations of weather seasons and their attenuations will also be observed. The duration of seasons with the attenuation factors are illustrated in Table 1. This table shows that in rainy season, maximum attenuation amongst all seasons has been observed.

Season	Duration	Attenuation (dB/km) [10]
Clear Season	March to Last June	0.23
Rain Season	July to September & Sept. to October (due to thunderstorms)	9.64
Fog Season	December to February	2.37

Table 1: Seasonal details with their duration

Many researchers have been worked on FSO and observed that communication with data rate up to 1.5 Gbps at the maximum distance of 2.5 km in different seasons [9]. But during present course of work, Point-to-One Point (P2OP) communications with data rate up to 5 Gbps at the distance of 10 km have been worked out with the better and acceptable results.

III. EXPERIMENTAL SETUP

During this course of work, Pseudo code generator with NRZ modulation format has been used to generate a bit stream of 5 Gbps bit rate. The architecture of the proposed system is having 8-channels DWDM link shown in the Fig.1. The average input power of CW laser has been adjusted according to the weather conditions like 20 dBm for a Clear season, 30 dBm for foggy season and 40 dBm for the rainy season. The Mach-Zehnder Modulator have been modulated the optical signals. For mixing of electrical signal to the optical domain in the transmitter, the Mach-Zehnder Modulators have been used. An 8:1 multiplexer has been used to combine the entire channels of different wavelength. Then the modulated signal has been transmitted over an FSO link with length 10 km shown in Fig.2. The different parameters of FSO channel which are used for simulation are defined in Table 2.

Parameters	Range
Power	Clear weather: 20 dB Fog weather: 30 dB Rain weather: 40 dB
Distance	10 km
Attenuation	Varying (Acc. to weather conditions defined in Table 1.)
Transmitter Aperture Diameter	5 cm
Receiver Aperture Diameter	20 cm
Beam Divergence	2 mrad

Table 2: Parameters of FSO Channel

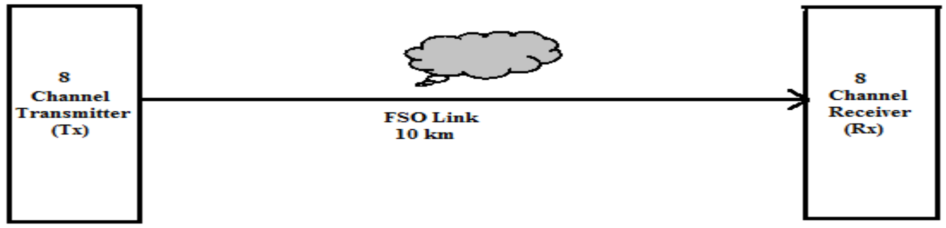


Fig.1 Architecture of transmitter and receiver in FSO system

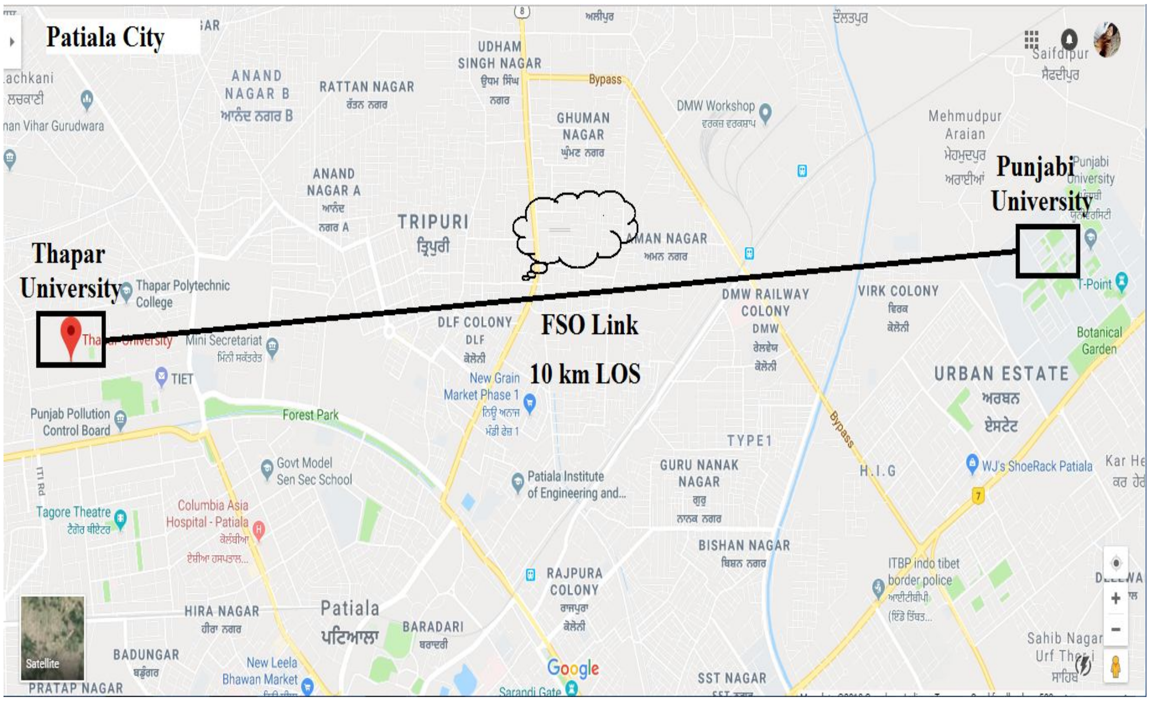


Fig.2 Architecture of FSO link with 10 km Line of sight (Los) [12].

At the Receiver end, the signal will be de-multiplexed by using de-multiplexer, which converts the single signal into eight channels of different wavelengths. There is a PIN photo-detector which is converting an optical signal to electrical signal. To investigate the performance of each channel at receiving node, the Bit Error Rate (BER) analyzer (eye diagram) is used.

IV. SIMULATION RESULTS AND DISCUSSIONS

In this paper, the simulations have been carried out using Optisystem7. The performance of the system has been investigated by using bit error rate analyzers. The system performance has been characterized out using Q-Factor against different wavelengths in different season. The graphical representations also described that the designed system is performing well and it is suitable at a bit rate of 5 Gbps during all seasons.

In clear season, an optical amplifier or repeater has been used after 5 km of transmission distance. The graphical representation of variations in the Q-factor with respect to the different wavelengths is shown in Fig. 3. The graph shows that there is variation in value of Q-factor, the reason behind it is that large transmission distance with minimum number of repeaters (after 5 km). In this season, due to low attenuation we have used the repeater after the maximum distance of 5 km which causes the fluctuations in the Q-factor. The performance of different channels if the system has been described by using eye diagrams in fig. 4.

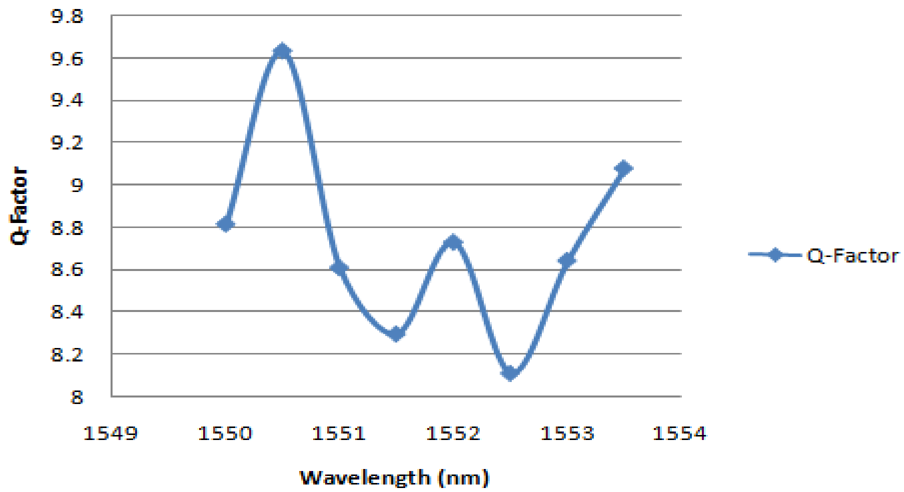
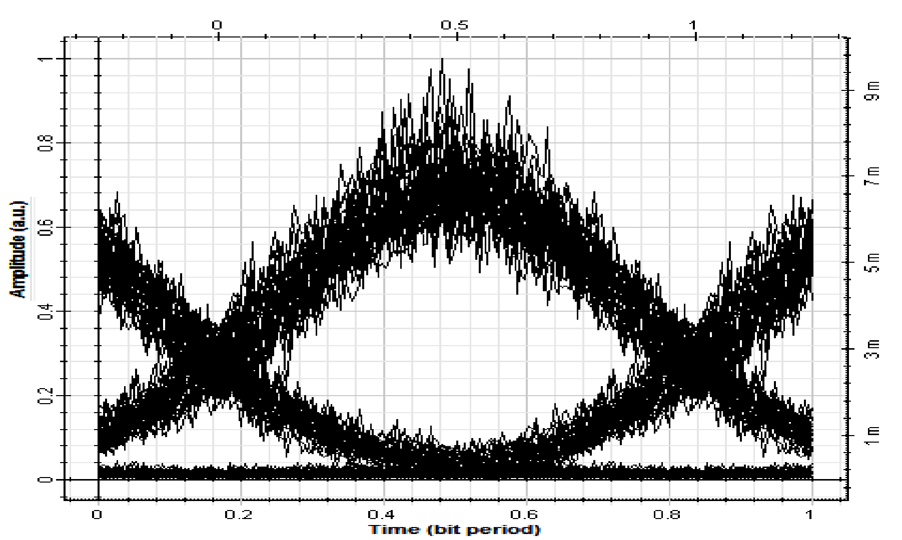


Fig. 3 Graphical representation of variations in Q-factor with respect to the different wavelengths at receiving node in clear season



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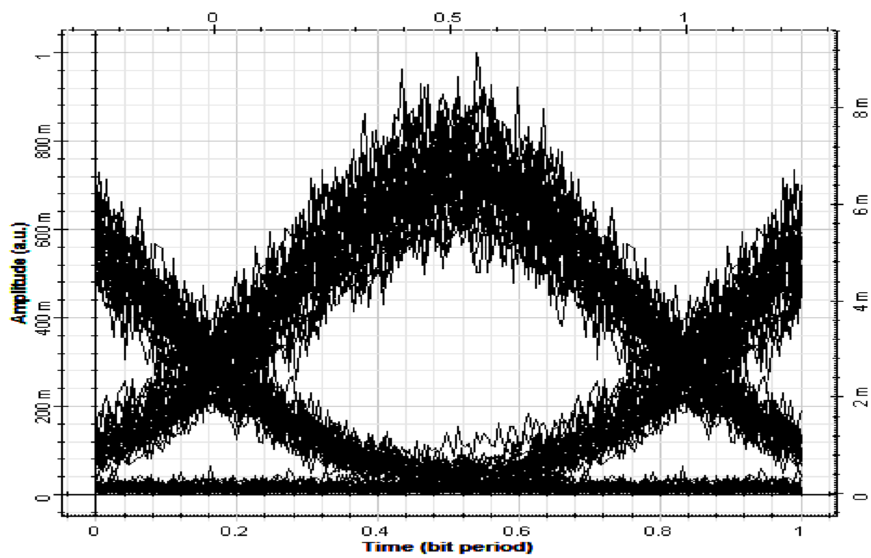

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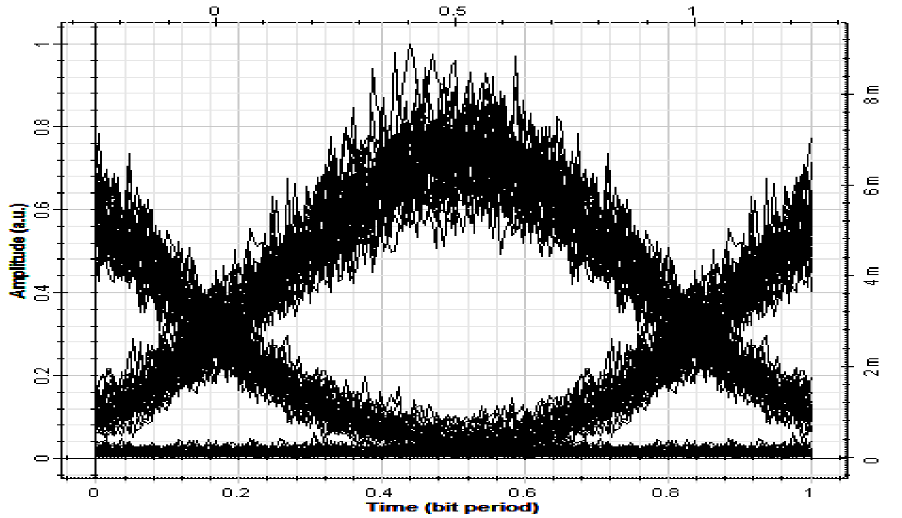
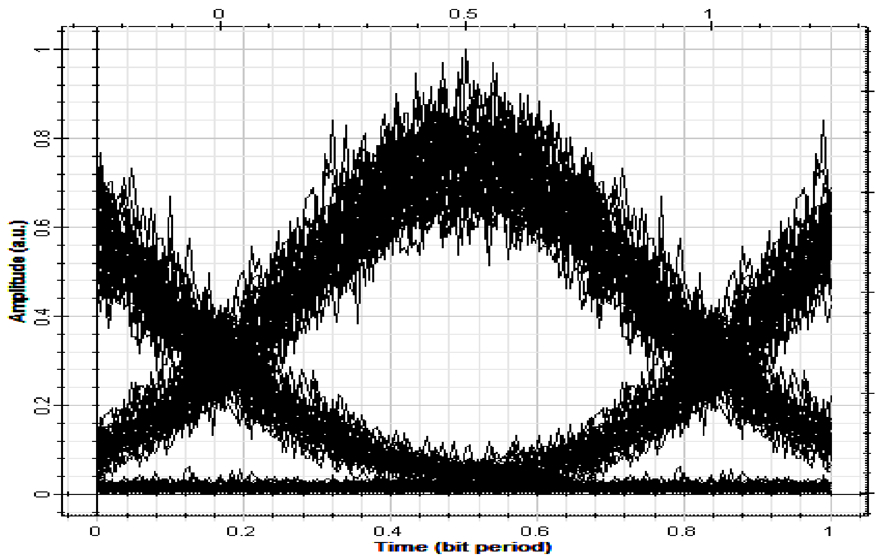
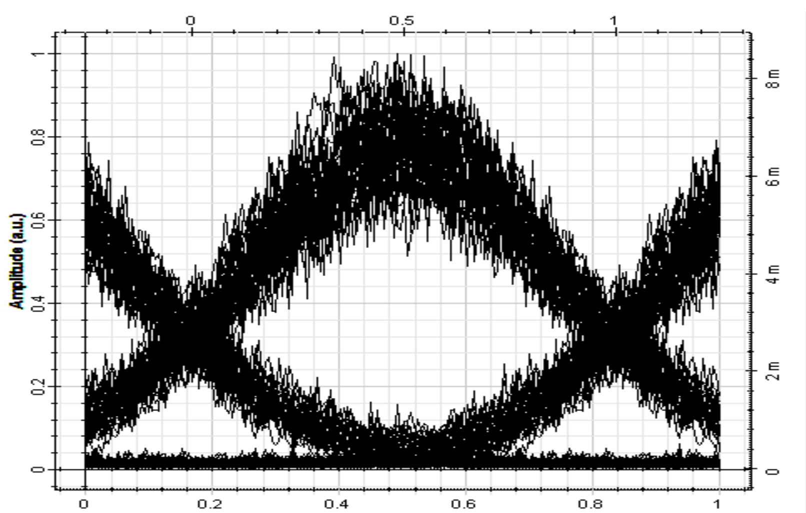

Amplitude (a.u.)
Time (bit period)
(c).


Amplitude (a.u.)
Time (bit period)
(d)


Amplitude (a.u.)
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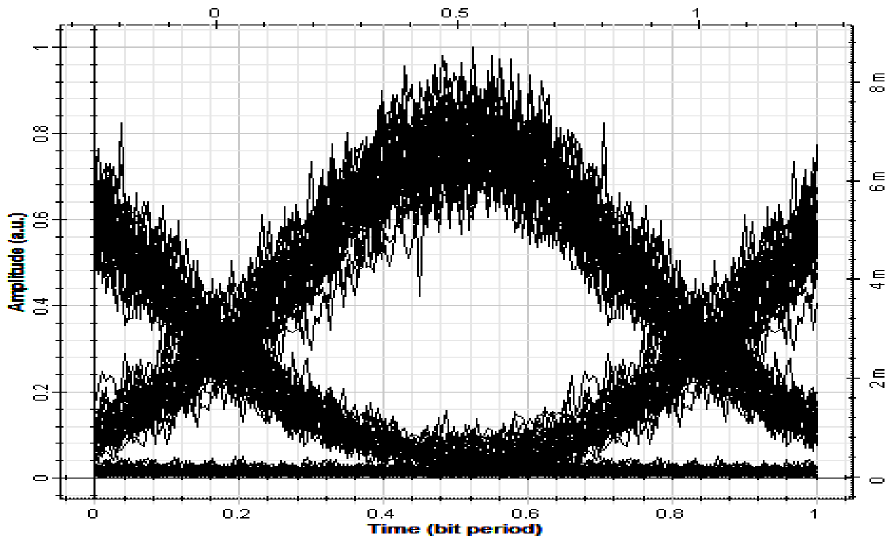

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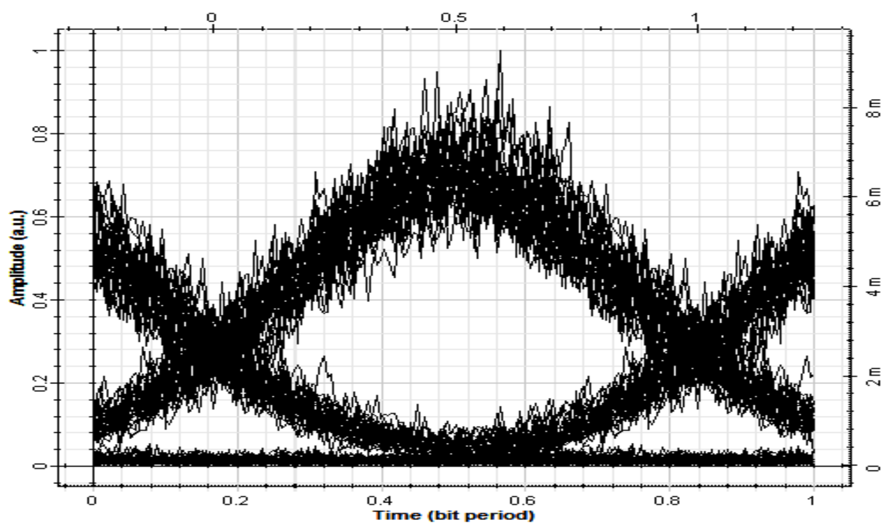

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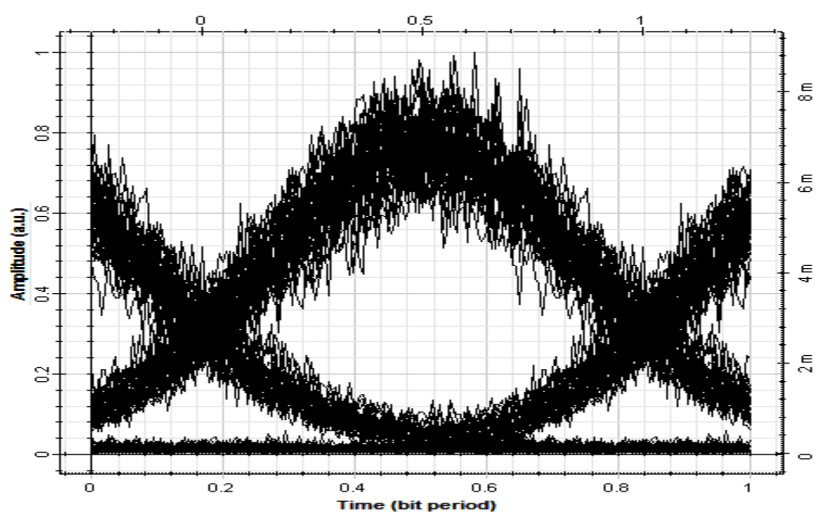


(h).

Fig. 4 Eye diagrams at different receiving channels (a), (b), (c), (d), (e), (f), (g), (h) of different wavelength.

In the winter/foggy season, the variation of Q-factor according to wavelength is less as compared to the clear season. The reason of less variation is that, an optical amplifier has been used after the maximum distance of 3 km. Fig. 5 describes graphical representation of the variation of Q-factor with respect to the different wavelengths at receiving end in foggy season. The performance of system at receiving end is shown by eye diagrams in Fig. 6.

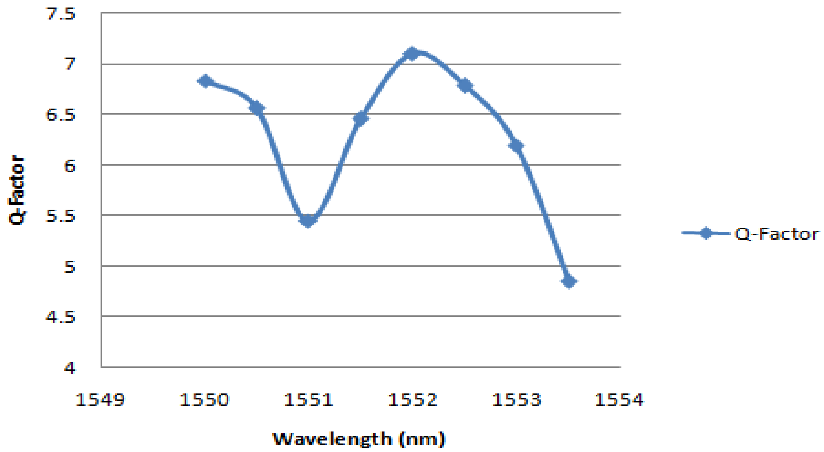
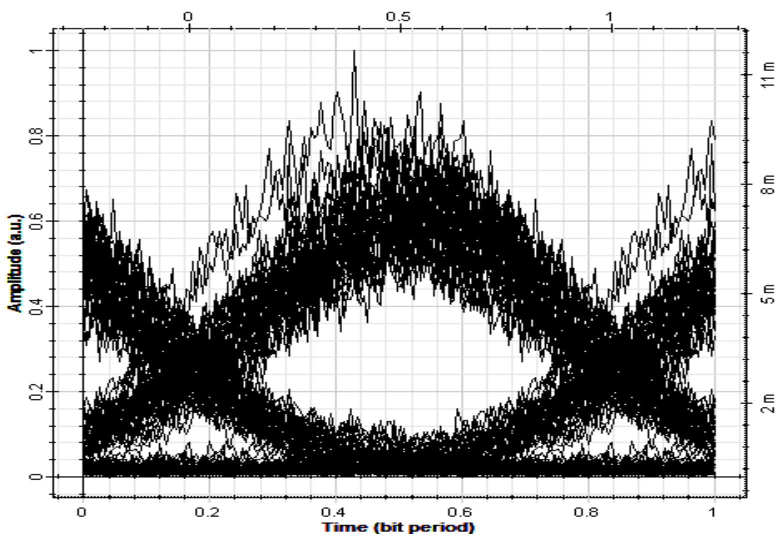


Fig. 5 Graphical representation of variations in Q-factor with respect to the different wavelengths at receiving node in foggy season



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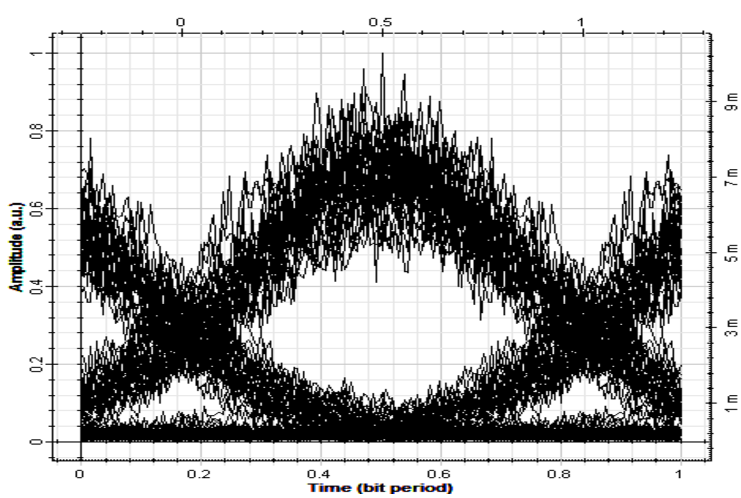

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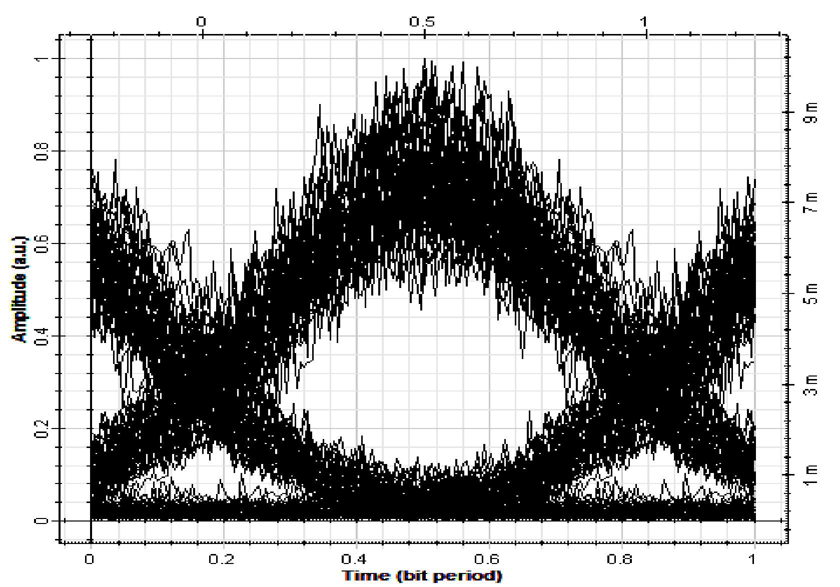
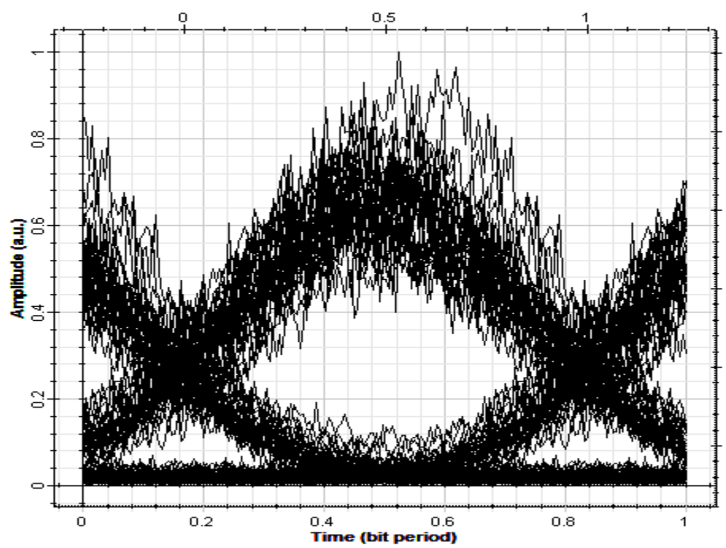
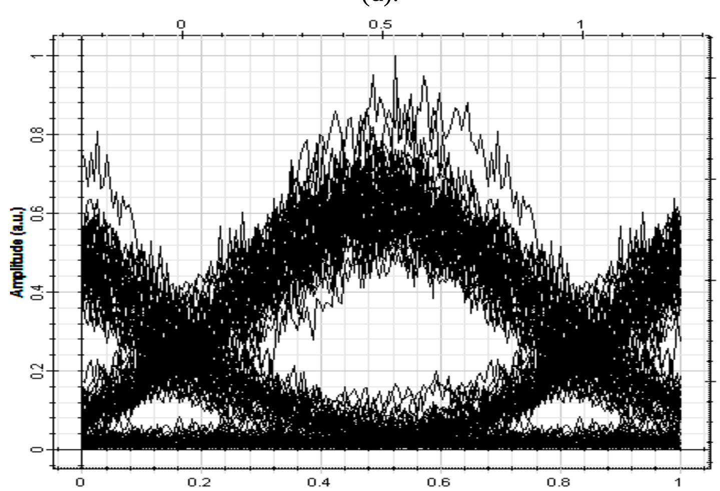
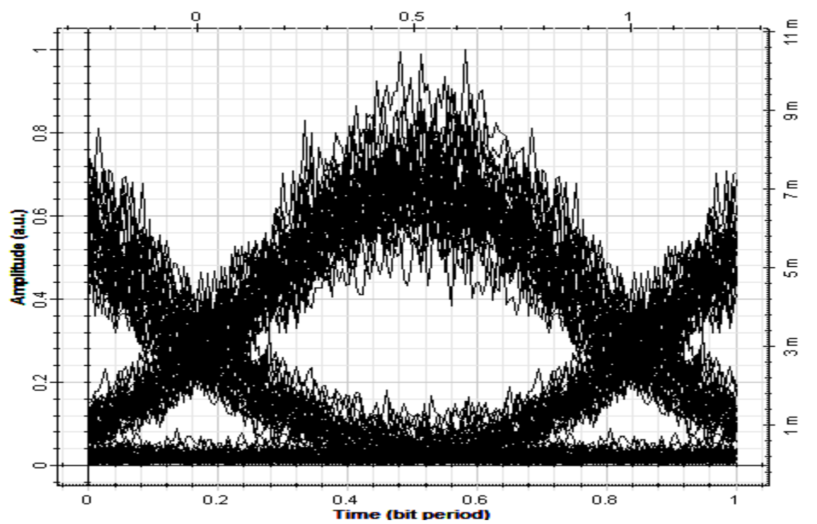

Amplitude (a.u.)
Time (bit period)
(c).


Amplitude (a.u.)
Time (bit period)
(d).


Amplitude (a.u.)
Time (bit period)
(e)



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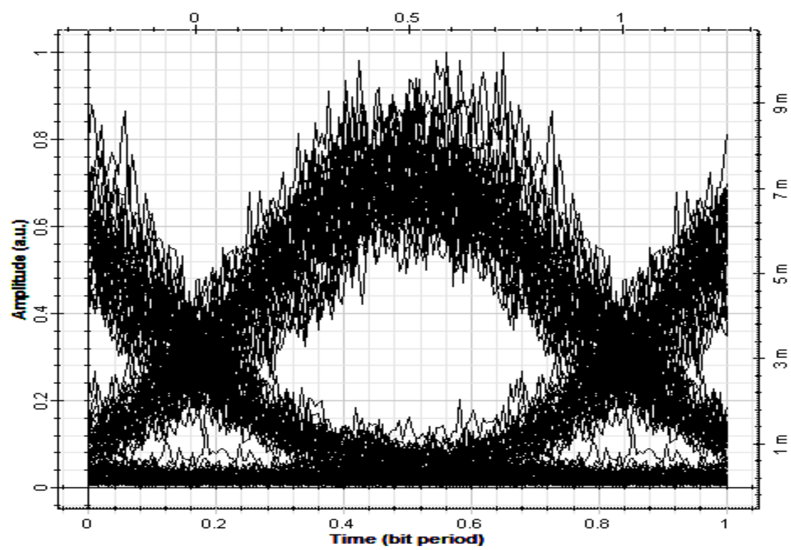

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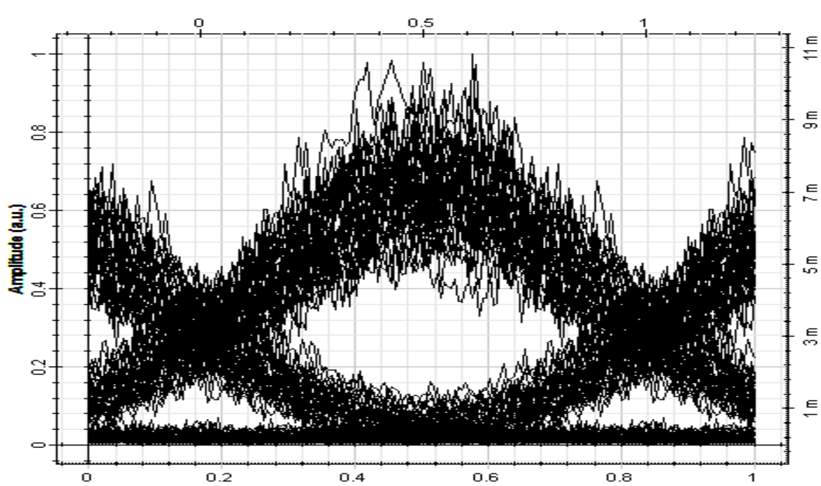


(h).

Fig. 6 Eye diagrams at different channels (a), (b), (c), (d), (e), (f), (g), (h) of different wavelength.

In rainy season, the size of droplet can lead to scattering of optical source which will ultimately reduce the link range due to scattering. In order to overcome the scattering and attenuation, the repeater or amplifier can be used to make the possibilities of FSO communication in rainy season. The variation of Q-factor with respect to different wavelength is described in the Fig.7. In our proposed system, a repeater/ amplifier has been used after 1 km of transmission distance. So the fluctuations in Q-factor with respect to wavelengths is less as compared to the other seasons, the reason behind it is that the number of amplifiers or repeater used in the system is more the others. The output eye diagrams in Fig. 8 also describe the performance of the each channel at receiving node.

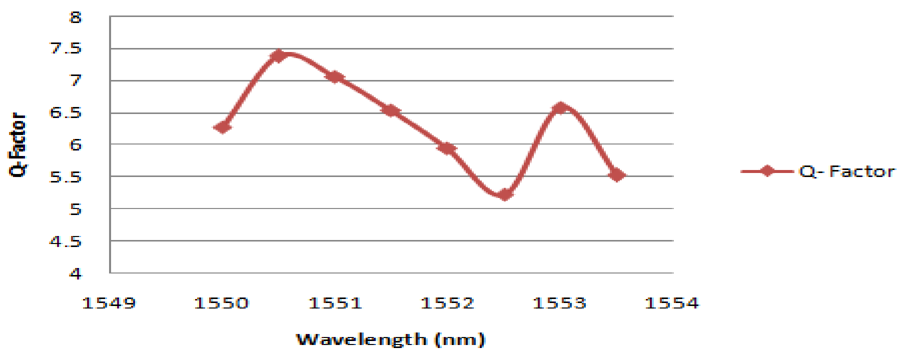
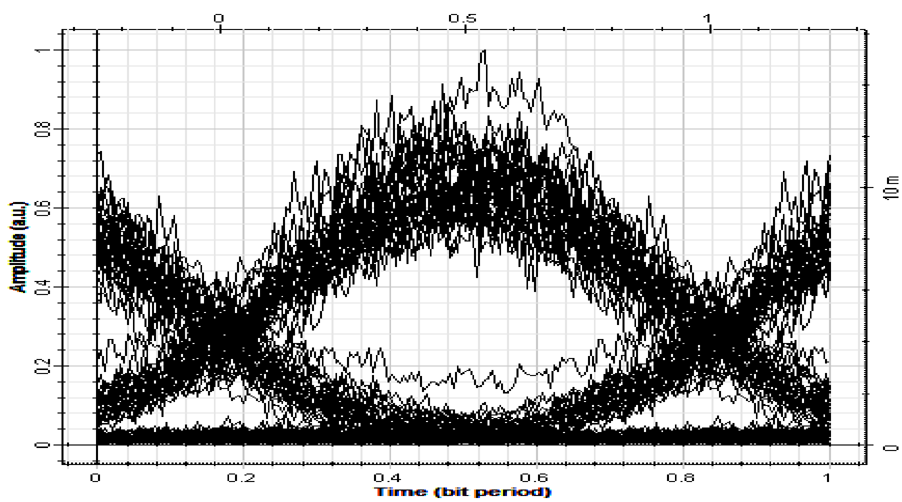


Fig. 7 Graphical representation of variations in Q-factor with respect to the different wavelengths at receiving node in rainy season



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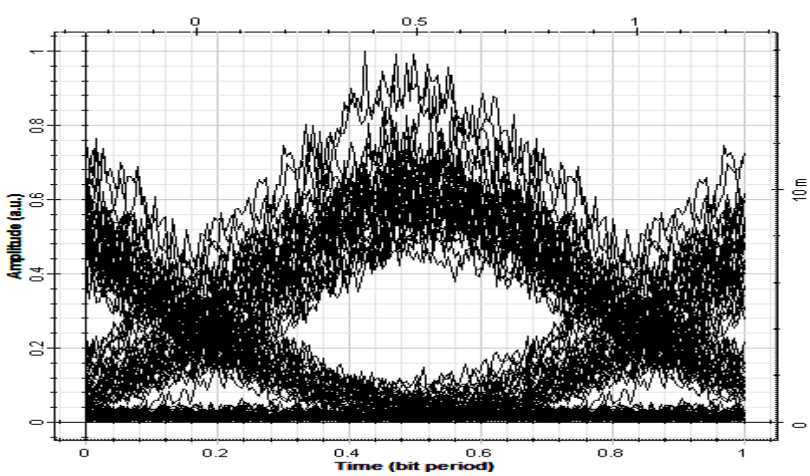

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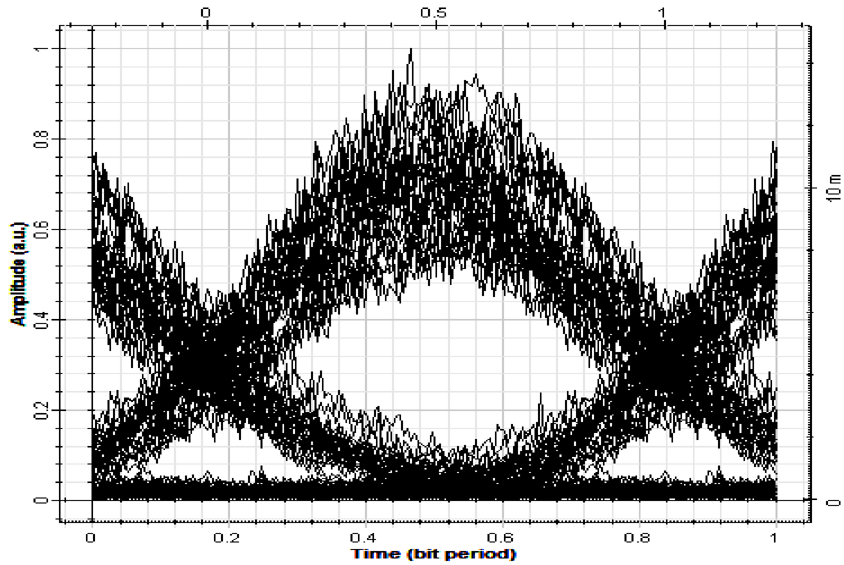
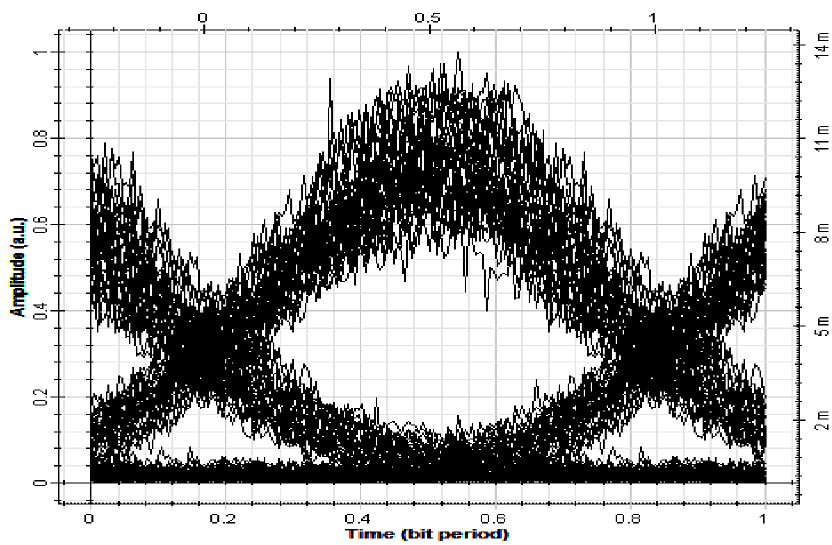

Amplitude (a.u.)
Time (bit period)

(c).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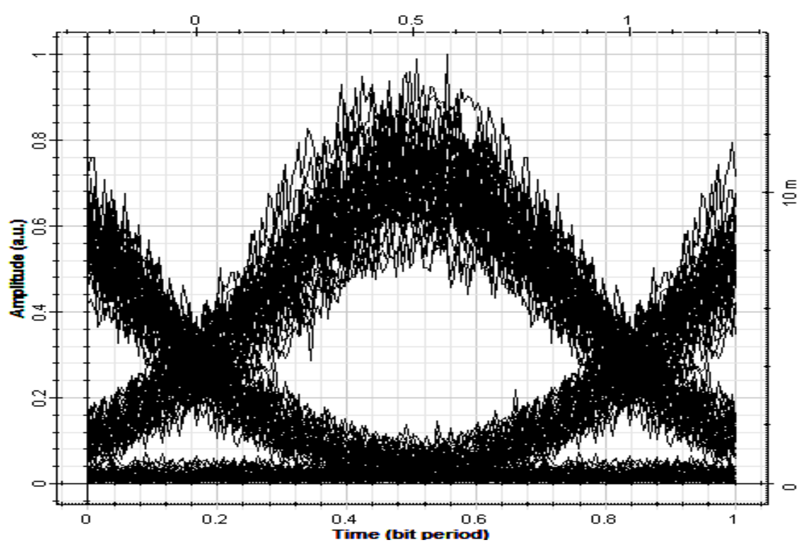
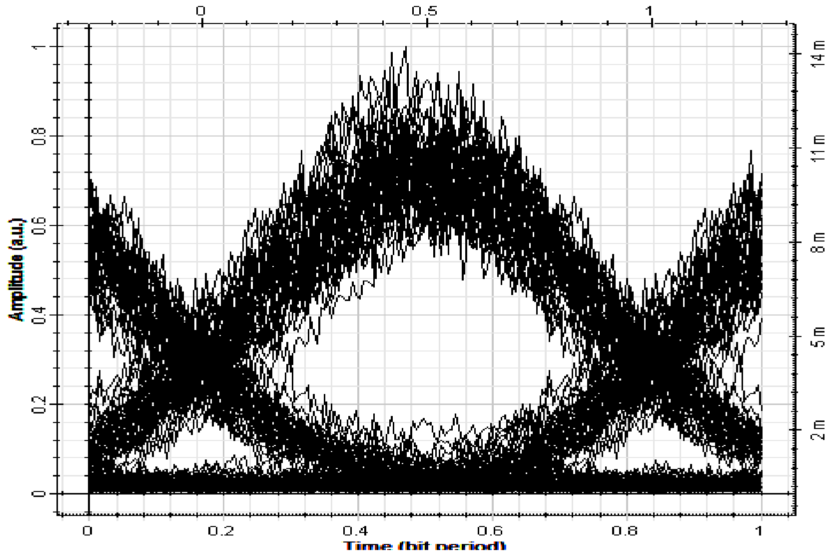
Time (bit period)

(d).


Amplitude (a.u.)
Time (bit period)

(e).



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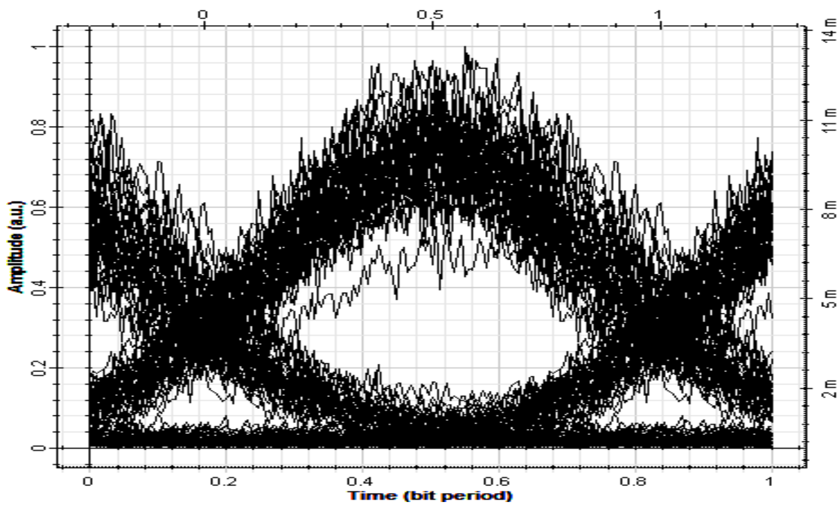

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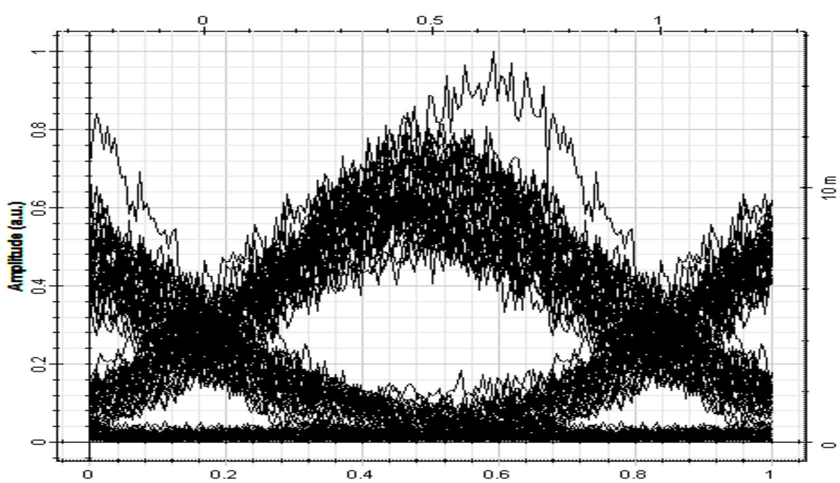

(h)

Fig. 8 Eye diagrams at different channels (a), (b), (c), (d), (e), (f), (g), (h) of different wavelengths.

V. CONCLUSION

In this work, an FSO communication system has been proposed in the city Patiala, Punjab, India. All the weather seasons of Patiala city has been analyzed to investigate the performance of the FSO communication. The results in terms of BER and Q-Factor at receiving node of the system have been calculated in all the weather seasons. It has been concluded that there is a need of repeaters or amplifiers in clear season after 5 km, in foggy season after 3 km and in rainy season after every 1 km respectively. Due to large communication distance and more attenuation in case of rainy season, more repeaters have been used. Further, it has been concluded that the output Q-Factor of the rainy season is better than other seasons.

VI. ACKNOWLEDGMENT

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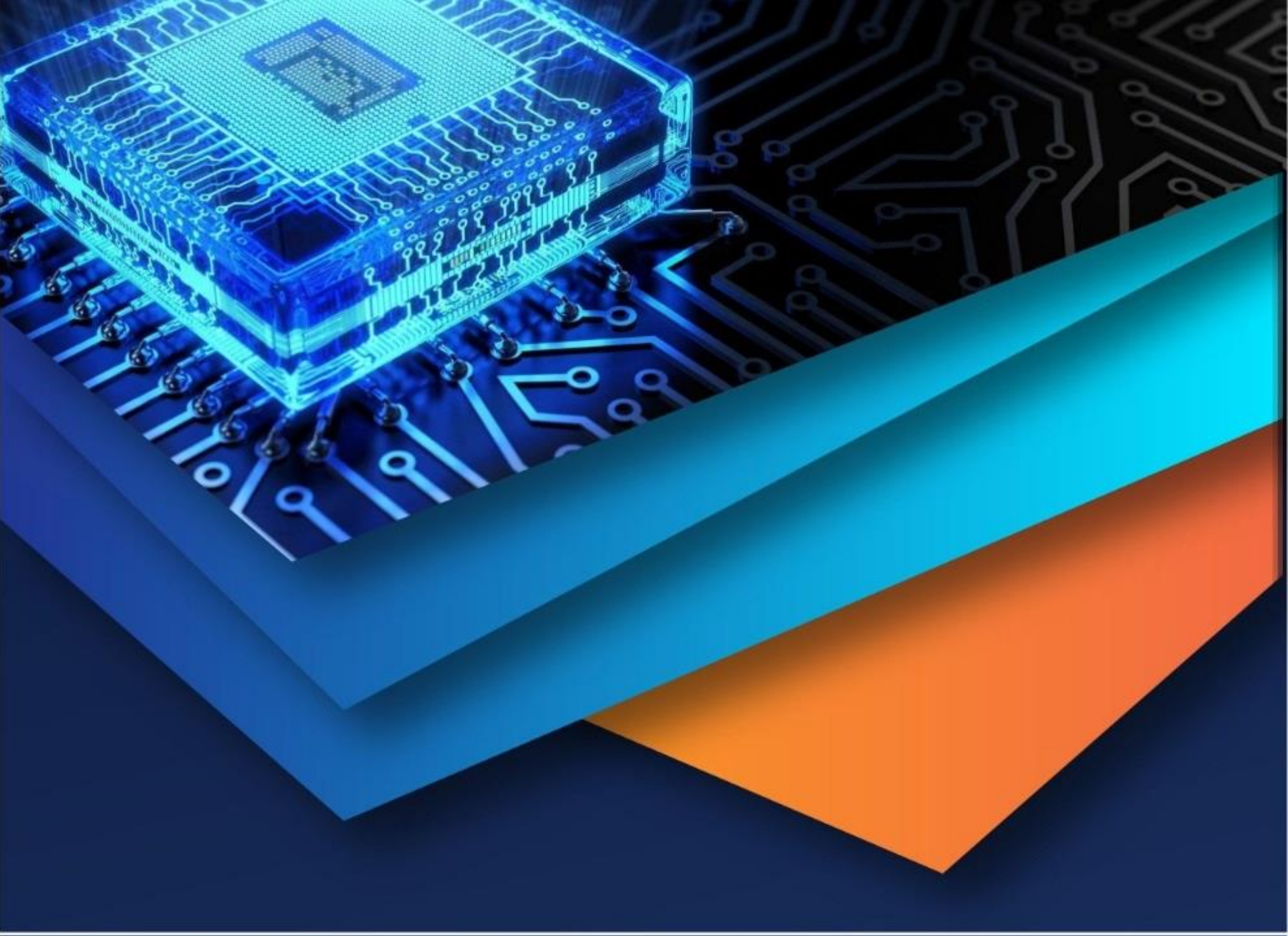

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