Modeling of Various Weather Conditions in WDM-FSO-PI (Polarization Interleaving) System in Comparison to WDM-FSO System

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Abstract— **Polarization Interleaving technique has many advantages such as excellent SNR performance, freedom from interference of continuous channels of wavelength multiplexed channels etc and proves to be a good choice for it's applications in WDM-FSO system employing polarization Interleaving(PI). This paper investigates the performance of WDM-FSO-PI system under the effect of atmospheric turbulences in comparison to WDM-FSO which does not employ the technique of polarization Interleaving. In this work 128Gbps data is sent through 16 channels each of capacity 8Gbps and is transmitted over free space optical link. Performance analysis is done in terms of SNR, power and eye diagrams.**

I. INTRODUCTION

Free Space Optics is referred to as optical wireless communication as it integrates optical carriers with wireless system and paves the way out to heterogeneous communication networks capable of supporting a wide range of services and applications [1]. Many of the aspects of FSO are related to optical fiber communication but the medium of transmission which is air/free space in FSO and glass in optical fiber differentiates the two from each other [2]. FSO has been the backbone for high speed trunking and has the capability to support mobile users. It is a building block for wide area networks. Optical transceiver with laser transmitter and receiver is used to provide full duplex communication via free space. Laser devices mounted on the top of roofs, buildings are used to transmit extensive amount of data providing line of sight communication. The quality and stability of link is highly dependent upon the effects of atmospheric changes because FSO is greatly responsive to the diverse climate state of affairs that are responsible to bound the FSO range [3]. It is of prime importance to take various system parameters into account while evaluating the performance of FSO link. External parameters include haze, fog, snow, dust, rain etc .that deteriorate the transmission path and puts a barrier on the network [4]. These environmental conditions are inevitable and their effect is important to be considered. WDM technique is employed in FSO helps enhancing the capacity of system due to increased number of channels and tightening the spacing between adjacent channels. But in WDM-FSO system the range up to which the link prolongs is limited by atmospheric turbulences. In addition to atmospheric factors ,the interference between contiguous channels of wavelength division multiplexed FSO can also pose severe challenges in Free Space Optical communication. Polarization Interleaving technique provides orthogonality between even and odd channels and hence interference reduction is achieved [5]. In this work, 128Gbps data is transmitted over FSO link by employing 16 channels each having bit rate of 8Gbps. The performance of proposed system is evaluated under the effect of different atmospheric conditions i.e. clear weather, Haze, Fog. The rest of the paper is organized as follows: section II gives system description, section III focuses on technical aspects results and discussion in section IV followed by conclusion and references in section V and VI respectively.

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II. SYSTEM DESCRIPTION

The proposed WDM-FSO-PI system is modeled using Optisystem from Optiwave Corp. In this design a typical WDM-FSO link consisting of WDM transmitter, FSO channel, and multiple receivers is considered. The block diagram in fig 1 shows the link under study. The WDM -FSO-PI system consists of 16 independent channels that range from 193.1 THz -195.850 THz with a channel spacing of 250 GHz and are put together by WDM technique. The capacity of each channel is 8Gbps , hence capacity of whole system is 128Gbps. The transmitter and receiver aperture areas are fixed to 5 cm and 30 cm respectively. The attenuation of Free Space is considered to be 0.11dB/Km depicting clear weather condition, 4dB/Km depicting Haze and 25 dB/Km for Fog condition. Mid- pointing losses and scintillation effects are not taken into consideration. At transmitting end, each of the channels having bit rate of 8Gbps is generated by pseudo random bit generator. Then after this data is encoded and further modulated by MZ modulator. The channels are divided into even and odd and are separately applied to polarization controller that changes the azimuth parameter of even and odd channels. Hence orthogonality is provided between adjacent channels [5].

The two polarization components of input signal are represented as E_{inx} and E_{iny} .The output signal after passing through polarization controller is given as:

$$E_{out}(t) = \begin{pmatrix} \sqrt{1-k}.\exp(j.\delta_x(t)) \\ \sqrt{k}.\exp(j.\delta_x(t)) \end{pmatrix} .\sqrt{|E_{inx}|^2} + \sqrt{|E_{iny}|^2} \quad (1)$$

the phase difference between the components in x and y direction, Where k is power splitting ratio parameter .

The splitting ratio is given as:

$$K= (1-\cos(2.\eta).\cos(2.\epsilon))/2 \quad (2)$$

And the phase difference is given as:

$$\delta_{yx} - arc\ sin\left(\frac{\sin(2.\epsilon)}{2.\sqrt{k.(1-k)}}\right) \quad (3)$$

The optical amplifiers with 13 dB gain are used for pre and post amplification. At the receiving end , the even and odd channels are de-multiplexed and then are applied to APD photodetectors having a dark current of 10nA. Table 1 shows the parameters and their specifications that are considered during simulation.

III. TECHNICAL ASPECTS OF WDM-FSO-PI LINK

Table 1: simulation Parameters

PARAMETER	VALUE
Bit rate of each channel	8Gbps
Channel Spacing	250 GHz
Total bit rate	128Gbps
Tx aperture diameter	5 cm
Rx aperture diameter	30 cm
Amplifier gain	13 dB
CW laser power	0 dBm
No. of channels	16

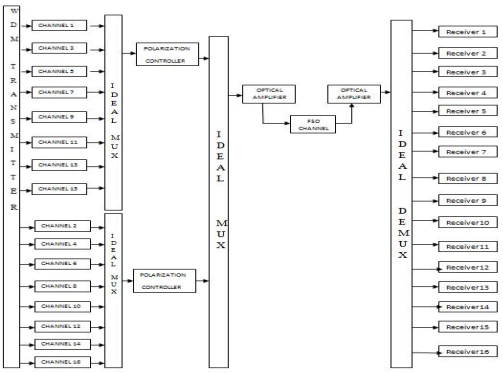


Fig 1: Block Diagram of proposed WDM-FSO-PI

IV. RESULTS AND DISCUSSION

The results are presented in this section. The SNR and total power measurement for channel no.4 in WDM-FSO system with and without the incorporation of polarization interleaving under different weather conditions i.e. clear weather, Haze and Fog has been done.

Table 2: Simulation Results

	WDM-FSO SYSTEM UNDER CLEAR WEATHER		WDM-FSO-PI SYSTEM UNDER CLEAR WEATHER	
DISTANCE	SNR	POWER	SNR	POWER
1	53.218466	-17.173114	58.991927	-15.388642
1.1	52.656677	-18.775453	58.800555	-16.990983
1.2	52.115792	-20.245937	58.583043	-18.46147
3	45.050846	-36.137421	53.876149	-34.353051
4.2	41.970975	-42.164844	51.401495	-40.380601
4.7	40.893122	-44.206954	50.534526	-42.422781
5	40.289764	-45.336812	50.05194	-43.552687
7	36.870802	-51.572235	47.382286	-49.78856
10	32.948069	-58.390003	43.392282	-56.607564
15	27.980417	-66.500114	35.277465	-64.722199
20	23.997018	-72.572871	29.19435	-70.805003
25	20.553463	-77.519806	24.226616	-75.772096
27	19.279146	-79.281283	22.452234	-77.546029
29	18.05115	-80.943911	20.773079	-79.224551

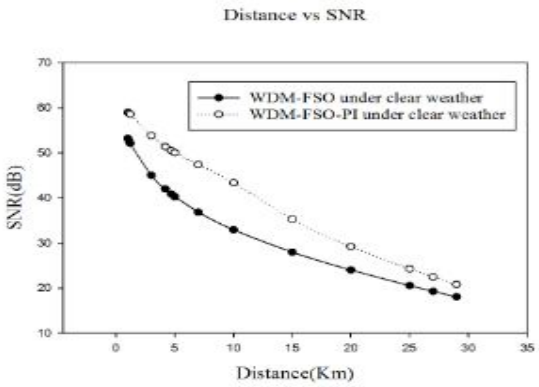
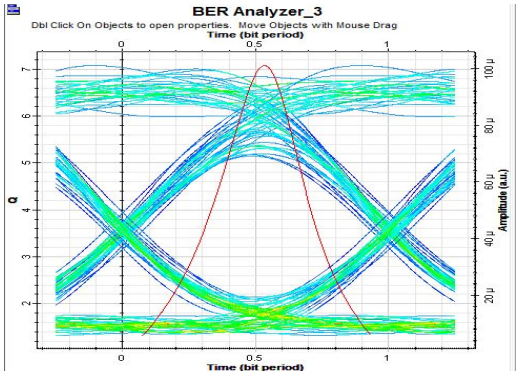
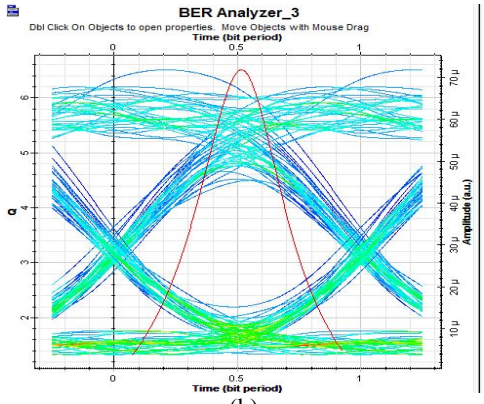


Fig 2: Comparison of WDM-FSO-PI and WDM-FSO systems under clear weather condition in terms of SNR



(a)



(b)

Fig 3: Eye diagrams representing the (a) WDM-FSO channel output at 25 Km and (b) WDM-FSO-PI channel output at 29 Km range

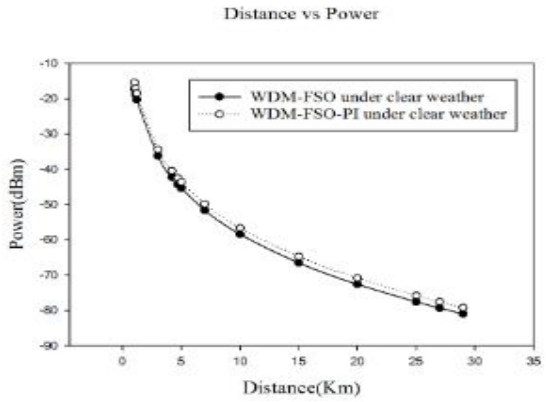


Fig 4: Comparison of WDM-FSO-PI and WDM-FSO systems under clear weather condition in terms of Power

It has been observed that WDM-FSO-PI system prolongs up to 29 Km whereas WDM-FSO system prolongs up to 25 Km with acceptable SNR and Power.

Table 3: Simulation Results under Haze

	WDM-FSO SYSTEM UNDER HAZE CONDITION		WDM-FSO-PI SYSTEM UNDER HAZE CONDITION	
DISTANCE	SNR	POWER	SNR	POWER
1	50.234204	-24.953094	57.607958	-23.16864
1.1	49.205119	-27.333424	56.959545	-25.54898
1.2	48.191918	-29.581898	56.26284	-27.797465
3	32.303942	-59.581898	42.306931	-57.692898
4.2	22.458932	-74.816536	26.943368	-73.05577
4.7	18.226595	-80.708462	21.01118	-78.986556
5	15.631342	-84.120058	17.54727	-82.448122
7	0	-100	0	-100
10	0	-100	0	-100
15	0	-100	0	-100
20	0	-100	0	-100
25	0	-100	0	-100
27	0	-100	0	-100
29	0	-100	0	-100

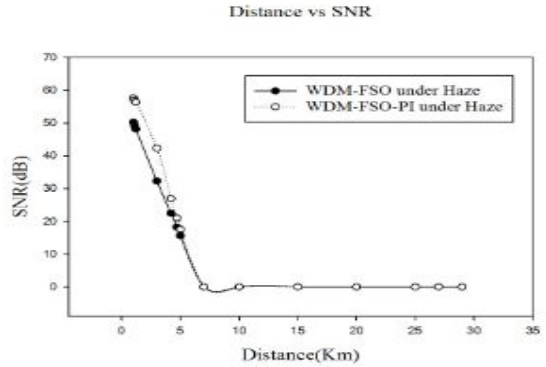


Fig 5: Comparison of WDM-FSO-PI and WDM-FSO systems under Haze condition in terms of SNR

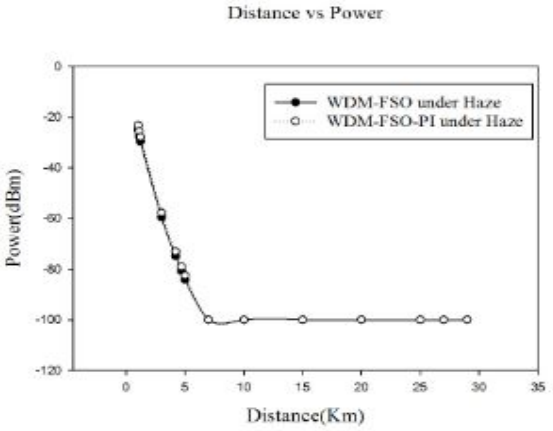
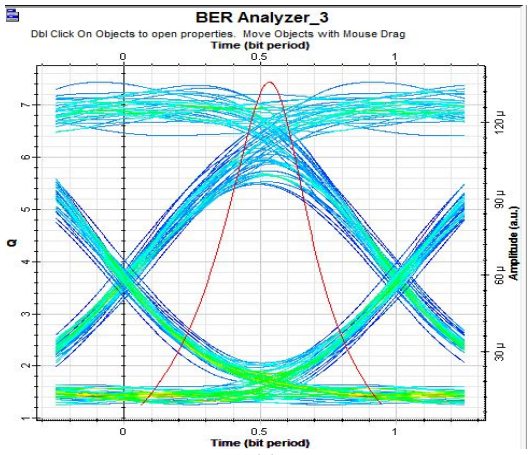
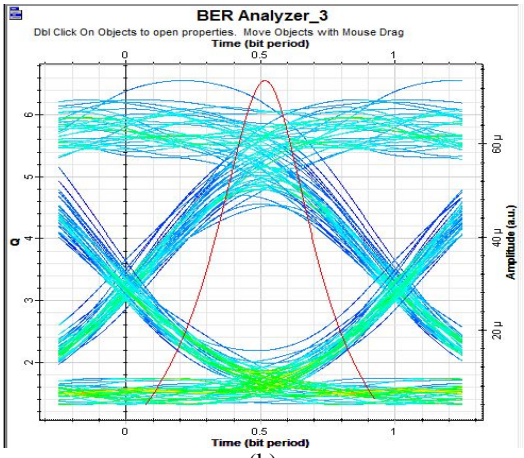


Fig 6: Comparison of WDM-FSO-PI and WDM-FSO systems under Haze condition in terms of Power



(a)



(b)

Figure 7: Eye diagrams representing the (a) WDM-FSO channel output at 4.1 Km and (b) WDM-FSO-PI channel output at 4.7 Km range.

It is evident from graphs and table that under under Haze condition WDM-FSO-PI system prolongs up to 4.7 Km whereas WDM-FSO system prolongs up to 4.1 Km with acceptable SNR and Power .Hence an improvement of 500 meters in range with the integration of Polarization Interleaving in WDM-FSO.

Table 4: Simulation Results under fog

	WDM-FSO SYSTEM UNDER FOG CONDITION		WDM-FSO-PI SYSTEM UNDER FOG CONDITION	
DISTANCE	SNR	POWER	SNR	POWER
1	27.696409	-66.94576	34.831353	-65.168296
1.1	23.356842	-73.513473	28.251011	-71.748262
1.2	18.80656	-79.925172	21.802524	-78.195523
3	0	-100	0	-100
4.2	0	-100	0	-100
4.7	0	-100	0	-100
5	0	-100	0	-100
7	0	-100	0	-100
10	0	-100	0	-100
15	0	-100	0	-100
20	0	-100	0	-100
25	0	-100	0	-100
27	0	-100	0	-100
29	0	-100	0	-100

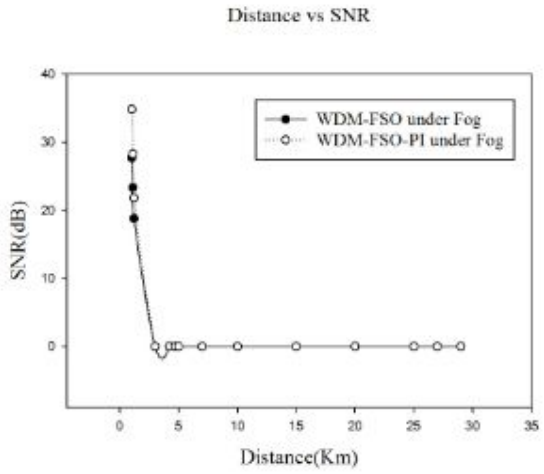


Fig 8: Comparison of WDM-FSO-PI and WDM-FSO systems under Fog condition in terms of SNR

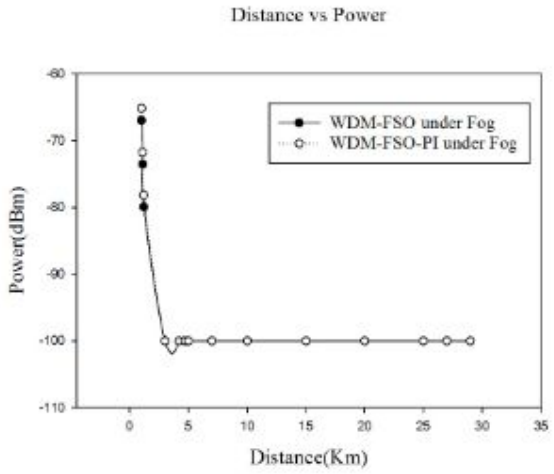
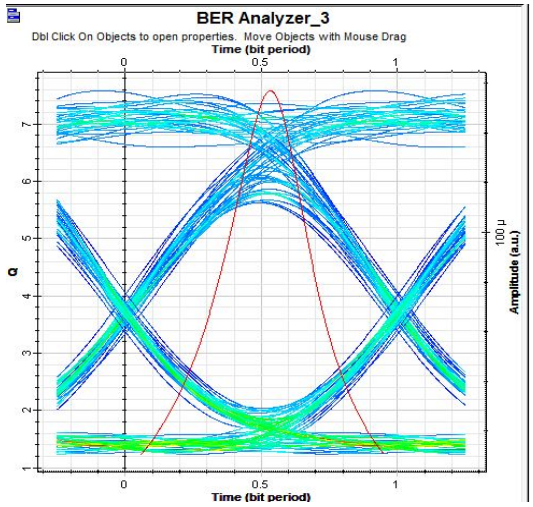
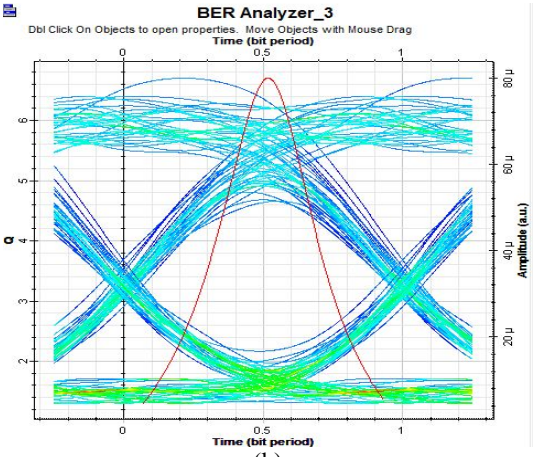


Fig 9: Comparison of WDM-FSO-PI and WDM-FSO systems under Fog condition in terms of Power



(a)



(b)

Fig 10: Eye diagrams representing the (a) WDM-FSO channel output at 1 Km and (b) WDM-FSO-PI channel output at 1.1 Km range.

From graphs and table it is observed that although under Fog condition (The typical attenuation value with acceptable visibility is considered to be 25 dB/Km) there is not much improvement in SNR and Power of WDM-FSO-PI system in comparison to WDM-FSO system but there is an improvement of 100 meters in range up to which the WDM-FSO link prolongs with the incorporation of Polarization Interleaving in WDM-FSO system.

CONCLUSION

In this article, WDM-FSO system is designed with the integration of Polarization Interleaving technique. It is concluded that by incorporating WDM technique in FSO system although the capacity is increased but the system is severely prone to fading with increasing attenuation in atmosphere. Due to which the range up to which the WDM-FSO link prolongs is bounded. But with the usage of Polarization Interleaving technique in WDM-FSO system , the contiguous channels are made orthogonal to each other, hence the effect of interference and fading is mitigated to a much larger extent. When the atmospheric attenuation is increased from 0.11 dB/Km to 4 dB/Km to 25 dB/Km depicting clear weather, Haze and Fog respectively then the

achievable distance with acceptable SNR and Power is extended in WDM-FSO-PI as compared to WDM-FSO system.

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