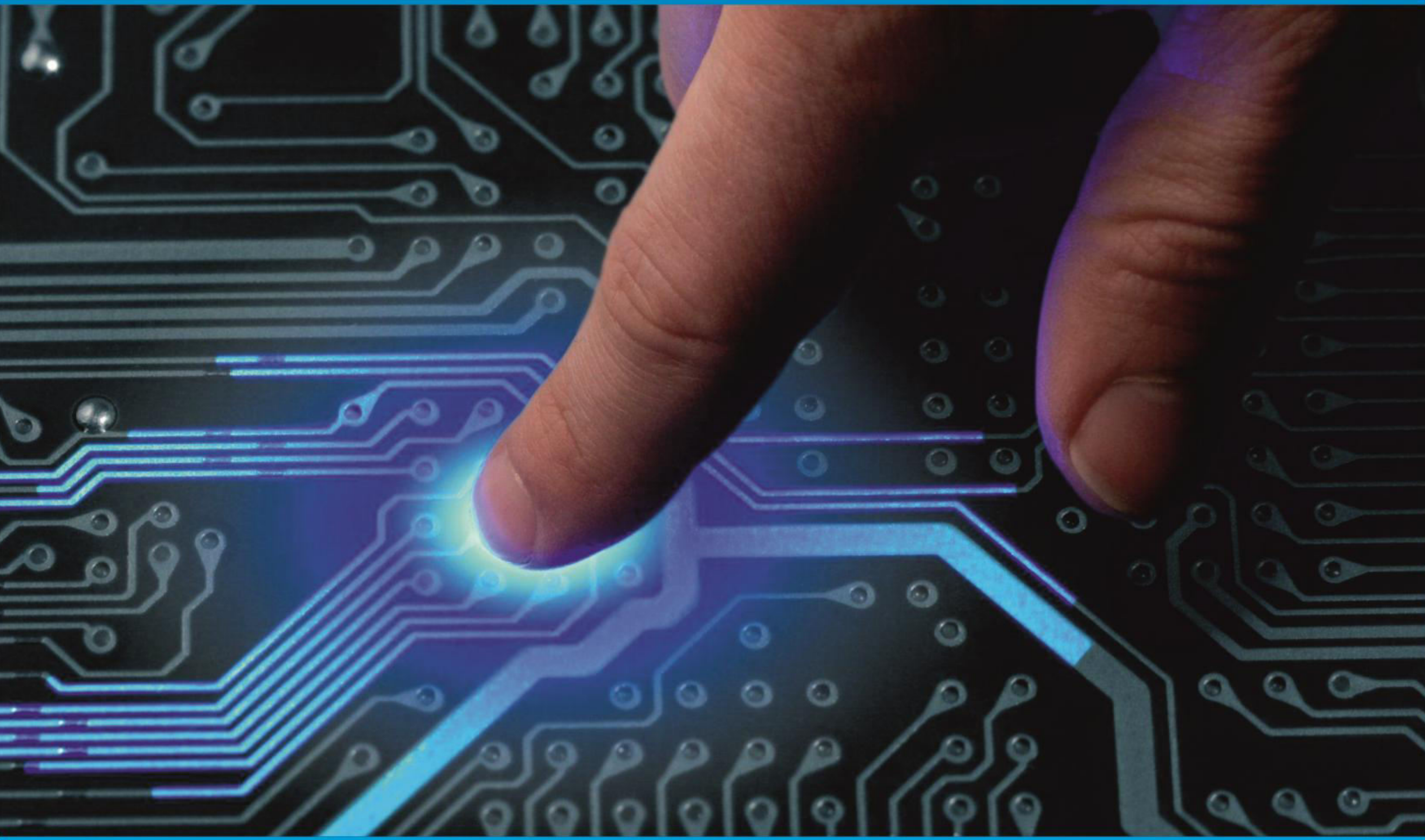
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 9, Issue 5, May 2021

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.488

9940 572 462 | 6381 907 438 | ijircce@gmail.com | www.ijircce.com

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 5, May 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0905002 |

Analysis of LDPC Coded OW Communication Performances with Two Different Channel Models

Bobby Barua[1], K. M. Akhteruzzaman[2], Dr. Masud Al Noor[3]

Ahsanullah University of Science and Technology, Bangladesh [1]

Manarat International University, Bangladesh[2]

Shanto-Mariam University of Creative Technology, Bangladesh[3]

ABSTRACT: The atmospheric channel for Optical Wireless (OW) has a large bandwidth and can accommodate many more users than an RF channel. However, air turbulence can decrease the performance of OW networks, especially at distances of one kilometer or more. When a suitable probabilistic model for turbulence is combined with appropriate modulation and coding techniques, the dependability of the communication channel may be determined. For OW communication in turbulent conditions, several channel architectures and modulation formats already exist. In this regard, we explore the Q-ary pulse position modulation (QPPM) in this study, which has the attractive property of being average-energy efficient with gamma-gamma and negative exponential atmospheric turbulence models under strong turbulent conditions. Instead of utilizing a simple binary channel code, we address the more practical aspect of channel coding once more. At the receiver, we conduct iterative soft demodulation and channel decoding using the low density parity-check (LDPC) code. The bit error rate (BER) is used to assess the performance (BER). Under the negative exponential channel model, the LDPC coded OW system with QPPM gives considerable coding gain over the gamma-gamma model.

KEYWORDS: Bit error rate (BER), low density parity check (LDPC) code,optical wireless (OW),probability of density function (pdf) , Q-ary pulse position modulation (QPPM).

I. INTRODUCTION

Long-haul intersatellite and deep-space interconnections might benefit from OW communication systems' flexibility and high-speed connection. OW connections are also difficult to intercept, resistant to external interference or jamming, and not subject to frequency spectrum rules [1-2]. The maximum range for terrestrial connection is 2 to 3 kilometers (1.2 to 1.9 miles), however the link's stability and quality are heavily reliant on atmospheric variables [3]. It is necessary to offer a statistical description of the turbulence in order to characterize the OW channel from a communication theory perspective [4-5]. The fluctuations of the medium may be seen as discrete cells of air or geometrical optics eddies, which may be thought of as lenses that randomly refract the optical wave front, generating a distorted intensity profile at the receiver of a communication system [6]. It is important to analyze the channel from the viewpoint of information theory with correct modulation method in order to develop a high-performance communication network for the atmospheric OW channel [7].

The gamma-gamma and negative exponential distribution models are two of the most prominent and well-known models. We used the low density parity-check (LDPC) code to calculate the channel capacity of a coded OW system in the presence of atmospheric turbulence and to identify the channel's maximum limit [8]. These coding techniques are only suited for binary codes; binary codes are ineffective for fixing demodulator output defects QPPM [9], therefore they are not suited for use with Q-ary symbols. The channel is modeled using gamma-gamma and the negative exponential model, and the performance results are assessed in terms of bit error rate assuming p.i.n. photodiodes are utilized. The LDPC coded OW system with QPPM gives considerable coding gain over the gamma-gamma model under the negative exponential channel model, according to the analysis.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 5, May 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0905002 |

II. SYSTEM MODEL

The block diagram of the PPM system is shown in Figure 1. First, we'll look at a Q-ary PPM mapper that sends $L=\log_2 Q$ bits per symbol and has a good power efficiency. The signals are defined by binary data bits in the transmitter, which are transformed into a stream of pulses corresponding to the QPPM symbol defined below and supplied to the laser. Waveforms are used to characterize signals.

$$
\begin{aligned}
s_0(t) &= A = \sqrt{2P},\ 0 \le t \le T_s/4 && \text{'00'}\\
s_1(t) &= A = \sqrt{2P},\ T_s/4 \le t \le T_s/2 && \text{'01'}\\
s_2(t) &= A = \sqrt{2P},\ T_s/2 \le t \le 3T_s/4 && \text{'10'}\\
s_3(t) &= A = \sqrt{2P},\ 3T_s/4 \le t \le T_s && \text{'01'}
\end{aligned} \qquad (1)
$$

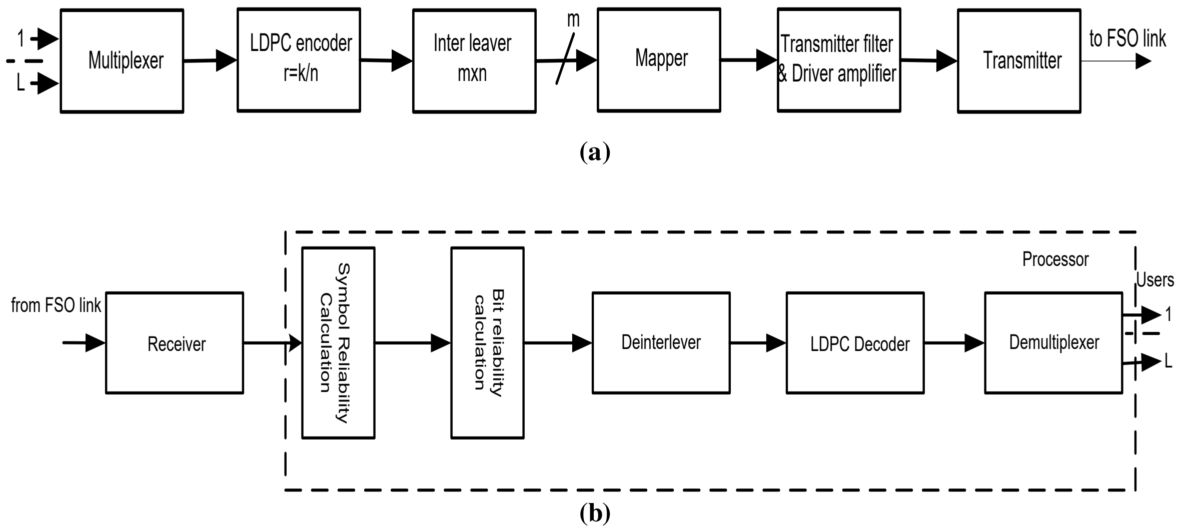


Fig. 1. Atmospheric optical wireless system (a) transmitter side and (b) processor configuration.

After signal detection (the demodulator block) and de-interleaving, channel decoding takes place at the receiver. The demodulation is done based on the light intensity of the received signal. After the optical/electrical conversion, the electrical signal is

$$r_e=\eta(I+I_\alpha)+n \qquad (2)$$

In the receiver, the received optical signal is focused onto a photodiode. The signal is received at the receiver.

$$P= P_R\times X \qquad (3)$$

Where, P_R is the average received optical power. X is the value of the transmitted data.
With responsibility R, the photodiode turns the incoming optical intensity into an electrical signal. With a zero-mean Gaussian noise, the shot and thermal noise are well represented. The received electrical signal, y is calculated as follows:

$$y= RP + n \qquad (4)$$

Where, P is the signal at the receiver *and* n is a signal-independent zero-mean white Gaussian noise with variance σ_R^2.

International Journal of Innovative Research in Computer and Communication Engineering

|e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 5, May 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0905002 |

III. CHANNEL MODELING

It is critical to describe the atmospheric OW channel using a correct model in order to create a high-performance communication link. For the intensity fluctuations at the receiver of an optical connection, many probability density functions (pdfs) have been proposed. These models are mathematically tractable and it is characterized by the Rytov variance σ_R^2.The turbulence induced fading is termed weak when $\sigma_R^2 < 1$ and this defines the limit of validity of the model.

$$\sigma_R^2 = 1.23 C_n^2 k^{7/6} L^{11/6} \quad (5)$$

Where, **k= 2π/λ is** the optical wave number, L is propagation distance, and Cn^2 is the refractive index structure parameter, which we assume to be constant for horizontal paths.

Gamma-Gamma Distribution

Al-Habash et al. [10] suggested a statistical model in which irradiance is factorized as the product of two separate random processes, each having its own Gamma PDF. The PDF of the intensity fluctuation is given by [10]

$$f(I) = \frac{2(\alpha\beta)^{(\alpha+\beta)/2}}{\Gamma(\alpha)\Gamma(\beta)} I^{\frac{(\alpha+\beta)}{2}-1} K_{(\alpha-\beta)}(2\sqrt{\alpha\beta I}), I > 0 \quad (6)$$

The Negative Exponential Distribution

In this circumstance, the amplitude fluctuation of the field crossing the turbulent medium is thought to obey the Rayleigh distribution, meaning negative exponential statistics for the irradiance, which has been empirically proven. That is to assume:

$$f(I) = \frac{1}{I_0} \exp\left(\frac{-I}{I_0}\right), I \geq 0 \quad (7)$$

Where $E[I] = I_o$is the mean received irradiance. During the saturation regime, the value of the scintillation index, $S.I \rightarrow 1$.

IV. THEORETICAL ANALYSIS

Consider the situation of low background radiation and equal-gain connections for a start. Because the other slots report zero counts by assumption (n_b=0), the only potential for judgment error is when each detector detects zero counts in time slot 1.

For Uncoded System

By the Poisson property and independence, we have SEP [9]

$$P_s = \int P_{s|A} f(I) dI = \frac{Q-1}{Q}\left\{\left[\int e^{-\frac{a^2\eta\left(\frac{E_S}{M}\right)}{hf}} f(I) dI\right]^N\right\}^M \quad (8)$$

In case of gamma-gammafading, the average symbol error becomes [9]

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |
|| Volume 9, Issue 5, May 2021 ||
| DOI: 10.15680/IJIRCCE.2021.0905002 |

$$P_s = \int P_{s|A} f(I) dI = \frac{Q-1}{Q} \int e^{-\frac{a^2\eta\left(\frac{E_S}{M}\right)}{hf}} \frac{2(\alpha\beta)^{(\alpha+\beta)/2}}{\Gamma(\alpha)\Gamma(\beta)} I^{\frac{(\alpha+\beta)}{2}-1} K_{(\alpha-\beta)}(2\sqrt{\alpha\beta I}) dI \quad \textbf{(9)}$$

In case of negative exponential fading, the average symbol error becomes

$$P_s = \int P_{s|A} f(I) dI = \frac{Q-1}{Q} \int e^{-\frac{a^2\eta\left(\frac{E_S}{M}\right)}{hf}} \frac{1}{I_0} \exp\left(\frac{-I}{I_0}\right) dI \quad \textbf{(10)}$$

For Coded System

The outputs of the N receivers in response to symbol q, denoted as $\boldsymbol{Z_{n,q}}$(n=1,2,…,N; q=1,2,…,Q), are processed to determine the symbol reliabilities λ(q) (q=1,2,…,Q) given by [9]

$$\lambda(q) = -\frac{\sum_{n=1}^{N}\left(Z_{nq} - \frac{\sqrt{E_s}}{M}\sum_{m=1}^{M} I_{n,m}\right)^2}{\sigma^2} - \frac{\sum_{n=1}^{N}\sum_{1\neq q}^{Q} Z_{n,I}}{\sigma^2} \quad \textbf{(11)}$$

where $\boldsymbol{E_s}$is the symbol energy of uncoded symbol in electrical domain (in the absence of scintillation), which is related to the bit energy $\boldsymbol{E_b}$by $\boldsymbol{E_s=E_b log_2 Q}$. $\boldsymbol{\sigma^2}$ is the variance of TA thermal noise (that is modeled as additive white Gaussian noise (AWGN)), and it is related to the double-side power spectral density N_0 by $\boldsymbol{\sigma^2=N_0/2}$.

All LDPC decoders function independently and in tandem for PPM modulation MAP. The LDPC decoders input reliabilities $L(c_j)$ are calculated from the symbol reliabilities λ(q) (q=1,2,…….,q) [q^{th} symbol corresponds to $c=(c_1,c_2,\ldots..c_j)$] as [10]

$$L(c_j) = \log \frac{\sum_{c:c_j=0} \exp[\lambda(q)]}{\sum_{c:c_j=1} \exp[\lambda(q)]} \quad \textbf{(12)}$$

International Journal of Innovative Research in Computer and Communication Engineering

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 5, May 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0905002 |

V. RESULTS AND DISCUSSION

The system described above is simulated using Matlab. The simulation parameters are given in Table I.

Table I: System Parameters used for computation

Parameter Name	Value
Bit Rate, B_r	10 Gbps
No. of transmitter	2
No. of receiver	4
Channel Type	Gamma-gamma and negative exponential
Scintillation Index, S.I.	3.0
Symbol energy with background noise	-170 dBJ
Symbol energy, Es	10^{-16} joules
Rytov Variance, σ_R	0.1-0.8
Tx/Rx optics efficiency, η	0.8
Distance, L	5 km
Operating wavelength, λ	850 nm

Figure 2 illustrates probability density function charts with typical scintillation index (S.I) and turbulence intensity values for many types of channel models. The gamma-gamma model, in particular, has a far higher density in the high amplitude zone, which has a far greater impact on system performance.

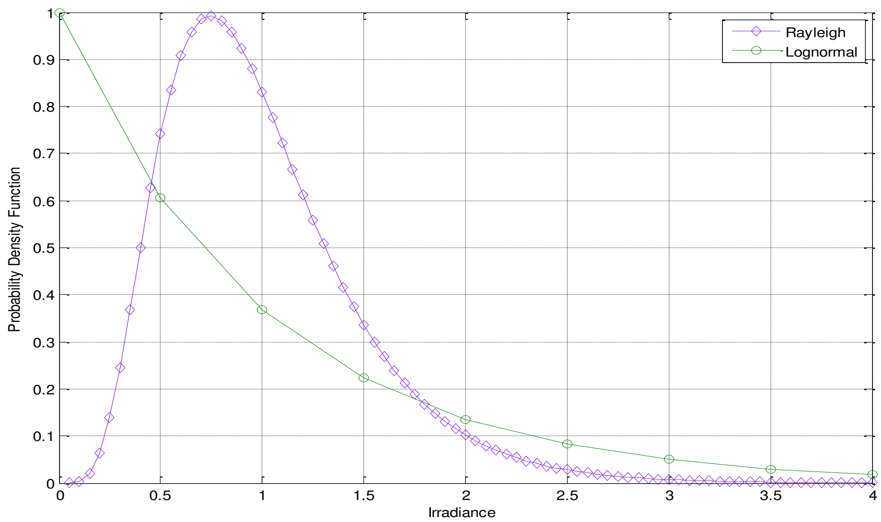


Fig2: Graphical representations of Probability of Distribution Function for two different channel models.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 5, May 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0905002 |

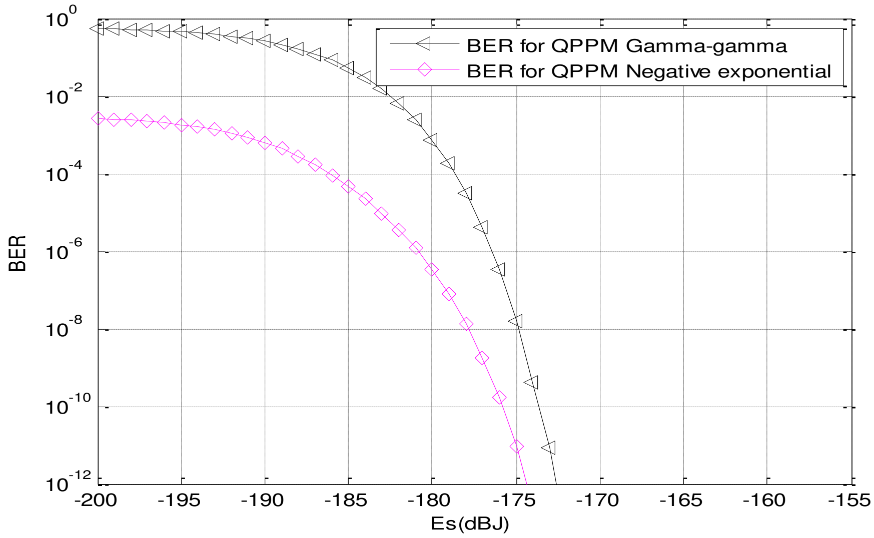


Fig3: Bit error rate vs. symbol energy plots for Q-ary PPM with various channel models.

The graphs of bit error rate vs symbol energy for the Gamma-gamma and negative exponential models with the Q-ary scheme are shown in Figure 3. The symbol energy for both models is essentially same for BER of 10^{-12}, according to the research. However, it differs at a rate of 10^{-2}, implying that using a negative exponential model for low data rates reduces the mistake probability.

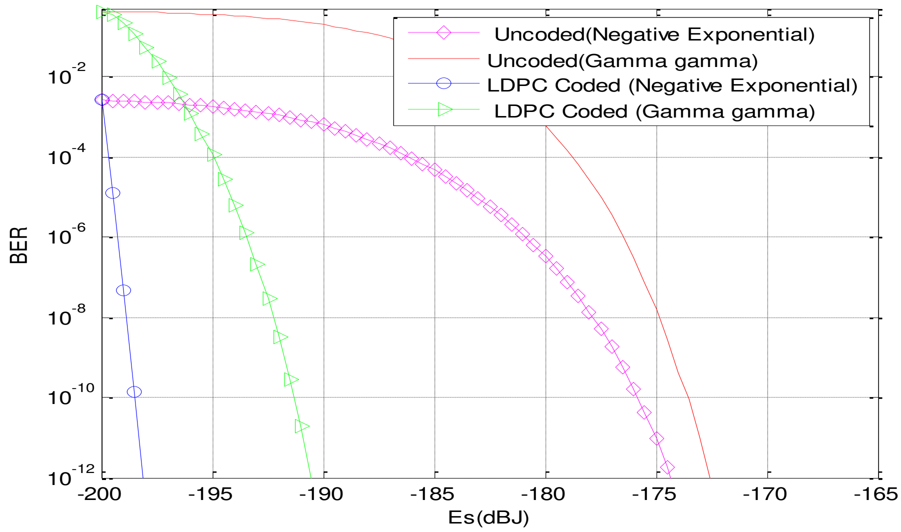


Fig4: Bit error rate vs. symbol energy plots for Q-ary PPM with various channel models in both uncoded and LDPC coded conditions.

The plots of bit error rate versus symbol energy for gamma-gamma and negative exponential model with QPP modulation scheme under uncoded and LDPC coded condition are shown in Fig.-4. From the figure it is found that the negative exponential model perform better than the gamma-gamma model under LDPC coded condition. Analysis also shows that the gamma gamma model provides 19 dB improvement at BER of 10^{-12} and for the negative exponential model it shows 26 dB improvement for the same rate of BER . For the better result we use M=2, N=4 Q=4 combination because it provide excellent coding gain [9]. The symbol energy due to background light is set to -170 dBJ for all these case.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 5, May 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0905002 |

VI. CONCLUSIONS

This research focuses on the BER expression for OW communication systems using QPPM with direct detection in both uncoded and LDPC coded conditions, taking atmospheric turbulence into account. The negative exponential model outperforms the positive exponential model for a narrower range of data, although the symbol energy for both models under uncoded conditions is nearly same at BER of 10-12. In comparison to the gamma gamma model for the identical layout, the negative exponential model provides 7 dB additional coding gain under coded conditions. Finally, under a strong turbulent environment, the negative exponential model outperforms the gamma gamma model with LDPC coded OW connection.

ACKNOWLEDGEMENTS

The authors would like to acknowledge with gratitude the support provides by the Dept. of EEE, Ahsanullah University of Science and Technology, Dhaka, Bangladesh and Dept. of EEE, Manarat International University, Dhaka, Bangladesh. And Shanto-Mariam University of Creative Technology.

REFERENCES

[1] K. Majumdar, Free-space laser communication performance in the atmospheric channel, Journal of Optical and Fiber Communications Reports 2(4), pp. 345–396 (2005).

[2] Bobby Barua and S. P. Majumder, “Analytical Performance Evaluation of a MIMO FSO Communication System with Direct Detection Optical Receivers under Turbulent Condition,” Integrated Optics and Lightwave: An International Journal (OPTLJ), vol. 1, no.1 pp. 35-44 (2018).

[3] Isaac I. Kim, **Bruce** McArthur, and E. Korevaar, "Comparison of laser beam propagation at 785 nm and 1550 nm in fog and haze for optical wireless communications," SPIEProceeding: Optical Wireless Communications III, vol. 4214, pp. 26-37 (2001).

[4] D. Killinger, “Free space optics for laser communication through the air,” Opt. Photon. News, vol. 13, no. 3, pp. 36–42 (2002).

[5] Bobby Barua and S. P. Majumder, “Performance Analysis of a Multiple Subcarrier Modulated FSO Communication System using Direct Detection Optical Receiver under the Effect of Weak Atmospheric Turbulence,” Journal of Optical Communications,” vol.39, pp. 1-9 (aop) (2018).

[6] Sujan Rajbhandari, Zabih Ghassemlooy, Paul Anthony Haigh, Thavamaran Kanesan, and Xuan Tang, "Experimental Error Performance of Modulation Schemes Under a Controlled Laboratory Turbulence FSO Channel," J. Lightwave Technol. **33**, 244-250 (2015).

[7] Bobby Barua and S.P. Majumder, “Performance Analysis of an LDPC Coded FSO Communication System with Different Modulation Technique under Turbulent Condition” ICCIT 2012, pp.214-217 (2012).

[8] I.B Djordjevic., LDPC-coded MIMO optical communication over the atmospheric turbulence channel using Q-ary pulse position modulation. Opt. Express 16,10026-10032 (2007).

[9] Bobby Barua and S.P. Majumder, “LDPC Coded FSO Communication System under Strong Turbulent Condition” ICECE2012, pp.414-417, (2012).

[10] M. A. Al-Habash, L. C. Andrews, and R. L.Phillips, “Mathematical model for the irradiance probability density function of a laser beam propagating through turbulent media,” Opt. Eng. 40, pp1554–1562 (2001).

INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor:
7.488

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

निस्केयर
NISCAIR

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

9940 572 462 6381 907 438 ijircce@gmail.com

Scan to save the contact details