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Performance analysis of PDM-CO-OFDM in FSO communication system under various weather conditions

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Abstract: - *Free space optical communication (FSO) is very impressive because of its high data rate, less cost, and license free long–range operation. However, the climate conditions like haze, rain, fog etc are the barriers for the achievement of the desired performance of an FSO link. Here, we have implemented a hybrid polarization division multiplexing (PDM) with coherent optical orthogonal frequency division multiplexing (CO-OFDM) at 100Gbps data rate. The proposed model enhances the system performance by increasing the user capacity by reducing the multipath fading effect. The efficiency of the proposed system is analyzed in terms of bit error rate (BER) and optical signal to noise ratio (OSNR) for three modulation schemes, i.e. BPSK, QPSK and 4-QAM.The system is simulated by using OPTISYSTEM 16.0 software. On the basis of simulation outcomes, it is reported that though QAM and QPSK have the same spectral efficiency, low BER is achieved in case of QPSK. This work shall be useful for the FSO application even in poor weather conditions.*

Keywords: - *Free space Optics, CO-OFDM, PDM, Acceptable link range, OSNR, BER*

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I. Introduction

Free space optical (FSO) communication is considered as leading wireless communication technology that provides line-of- sight communication with a higher bandwidth at higher data rate. It is same as fiber optics instead of using light for transmission of data. The important characteristics of the FSO system are high security, easy installation , low cost and also license free long range spectrum [1]. It is highly sensitive to absorption, scattering, scintillation, temperature variations etc. that causes optical loss, signal variations and instability in the amplitude level due to which received power is getting faded. . Multiple TX/RX is used to enhance the link range, which is called spatial diversity technique [2].

In an OFDM scheme, the serial data stream is divided into number of parallel orthogonal sub channels. This increases the transmission rate. The OFDM is primarily attracted because it reduces multipath interference at the receiver i.e. inter symbol interference, inter channel interference and fading. Coherent optical OFDM is widely used for long haul optical communication because it shows high tolerance to chromatic dispersion and polarization mode dispersion. The beams of laser source are orthogonally polarized in polarization division multiplexing (PDM) to enhance the data rate. The advantages of PDM have less-cost implementation, highly spectrally efficient and magnified transmission capability [3]. The investigation of CO-OFDM-FSO link is done for 2Gbps and 5Gbps data rate during bad weather conditions. [4] .The performance of hybrid PDM/OFDM FSO transmission is illustrated at data rate of 2Gbps [5]. The performance of RF signal over optical FSO links using CO-OFDM is observed at a distance of 1km [6]. Coherent optical OFDM reduces chromatic dispersion, polarization mode dispersion, and theoretical fundamentals are reviewed [7]. The act of M-QAM–OFDM FSO transmission link is studied [8]. The performance of FSO communication with different channel model is presented [9]. The performances of 120Gbps single channel coherent DP-16-QAM is investigated for various climate conditions [10].

In this paper, the evaluation is performed based on simulations results of different modulation techniques for haze, rain and fog conditions. The gamma-gamma channel model is considered here. The purposed model is the PDM-CO-OFDM with QPSK modulation technique that achieves high range with less OSNR requirement than 4QAM because QPSK is less susceptible to noise. This article is arranged in the following manner. Section-2 describes the system model and principle of working. The proposed model is described in section-3. Section4 displays the simulation results and discusses the system performance. The conclusion of this work is presented in section-5.

II. System Design

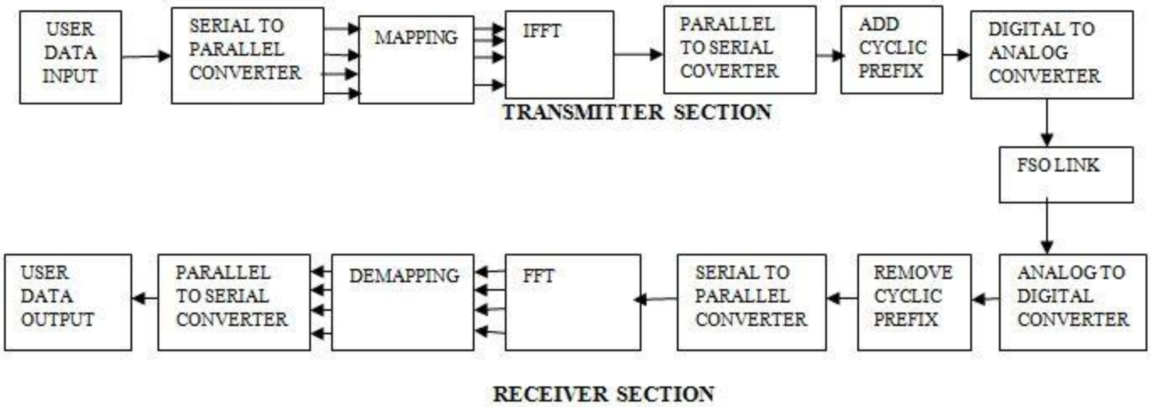


Figure 1: Block diagram of basic OFDM system

The schematic diagram of PDM-CO-OFDM model is shown in Figure 2. The system model has three sections: transmitter, FSO channel, and receiver. The transmitter portion includes a CW laser diode, polarization beam splitter, PSK/QAM sequence generator, OFDM modulator, and RF to optical converter. The block diagram of the OFDM system is presented in Figure 1. The OFDM modulator has serial to parallel converter to generate parallel data from serial data streams. The mapping has done on the basis of modulation scheme i.e. BPSK, QPSK and QAM .The inverse Fast Fourier transform(IFFT) ensures that the carriers are orthogonal to each other. Guard interval is used to minimize the inter symbol interference.

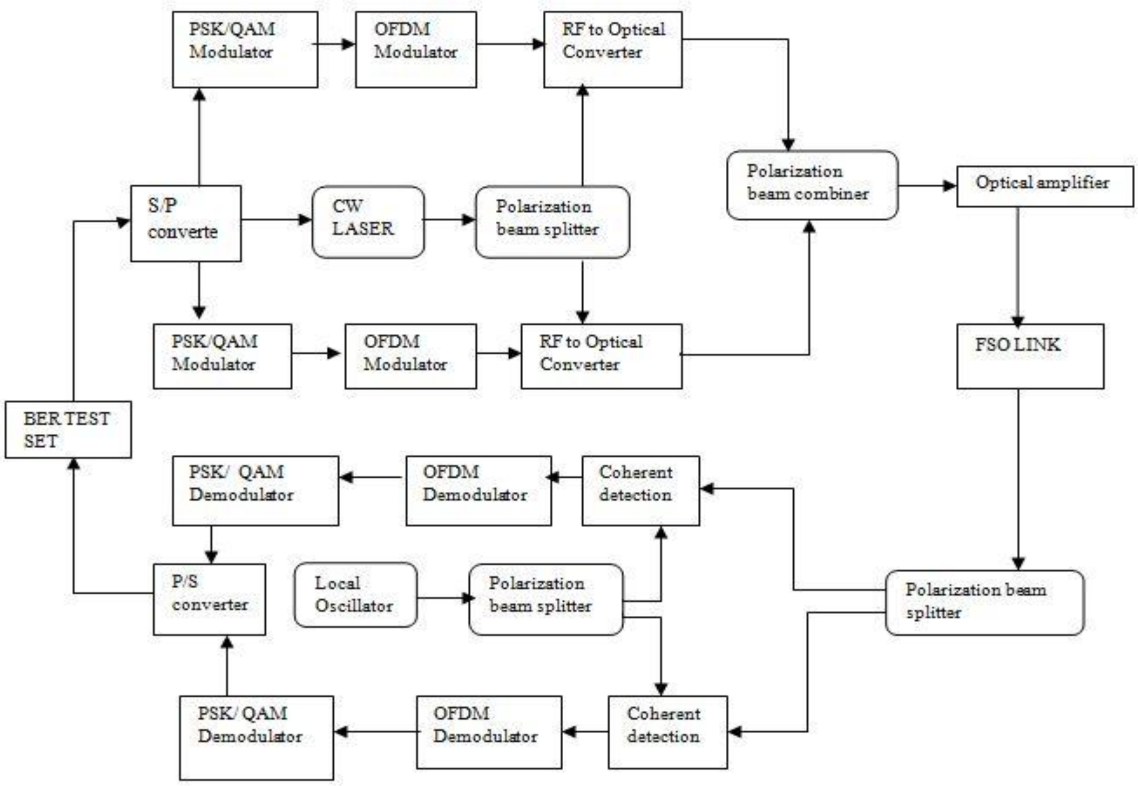


Figure 2: Block diagram of PDM-CO-OFDM system

The polarization beam splitter divides the laser power in to two polarized signals i.e. X polarized and Y polarized. The RF to Optical converter consists of two dual port Mach- Zehnder modulator (MZM), electrical gain, electrical bias, a cross-coupler and a $\frac{\pi}{2}$ phase shifter. This block converts the electrical signal in to an optical signal. The MZM modulator is set off at its null point for operation. The signals are combined by using polarization beam combiner, which are then transmitted over free space channel through FSO link.

There are three parts in a FSO channel i.e. transmitter telescope, receiver telescope, and free space channel. The FSO system is focussed on high link range and high link accessibility. The mathematical derivation for link equation is described as [3]:

$$P_R=P_T\left(\frac{d_R{}^2}{(d_T+\theta\ Z)^2}\right)10^{-\sigma Z/10} \qquad (1)$$

Where, P_R is the received optical power P_T is the transmitted power, d_R is the receiver aperture diameter, d_T is the transmitter aperture diameter, θ denotes beam divergence, σ is the attenuation coefficient for different weather conditions, and Z is the link range. The Gamma-Gamma distribution is used for channel modelling. The probability intensity is given as [3].

$$P(I)=\frac{2(\alpha\beta)^{(\alpha+\beta)/2}}{\Gamma(\alpha)\Gamma(\beta)}I^{[(\alpha+\beta)/2]-1}K_{\alpha-\beta\left[2(\alpha\beta I)^{1/2}\right]} \qquad (2)$$

Where, Γ and K are the Gamma and Bessel functions, respectively. α and β corresponds to the large and small scale effects of disturbance, respectively, which are expressed as follows [3]:

$$\alpha=\left\{exp\left[\frac{0.49\sigma^2}{(1+1.1\sigma^{12/5})^{7/6}}\right]-1\right\}^{-1} \qquad (3)$$

$$\beta=\left\{exp\left[\frac{0.51\sigma^2}{(1+0.69\sigma^{12/5})^{5/6}}\right]-1\right\}^{-1} \qquad (4)$$

Where, $\sigma^2=1.23C_n^2\ k^{7/6}Z^{11/6}$ is the Roytov variance, k=$\left(\frac{2\pi}{\lambda}\right)$ represents the optical wave number, and λ represents the operating wavelength, and C_n^2 is taken as given in Table I, which corresponds to medium turbulence [3]. In the receiver section, an optical Gaussian filter with 50GHz bandwidth is used to filter the received signal. The received signal is divided into two orthogonal polarization states by polarization beam splitter. The signal is recovered by using an optical coherent dual-polarization PSK receiver. It is based on homodyne receiver design that consists of a local oscillator (LO), balanced photo detectors and electrical amplifiers. The LO is a CW laser source of the same parameters that are used during transmission. Balanced photo detectors are used to detect signal variations, to produce high-signal-to noise (SNR) ratio and to cancel laser noise [3]. The demodulated signal is further decoded by PSK decoder. The simulation results are obtained by BER test set, electrical constellation Visualize, and Optical Spectrum Analyzer.

III. Proposed Model

Figure 3 shows the simulation layout of proposed model. The system is simulated by using OPTISYSTEM 16 software. QPSK modulation technique is used for signal mapping. 4QAM and QPSK have same spectral and bandwidth efficiency, But QAM is more susceptible to noise. In order to achieve a low BER, QPSK modulation scheme has taken in to consideration. BPSK is the most robust of all PSK but symbol rate of BPSK is 1bit/symbol. So QPSK has higher spectral efficiency compared to BPSK. By comparing the three modulation schemes, QPSK is more suitable for long-haul communication. Table I and Table II represent the link parameters and attenuations respectively.

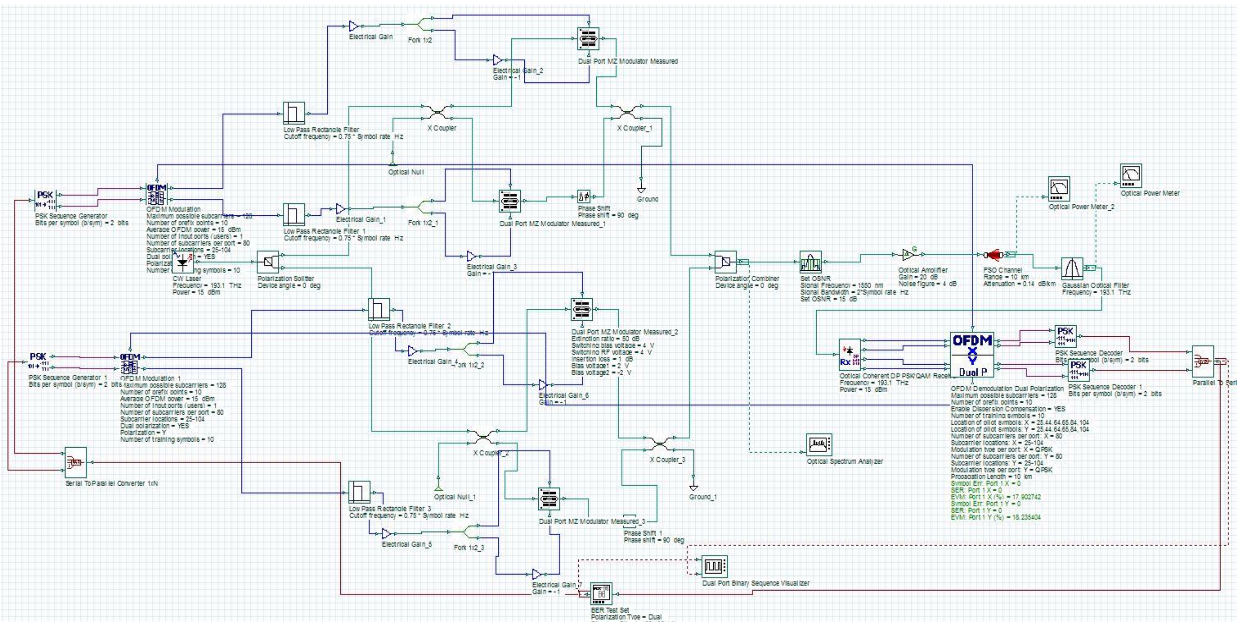


Figure 3: Simulation layout of QPSK modulated PDM-CO-OFDM

Table I: Parameters values used for simulation

Parameter	Value
Bit rate	100Gbps
OFDM subcarrier No.	128
Used OFDM sub-carrier No.	80
No. Of prefix point	10
Dark current	10nA
PIN Responsivity	1 A/W
Transmitter telescope antenna diameter	5cm
Receiver telescope antenna diameter	20cm
Beam divergence	2mrad
Refractive index , C_n^2	$5\times10^{-15}m^{-2/3}$
Operating frequency	193.1THz
Optical amplifier gain	20dB

Table II: Attenuation values for different weather condition

Weather type	Attenuation in dB/Km
Clear	0.14
Haze	4
Rain	9.64
Low Fog	34

IV. Results And Discussion

The performance of the system is observed in terms of BER for haze, rain and fog under moderate turbulence effect. The OSNR is set by using “Set OSNR” component for simulation purpose. The OSNR is defined as:

$$\text{OSNR (dB)} = P_s(\text{dB}) - P_n(\text{dB}) \qquad (5)$$

Where P_s represents the total signal power within the signal bandwidth and P_n is the noise power measured at 0.1nm bandwidth window. To achieve a certain log (BER) ≤ -2.42 i.e. FEC threshold limit [3], the minimum required OSNR shows the resistance of the modulation technique to noise over a bounded bandwidth (0.1 nm). The OSNR value of a modulation technique is inversely related to the Euclidian distance. The OSNR has taken 10dB, 15dB, and 15.5 dB to attain the FEC limit in BPSK, QPSK, and 4QAM respectively.

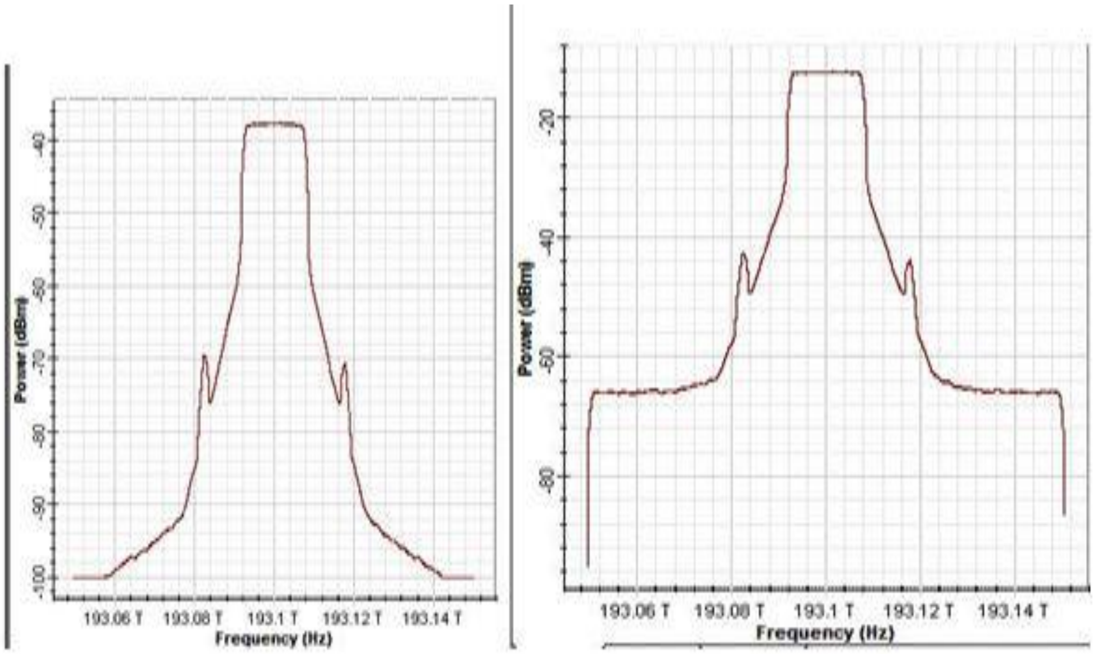


Figure 4: Optical Spectrum of received signal and transmitted signal, respectively

The optical spectrum of transmitted signal and received signal is shown in Figure 4. The receiver received almost proper signal as transmitter having maximum frequency at 193.1THz. Each modulation scheme is evaluated over 50GHz bandwidth and the spectral efficiency at this bandwidth is calculated to be 1bits/sec/Hz for BPSK, 2bits/sec/Hz for 4QAM and QPSK. Figure 5 represents the relation between OSNR and log(BER) for BPSK, QPSK and 4QAM modulation techniques. It is shown that 5dB more OSNR value is required in 4QAM and QPSK than BPSK to achieve the same BER value. . But QPSK has high spectral efficiency than BPSK. Therefore, in further analysis of the proposed PDM-CO-OFDM based FSO system, QPSK mapping scheme has taken in to consideration. The constellation diagram of different modulation technique is shown in Table III. In BPSK modulation, the data is successfully retrived up to 18km, 4km, 2.2km, 0.87km for clear, haze, rain, and low fog conditions, respectively. In QPSK modulation, the data is successfully retrived up to 16km, 3.75km, 2.15km, 0.86km for clear, haze, rain, and low fog conditions, respectively. In 4QAM modulation, the data is successfully retrived up to 15km, 3.6km, 2.02km, 0.8km for clear, haze, rain, and low fog conditions, respectively. Figure 6 represents that the transmitted data is successfully received at the receiver by dual port binary sequence visualizer. Figure 7 shows the relation between transmission range and log (BER) for different weather condition. The log(BER) increases with increase in link range. The BER value also depends upon the atmospheric attenuation co-efficients.

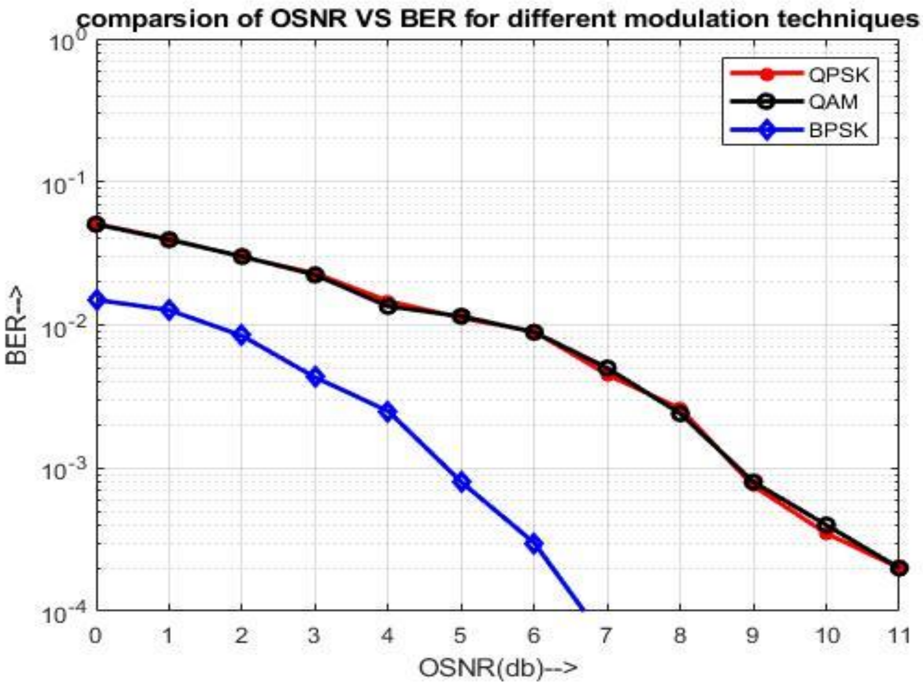
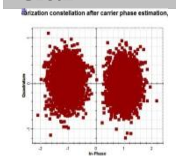
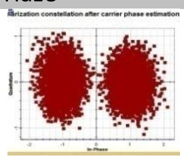
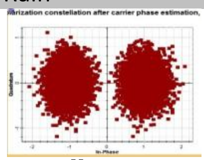
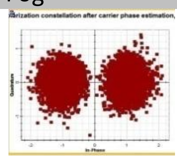
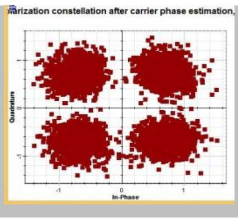
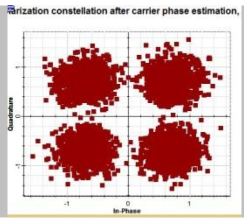
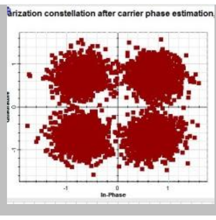
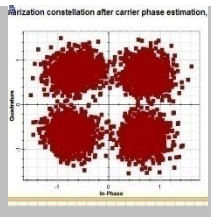
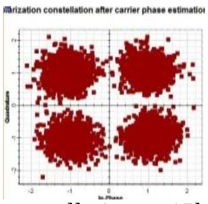
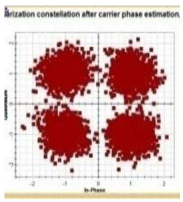
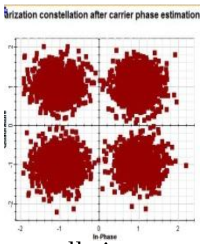
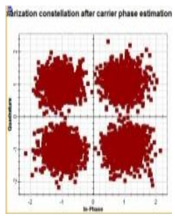


Figure 5: OSNR versus BER for BPSK,QPSK, and 4QAM technique

Table III: Constellation plots for various weather conditions using BPSK, QPSK, AND 4QAM at their acceptable range

Modulation Technique	**Weather conditions**			
	Clear	Haze	Rain	Fog
BPSK	 constellation at 18km	 constellation at 4km	 constellation at2.2km	 constellation at 0.87km
QPSK	 constellation at 16km	 constellation at 3.75km	 constellation at 2.15km	 constellation at 0.86km
4QAM	 constellation at 15km	 constellation at 3.6 km	 constellation at 2.02km	 Constellation at 0.8km

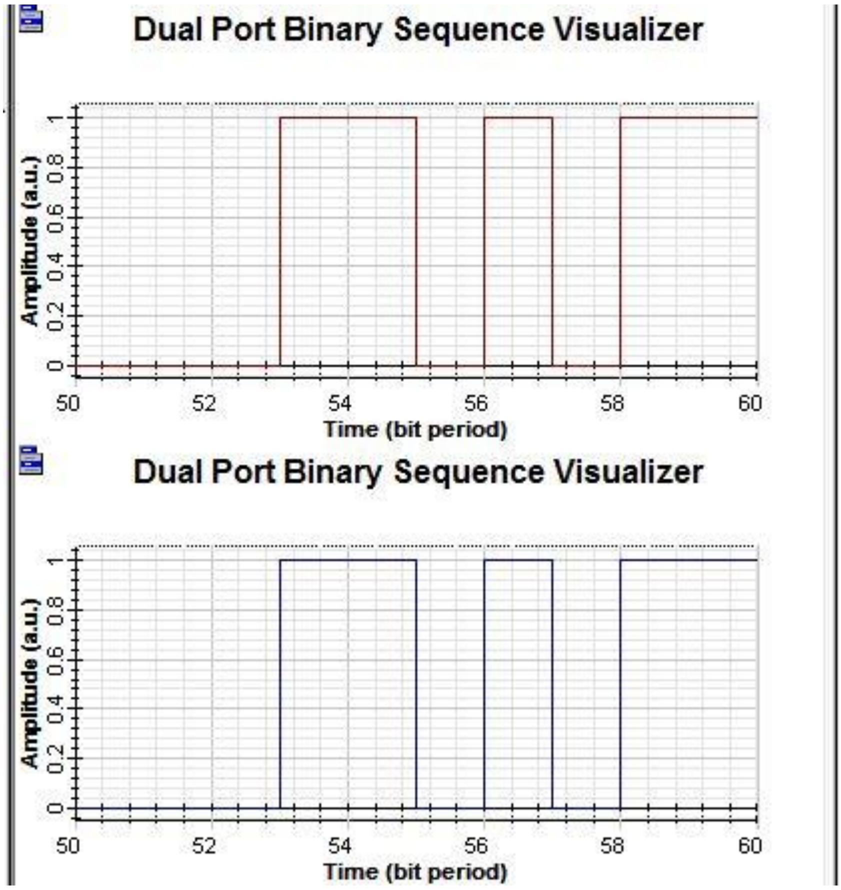


Figure 6: Transmitted signal and Received signal, respectively

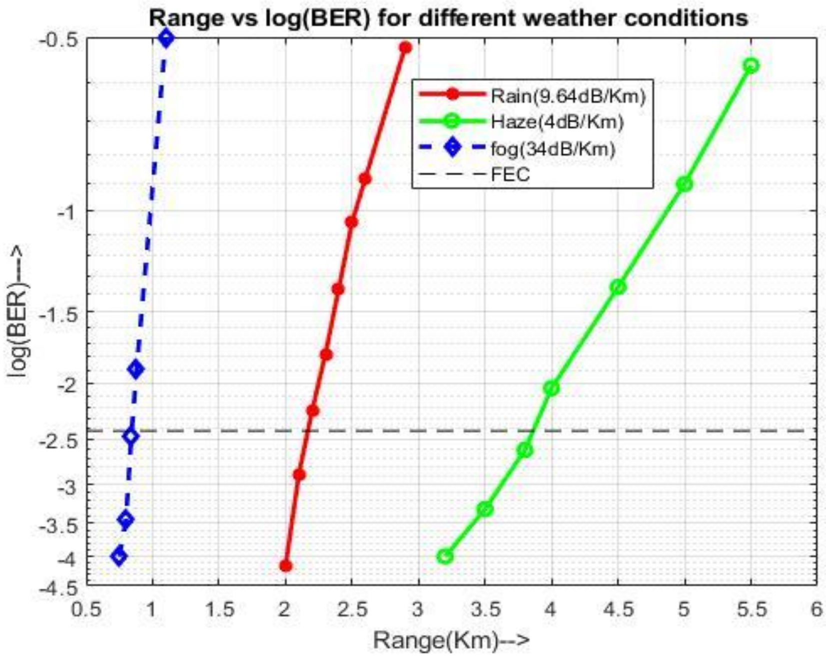


Figure 7: Range versus BER for different weather conditions

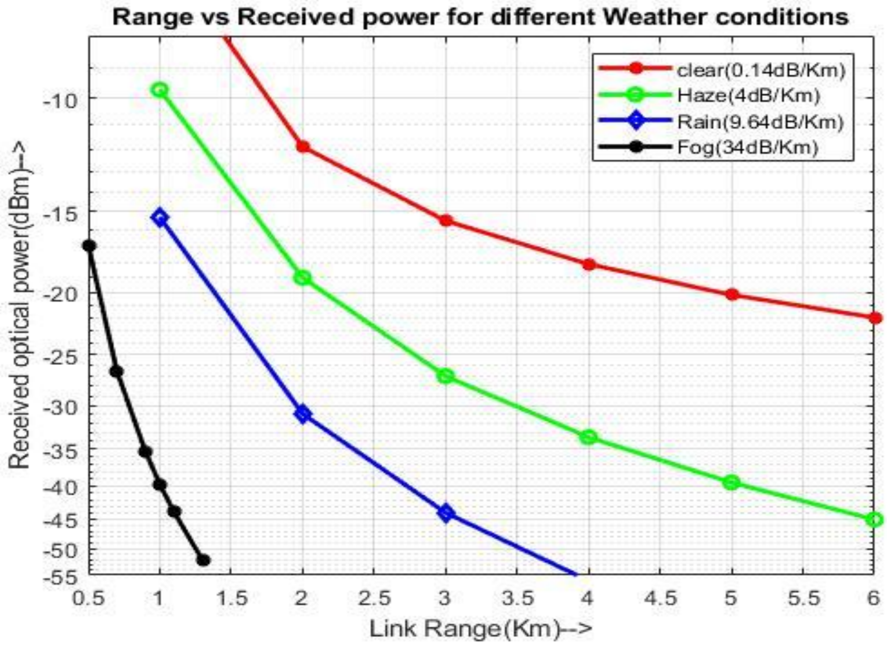


Figure 8: Received optical power versus range under different weather condition

From Figure 8 , it is shown that the received optical power depends upon the link range and also atmospheric attenuation co-efficients. It decreases with increase in link distance and attenuation co-efficients. For the evaluation of our system, Table IV represents the comparison of our model with literature. The proposed system has high transmission range at lower OSNR value.

Table IV: performance comparison of the proposed model with literature

Methods	Climate conditions	Attenuation in dB/km	Data rate in Gbps	Maximum range in km
CO-OFDM FSO using QAM scheme[4]	Clear	0.155	5	27
	Mild rain	4.285	5	4.3
	Mild fog	33.96	5	1.1
CO-OFDM FSO using 8TX/RX [2]	Clear	0.155	10	150
	Mild rain	4.285	10	4
	Mild fog	33.96	10	0.8
Hybrid PDM-CO-OFDM based FSO link using 4-QAM scheme [3]	Clear	0.14	100	15
	Mild haze	4	100	3.6
	Mild rain	9.64	100	2.02
	Low fog	34	100	0.8
PDM-CO-OFDM based FSO link using QPSK scheme(present work)	Clear	0.14	100	17
	Mild haze	4	100	3.75
	Mild rain	9.64	100	2.2
	Low fog	34	100	0.86

V. Conclusion

In this paper, performance of hybrid PDM-CO-OFDM technique is evaluated for three modulation schemes (BPSK, 4QAM, and QPSK) under clear, haze, rain and fog conditions. On the basis of simulation results, BPSK requires less OSNR achieving highest range but phase ambiguity problems occur at the receiving end. So QPSK is considered here as QAM is more susceptible to noise. Further, the system performance of 100Gbps QPSK data with the range variation up to 18km is done at OSNR 15dB. The proposed system is compared with the reported work. It provides high capacity and high speed for long haul transmission.

References

[1]. A.Kumar, A.Dhiman, D.Kumar, N.Kumar, "Free Space Optical Communication System under Different Weather Conditions", IOSR Journal of Engineering (IOSRJEN), vol. 3, no. 12, pp. 52-58, 2013.

[2]. V. V. Sudheer and A. Mandloi, "Enhanced coherent optical OFDM FSO link using diversity for different weather conditions IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), 2016, pp. 1221-1225, doi: 10.1109/RTEICT.2016.7808026.

[3]. M. Singh, J. Malhotra, M.S. Mani Rajan, D. Vigneswaran, M.H. Aly, "A long-haul 100 Gbps hybrid PDM/CO-OFDM FSO transmission system: impact of climate conditions and atmospheric turbulence" Alexandria Eng. J. (2020) ,10.1016/j.aej.2020.10.008.

[4]. P. Patel, V. Mishra and V. Singh, "Performance analysis of CO-OFDM FSO system under different weather conditions," 2014 2nd International Conference on Emerging Technology Trends in Electronics, Communication and Networking, 2014, pp. 1-5, doi: 10.1109/ET2ECN.2014.7044972.

[5]. G. Kaur, D. Srivastava, P. Singh, Y.Parasher, "Development of a novel hybrid PDM/OFDM technique for FSO system and its performance analysis",Optics & Laser Technology,Vol. 109,2019.

[6]. S. Srikanth, P. Sriram and D. S. Kumar, "Performance analysis of OFDM employing free space optical communication system," 2015 2nd International Conference on Electronics and Communication Systems (ICECS), 2015, pp. 70-74, doi:10.1109/ECS.2015.7125002.

[7]. W. Shieh, H. Bao, and Y. Tang, "Coherent optical OFDM: theory and design," Opt. Express 16, 841-859 (2008).

[8]. Sangeetha R.G., I .Jaiswal, Suchetha M, " Performance of M-ary quadrature amplitude modulation -based orthogonal frequency division multiplexing for free space optical transmission", IET Optoelectronics. 10. 10.1049/iet-opt.2015.0091.

[9]. A. Kaur, R. K. Panchal, "Analysis the effect atmosphere turbulence in free space optical (FSO)communication systems", International Journal ofEngineering and Innovative Technology (IJEIT) Volume 3,Issue 11, May 2014.

[10]. Kakati D, Arya SC, "Performance of 120 Gbps single channel coherent DP-16-QAM in terrestrial FSO link under different weather conditions", Optik, Volume 178,2019.

Meetarani Swain, et. al. "Performance analysis of PDM-CO-OFDM in FSO communication system under various weather conditions." *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)* 16(3), (2021): pp: 14-22.