BER ANALYSIS OF HYBRID-FSO COMMUNICATION SYSTEM OVER LOG-NORMAL ATMOSPHERIC TURBULENCE MODEL USING PIN BASED RECEIVER

[1] Ankur Sood, [2]Neeru Bala, [3]Manoranjan Kumar, [4] Harsh kumar

[1]Assistant Professor, [2]Assistant Professor, [3] Assistant Professor, [4]Assistant Professor

[1]Department of Electronics & Communication Engineering,

Dr. Akhilesh Das Gupta Institute of Technology & Management ,Delhi, India

Abstract : In this paper, BER is analysed in Free Space Optical (FSO) communication system. In FSO system, Log normal atmospheric turbulence model is used to analyse the link. To minimize the scintillation effect, a PIN detector can be employed at the receiver. Numerical results shows that hybrid modulation technique shows better results as compared to simple SIM based modulation technique. Spatial diversity technique is also applied for performance improvement for the proposed system.

***Index Terms* - Free space optics (FSO). Signal to noise ratio (SNR). Scintillation. Bit error rate (BER). Subcarrier intensity modulation (SIM).**

I. INTRODUCTION

In unguided propagation medium using optical carriers are used such as visible light, infrared (IR) and ultraviolet (UV) bands are utilized for optical wireless communication (OWC). It is also referred to as free space optical (FSO) communication for high rate transmission between two points which are several kilometre distances apart. FSO have very high bandwidth available so that higher data rates can be transmitted easily.

Optical wireless communication (OWC) uses either LED or Laser as transmitters. Optical wireless communication (OWC) can be used in diverse range of communication applications due to different traffic patterns and requirements of higher data rates. Optical wireless communication (OWC) can be used for ultra-short range e.g., chip to chip communication, short range OWC in wireless body area network (WBAN) & wireless personal area network (WPAN), medium range OWC for WLAN, long range OWC for inter-building connection and ultra-long range OWC for inter-satellite link or deep space link. OWC products with high data rates of 10Gbps and higher are available in market. Free space optical (FSO) technology uses frequency above 300GHz which comes under unlicensed band. Its applications include campus connectivity, video surveillance & monitoring, back haul for cellular system, disaster recovery, security & broadcasting [1]-[2].

FSO is used for faster data rate transmission upto certain distances in the range of 300GHz unlicensed band. The main challenge in FSO is atmospheric turbulence which is mainly due to variation in temperature and pressure in atmosphere. It will change the amplitude and phase of the received signal [3]-[4].

FSO is less affected by snow and rain but heavily influenced by fog which limits the link range. In the dense fog condition (with attenuation up to 300dB/km), availability of the link is limited to 100 m.

The performance of FSO communication systems suffer severely from the turbulence. The turbulence is the results of wind and temperature gradients that create air pockets with varying refractive index. The traversing light beam experience random fluctuation in its intensity (scintillation) and phase, leading to degradation in performance.

Intensity fluctuation due to atmospheric turbulence will occur which is known as scintillation. Bit error rate will increase and signal strength will deteriorates due to scintillation[5]. Different modulation techniques can be used in the FSO communication system. On-Off keying (OOK) modulation technique used for FSO system has advantage of its low cost and simplicity but it has the limitation of low power efficiency and poor performance in variations in the signal intensity [3].Pulse position modulation (PPM) is proposed as it has better power efficiency but it has poor bandwidth efficiency.

Subcarrier intensity modulation (SIM) techniques is being proposed to remove the limitations of OOK and PPM. Spatial diversity techniques can be Maximum ratio combining (MRC), equal gain combining (EGC), selection combining for single input multiple output (SIMO) system to minimize the effect of scintillation to further improve the BER performance[6]-[8].

II. FSO COMMUNICATION SYSTEM MODEL

The optical carrier can be modulated in its frequency, phase, intensity and state of polarization. The intensity modulation is preferred due to its simplicity in implementation. Various modulation schemes have their advantages and challenges. While selecting a modulation scheme, various parameters such as power efficiency, bandwidth efficiency and BER are considered.

A. Tx & Rx Block Diagrams

Transmitter has NRZ pulse generator, PRBS (Pseudo Random Bit Sequence) generator, a laser source and (MZM) Mach Zehnder Modulator and is received by APD or PIN photo diode. A low pass Bessel filter is utilized to get the desired signal at the output [4].

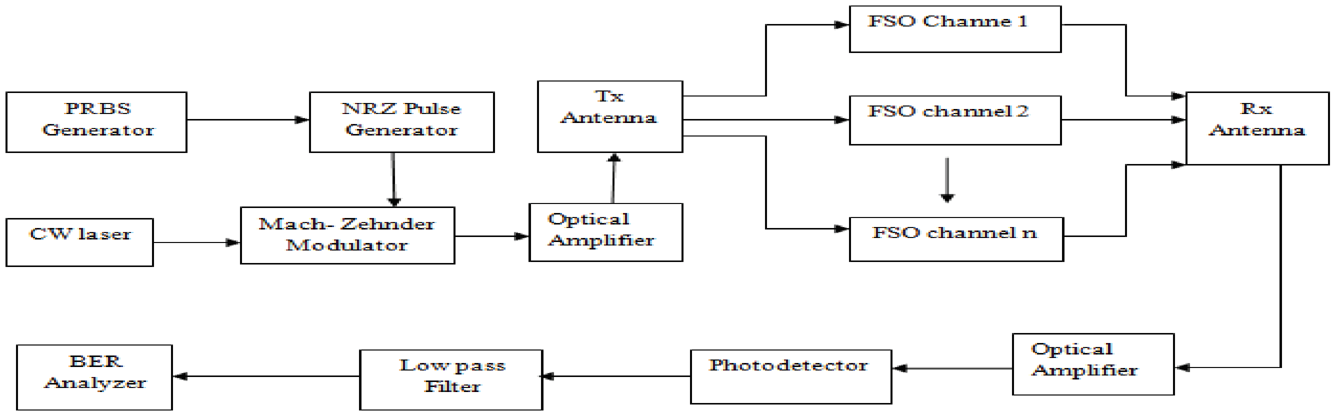

Fig.1 Block diagram of FSO system

B. Modulation Scheme

For an FSO communication system, the hybrid PPM-BPSK-SIM can be described as follows: First, a block of $M = \log_2 L$ data bits is converted into the symbol format of PPM, here, M is the number of bits per symbol or the modulation order, and L is the average length of symbol; the PPM code-word will become a new array of data after a parallel-to-serial conversion; finally the new array of data is modulated into the subcarrier signal using the BPSK signal. Since the modulated subcarrier signal is sinusoidal having both positive and negative values, a DC bias is added to the BPSK signal before it is used to drive the laser diode. This will ensure that the bias current is always equal to or greater than the threshold current.

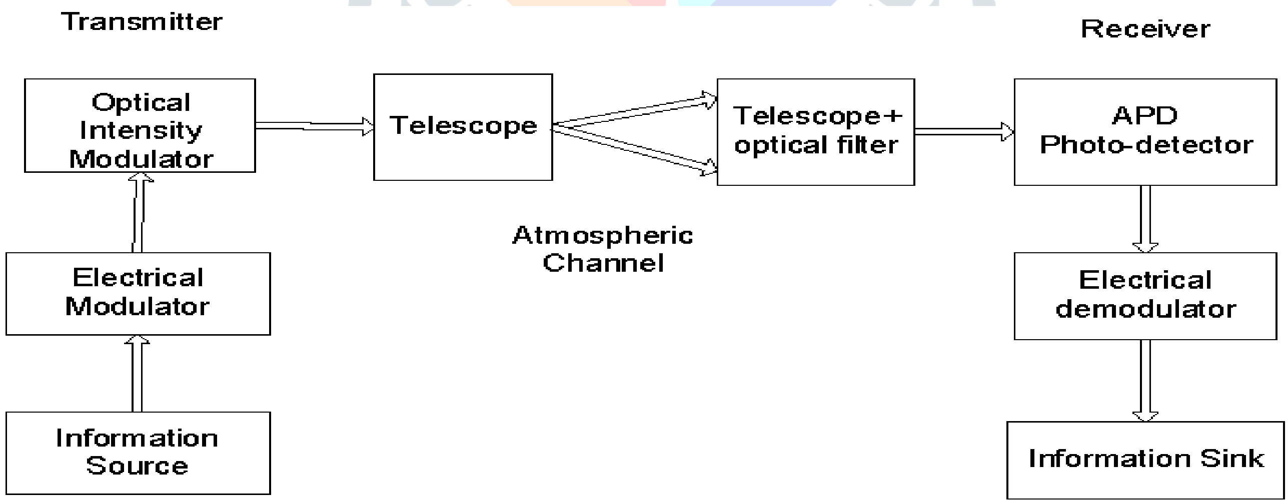

Fig.2 Block diagram of FSO system using BPSK-SIM and APD detector

At the receiver end, the incoming optical radiation is filtered through an optical band pass filter (OBPF), then it is converted into electrical signal, which is detected by an APD or PIN detector directly. Photocurrent is always proportional to the modulated signal [5].

III. CHANNEL MODELLING

In the hybrid-SIM technique, the PPM signal modulates the RF sub-carrier signal using BPSK–SIM modulation scheme and the resultant modulated signal modulates the optical source signal. In receiver side, the optical signal is converted to the electrical signal in the direct photo-detection process.
The random variation of atmosphere may cause inhomogeneity in temperature, density and refractive index. When the signal propagates through the atmosphere, the light intensity fluctuations occur, which will degrade the performance of the system.
In order to reduce the effect, several probabilistic models are proposed for the turbulence, including log-normal, gamma-Gamma and K distributions. The probability density function of Gamma-Gamma distribution is given by[4]

$$p(I) = \frac{2(\alpha\beta)^{\frac{\alpha+\beta}{2}}}{\tau(\alpha)\tau(\beta)} I^{\frac{\alpha+\beta}{2}} K_{\alpha-\beta}(2\sqrt{\alpha\beta I}), \quad I > 0 \qquad (1)$$

where Γ(·) is the Gamma function, Kα-β(·) is modified Bessel function of the second kind, I is light intensity, α and β are the effective numbers of small-scale and large-scale eddies of scattering environment, respectively. For a plane wave, they can be given by [4]

$$\alpha = \left[\exp\left(0.49 \frac{\sigma_R^2}{\left(1+1.11\sigma_R^{\frac{12}{5}}\right)^{\frac{7}{6}}}\right) - 1\right]^{-1} \qquad (2)$$

$$\beta = \left[\exp\left(0.51 \frac{\sigma_R^2}{\left(1+0.69\sigma_R^{\frac{12}{5}}\right)^{\frac{5}{6}}}\right) - 1\right]^{-1} \qquad (3)$$

Here, we have considered the path loss and the receiver noise effects for the performance evaluation of the system.

A. Path loss:

The phase and amplitude of the transmitted optical signal get attenuated during the long distance propagation because of absorption, refraction, scattering, misalignment, etc. So the total path loss due to the atmospheric attenuation is given by[2]

$$a_c = \frac{A_d}{\pi(\frac{\phi_d L_p}{2})} \exp(-\beta_e L_p) \qquad (4)$$

B. Noise effects in the receiver:

The noises observed in the FSO communication system by the PIN detector are background noise and thermal noise. The background noise occurs because of the radiations from both the sun and sky, which affects the receiver sensitivity is given by [5]

$$\sigma^2_{Bg} = 2qRB\,(I_{sun}+I_{sky}) \qquad (5)$$

In high-frequency operation, the thermally generated electrons fluctuation leads to thermal noise. It is given by [5]

$$\sigma^2_{th} = 4k_B TB/R_L \qquad (6)$$

So the total noise variance for the PIN detector can be expressed as [5]

$$\sigma^2_N = \sigma^2_{Bg+} \ \sigma^2_{th} \qquad (7)$$

The output photo-current of the photo-detectors is given by [4]

$$i_e(t) = \sum_{i=1}^{N} \frac{Ra_c}{N} I_i \sum_{j=1}^{M} I_j [1 + m_0 cos(\omega_c t + a_j \pi) h(t-(j-1)Ts] \qquad (8)$$

For the composite signals from N receivers, both signal power and noise variance are increased N times. So the average SNR for the '*N*' receivers by EGC technique will be as [4]

$$S_{EGC} = \sqrt{N}(R \frac{m_o a_c}{2\sigma_{M-PPM}})^2 [\sum_{i=1}^{N} I_i]^2 \qquad (9)$$

IV. RESULTS & DISCUSSIONS

Hybrid-SIM (PPM–BPSK–SIM) modulation scheme is applied for the performance improvement of the FSO system. EGC diversity technique is used for the further improvement of the error performance.

Both the log-normal and gamma–gamma models are taken into consideration as the channel model for the BER analysis. The BER and the capacity are calculated at various turbulence conditions for channel models.

The turbulence strength for weak and medium turbulence level over the log-normal model have been considered for the BER analysis. Similarly, for the gamma–gamma channel model, the turbulence conditions are strong.

A. BER performance

For evaluating the BER performance, hybrid modulation scheme can be compared with the PPM scheme and BPSK-SIM scheme by analysing simulation results. Results of simulation and error probabilities are done by using lognormal turbulence channel. Strength of turbulence is compared for various values of turbulence parameter, Cn^2 and the value of BER is analysed. BER will vary in the range of 10^{-9} to 10^{-6}. Various parameter values are considered in the analysis.

TABLE I
NUMERICAL SIMULATION PARAMETERS

Name	Symbol	Value
Wave length	λ	850nm
Link distance	L	1000 m
Noise temperature	T	300
Responsivity	R	1
Load resistance	R_L	1000 ohm
Bit rate	R_b	1.55Gb/s
Modulation index	m	1
Boltzmann's constant	B_K	1.38×10^{-23}W/K/Hz
Electron charge	q	1.69×10^{-19}C

So, the hybrid model improves the system performance over the lognormal turbulence channel.

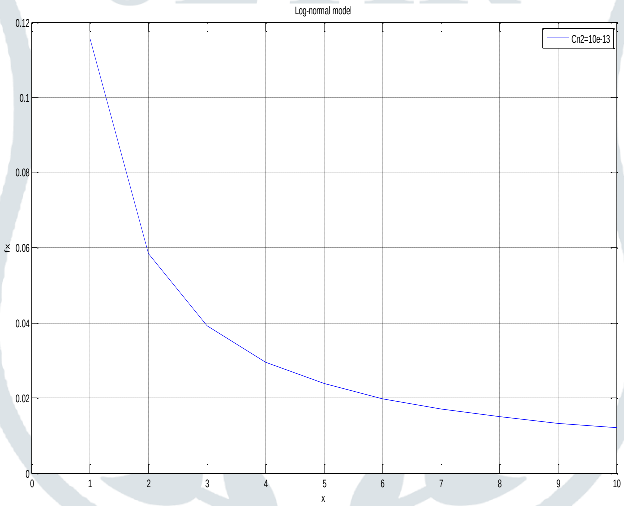

Fig.3 Log Normal Model performance for $C_n^2=10^{-13}$.

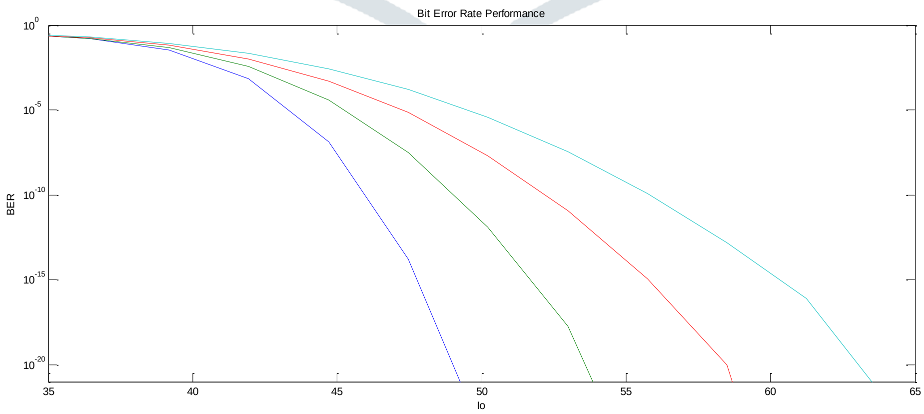

Fig.4 BER performance for various scintillation index parameter values

When the average length is changed, its BER will vary with L between transmitter and receiver. BER performance will decrease with increase in L. With increase in L, the modulation order M is enlarged, so more data is converted from parallel to serial at transmitter end. At receiver end, data is converted from parallel to serial after demodulation, so error probability increases. Similarly, link distance L_d will also affect the system performance by enlarging the log intensity variance.

V.CONCLUSION

It is observed that the error rate performance is improved significantly when the diversity order increases. Similarly, we have found that there is a significant enhancement in capacity is achieved with the increase of the number of detectors in EGC diversity technique.

Thus, the hybrid-SIM modulation scheme with spatial diversity technique can be used for improving the performance of the FSO system.
We describe the modulation and demodulation unit models for transmitter, relay and receiver. The hybrid scheme has a stronger ability to resist the disturbance of turbulence and improve the practicality of hybrid modulation technology in FSO system.

It also reveal that under average power constraint, the proposed modulation technique outperforms ordinary MPPM (both coherent and direct detected) scheme at all values of signal-to-noise ratio and outperforms ordinary BPSK at moderate and high levels of signal-to-noise ratios. In addition, the proposed scheme achieves much higher bandwidth utilization efficiency than that of the ordinary schemes.

REFERENCES

[1] Mohammad Ali Khalighi, "Survey on free space optical communication: A communication theory perspective", IEEE, vol.16,no.4, 2014.

[2] Wenxiao Shi, Pengxia Wu, Wei Lui, "hybrid polarization division multiplexed quadrature phase shift keying and multi-pulse pulse position modulation for free space optical communication", ELSEVIER, pp.63-73,optcom August 2014.

[3] Hossam Selmy, hossam M.H.Shalaby and Zen-Ichiro Kawasaki "Proposal and Performance Evaluation of a hybrid BPSK-Modified MPPM Technique for Optical Fiber Communication Systems", Journal of Lightwave technology, Vol.31,no.22, pp. 3535-3545, November 15,2013

[4] Asghar Gholami, Zabih Ghassemlooy and Sujan Rajbhandari, "Hybrid PPM-BPSK Subcarrier Intensity Modulation for Free Space Optical Communications",IEEE, pp.36-39,ResearchGate, 2011.

[5] WANG Zhuo , SHI Wen-xiao and WU Peng-xia,"PDM-DPSK-MPPM hybrid modulation for multi-hop free space optical communication", optoelectronics letter, Vol.12 No.6,1 November 2016.

[6] Wasiu O. Popoola, "BER and Outage Probability of DPSK Subcarrier Intensity Modulated Free Space Optics in Fully Developed Speckle", Journal of communications, vol.4, no.8, September 2009.

[7] Haitham S.Khallaf, Hossam M. H.Shalaby, "Performance Analysis of a hybrid QAM-MPPM Technique over Turbulence free and Gamma-Gamma Free Space Optical Channels", *Optical* Communication Journal, vol.9, no.2, February 2017.

[8] Xuigui Song, Julian Cheng, "Subcarrier MPSK/MDPSK Modulated Optical Wireless Communications in Lognormal Turbulence", IEEE WCN conference, 2015.