PERFORMANCE EVALUATION OF MODULATION SCHEMES IN FSO SYSTEMS UNDER DIFFERENT CHANNEL SETTING

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Abstract — *Today's communication scenario poses growing demand for high speed and high rate applications built on technologies that can withstand impairments encountered at different points in the communication setup. This requires large bandwidth as the number of users in mobile communication has increased considerably with time. The bandwidth limited technologies available such as RF/microwave, optical fiber, copper and coaxial cables will fail to achieve these requirements. This makes Free Space Optical (FSO) communication an inevitable technology that needs to be adopted for addressing the communication bottleneck. FSO with its inherent advantages of offering very high data rate in unlicensed spectrum, ease in deployment and inexpensive development cost acts as a complementary scheme to the existing technologies. However atmospheric conditions is a major concern in FSO propagation as intensity of propagating optical signal reduces significantly in worse weather conditions. This necessitates pumping of additional optical energy or concentrating and focusing of power in narrow areas which is best taken care by a suitable modulation scheme. This paper compares the performance of various modulation techniques in FSO systems on the basis of mean optical power received needed to minimize the error rate for a defined input data rate. It is an indispensable requirement for a modulation technique to utilize power efficiently. At the same time challenges in transmitter and receiver design and the bandwidth requirement are equally important in the selection of a modulation technique*

Keywords — *FSO, Atmospheric turbulence (AT), BER, Gamma-Gamma, Log-normal*

I. INTRODUCTION

Practical FSO systems mostly employs IM/DD scheme in various applications. The major threat is heavy fog encountered during FSO transmission. The straightforward approach to overcome the high attenuation due to worse atmospheric conditions such as fog is to increase the optical power of the transmitter. The transmission of optical power is constrained by several factors like eye safety, power consumption and device limitation. Modulation schemes such as quadrature amplitude modulation (QAM) and multilevel pulse amplitude modulation (PAM) are bandwidth efficient but not power efficient. To meet the eye and skin safety standards limited power emission of optical source is required. In case of battery powered device it is advisable to maintain minimum electrical power consumption which in turn restricts transmit optical power. Hence the first and foremost criterion while evaluating modulation technique is the power efficiency. Theoretically optical signal is considered of having unlimited bandwidth even then other factors such as channel capacity, receiver area in the system limits the spectrum practically available for communication. Modulation techniques having high bandwidth requirement are prone to inter symbol interference (ISI) and hence invite a high power penalty. This makes bandwidth the second most essential parameter in deciding a modulation technique. In adverse conditions any modulation scheme needs to offer a least tolerable BER. This requires the modulation method to oppose many factors for example atmospheric turbulence, phase jitter as a result of changes in signal power [2]. Other deciding factors include ability to discard interference from non-natural sources of ambient illumination, design simplicity making it cost feasible, resistance to ISI arising due to multipath propagation.

II. Atmospheric Turbulence Models

Turbulent medium is a major threat on the information carrying optical beam resulting in fading of received irradiance. AT is categorised based on the extent of refractive index deviation and in homogeneities [1]. Turbulence regimes may be categorised as weak, moderate, strong and saturation. Due to complexity attached with the mathematical modelling of AT, a universal model does not exist that can describe the all turbulence regimes[3]. Two of the most used models for depicting irradiance fluctuation are log-normal and gamma-gamma models.

Log-Normal Turbulence Model

Log-Normal model is widely used for weak turbulence conditions. The log normal distribution has a probability distribution function defined as

$$p(I) = \frac{1}{\sqrt{2\pi\sigma_l^2}} \frac{1}{I} \exp\left\{-\frac{(\ln(I/I_0) - E[l])^2}{2\sigma_l^2}\right\} \quad I \geq 0$$

Where I is the field irradiance in the turbulent medium, E[l] indicates mean log intensity, σ_l^2 is the log irradiance variance defined in terms of the refractive index structure parameter C_n^2 as

$$\sigma_l^2 = 1.23 C_n^2 k^{7/6} L_p^{11/6}$$

Gamma-Gamma Turbulence Model

This model is derived from the modulation process in which the optical radiation fluctuation travelling in a chaotic atmosphere is considered to contain small-scale and large-scale effects. Small-scale effects result when atmospheric eddies/cells are smaller compared to Fresnel zone or the coherence radius whichever is less significant. Alternatively large scale fluctuations are produced when turbulent eddies are larger compared to the first Fresnel zone or the scattering disk whichever is more significant.

The gamma-gamma irradiance distribution function is given by

$$p(I) = \frac{2(\alpha\beta)^{(\alpha+\beta)/2}}{\Gamma(\alpha)\Gamma(\beta)} I^{(\alpha+\beta/2)-1} K_{\alpha-\beta}\left(2\sqrt{\alpha\beta I}\right) \quad I > 0$$

where α and β refers to the effective number of large and small scale eddies resulting from the scattering process respectively. $K_n(.)$ is the modified Bessel function of the 2nd kind of order n and Γ(.) indicates the gamma function

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III. Proposed Design

The proposed idea is to simulate FSO transmission using several modulation techniques under atmospheric turbulent conditions. The system is designed with the considered range of 1400m and the laser source of wavelength about 1550nm. The system consists of a narrow beam of the continuous wave laser (CW laser) generated with a frequency of about 193.1 THz. The source transfers its beam to the Mach Zehnder Modulator (MZM) that modulates the optical signal with carrier signal as modulating signal[4]. The signals from the PRBS (Pseudo random bit sequence) codes the optical signals as 0's and 1's and transmits to the NRZ (non-return to zero) pulse generator or OQPSK (offset quadrature phase shift keying) pulse generator or PSK (phase shift keying) pulse generator or QAM (quadrature amplitude modulation) pulse generator. The narrow beams of light rays are propagated through the FSO channel with the wavelength of about 1550nm.The optical signal propagates through the channel to the optical receiver consisting of an Avalanche photodiode (APD).

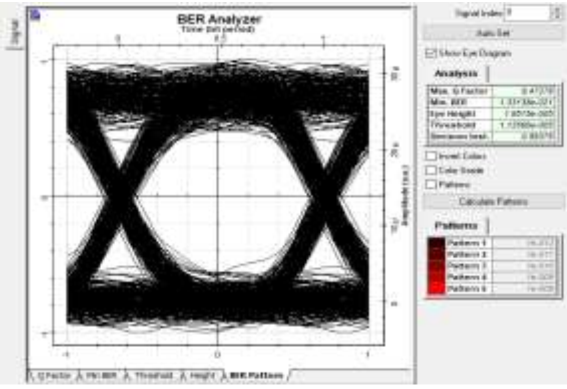
IV. Simulation Results

Following table shows a comparison of the various parameters for different modulation techniques used to modulate the random generated sequence under gamma-gamma and log normal channel setting. It is seen that BER of PSK is minimum compared to other techniques for gamma-gamma whereas in a log normal FSO channel NRZ technique offers minimum BER.Q factor is high for PSK under gamma-gamma channel and for NRZ in log normal channel.

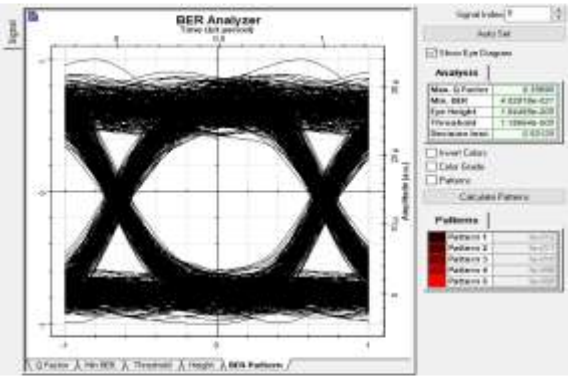
Channel type	**Parameter**	**NRZ**	**OQPSK**	**PSK**	**QAM**
Gamma-Gamma	Max Q factor	9.472	9.378	9.615	9.521
	Min BER	1.33×10^{-21}	3.33×10^{-21}	3.41×10^{-22}	8.36×10^{-22}
	Eye Height	1.85×10^{-5}	1.84×10^{-5}	1.85×10^{-5}	1.86×10^{-5}
	Transmitted optical power	21.526 dBm	22.007 dBm	21.943 dBm	21.408 dBm
	Received optical power	-23.688 dBm	-23.207 dBm	-23.271 dBm	-23.806 dBm
Log-normal	Max Q factor	9.356	9.309	9.136	9.295
	Min BER	4.02×10^{-21}	6.39×10^{-21}	3.22×10^{-20}	7.192×10^{-21}
	Eye Height	1.84×10^{-5}	1.82×10^{-5}	1.82×10^{-5}	1.84×10^{-5}
	Transmitted optical power	21.535 dBm	22.040 dBm	22.071 dBm	21.606

					dBm
	Received optical power	-23.679 dBm	-23.175 dBm	-23.143 dBm	-23.609 dBm

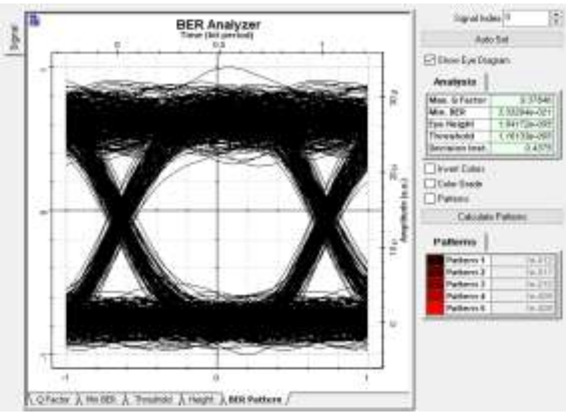
BER pattern of NRZ technique in Gamma-gamma Channel setting



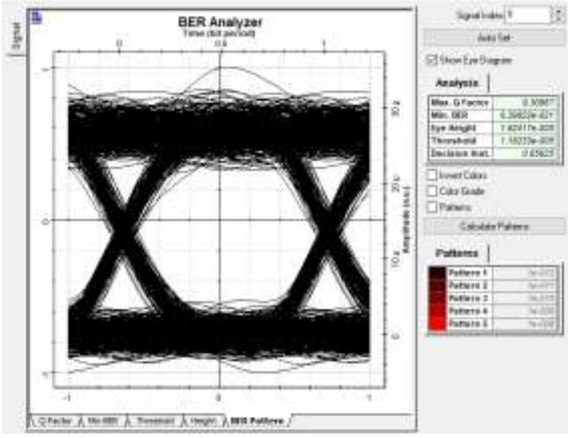
BER pattern of NRZ technique in Log normal Channel setting



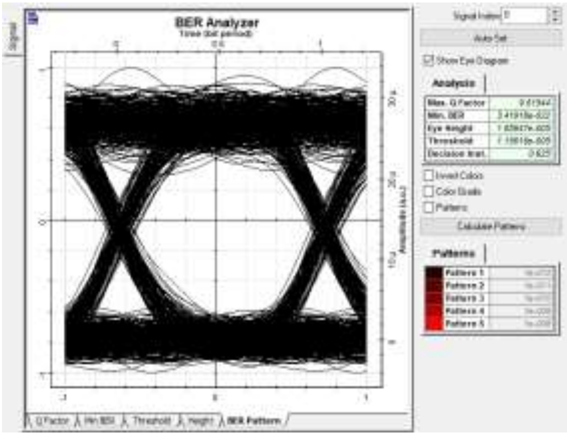
BER pattern of OQPSK technique in Gamma-gamma Channel setting



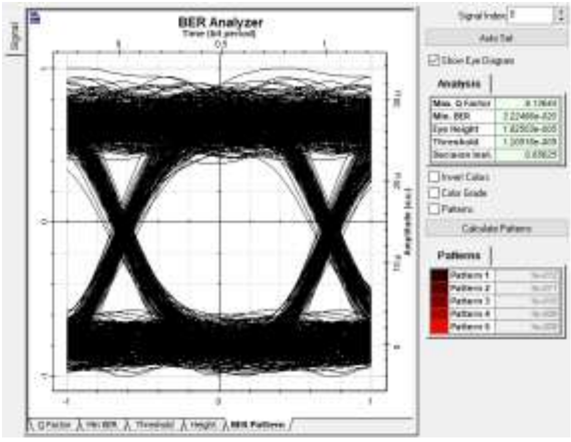
BER pattern of OQPSK technique in Log normal Channel setting



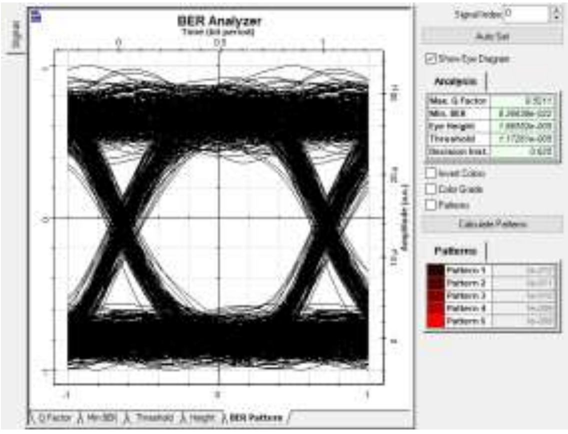
BER pattern of QPSK technique in Gamma-gamma Channel setting



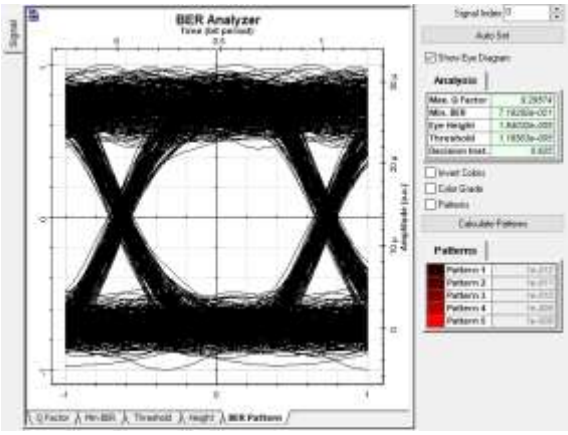
BER pattern of QPSK technique in Log normal Channel setting



BER pattern of QAM technique in Gamma-gamma Channel setting



BER pattern of QAM technique in Log normal Channel setting



V. CONCLUSIONS

The aim of this work is to setup and investigate a FSO link performance analysis under different modulation techniques. The comparative study depicts that the transmission system having the NRZ pulse is best suited for the log-normal channel setting compared to other modulation formats as it provides the highest gain and minimum BER. The optical transmission system is modelled using the Optisystem software. Analysis of system performance is based on the BER performance. The simulation results show that PSK modulated MZ modulator gives better performance in terms of BER in comparison with the other modulation techniques like OQPSK, NRZ and QAM for gamma-gamma channel. Similarly for the analysis of BER performance by varying the channel model to log-normal, NRZ using MZ modulator gives better BER performance as compared to other modulation techniques and PSK gives the worst BER performance.

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