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# Study of BER Performance of Gamma Gamma Channel Model for Free Space Optical Communication

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***Abstract—In this paper, Gamma-Gamma Channel model has discussed with the assumption of imperfect CSI. This channel model is used to describe fading in mathematical form. BER performance of this channel model is shown according to turbulence scenario based on BER equation available. Here Gauss-Markov model is used for the case of imperfect CSI.***

***Keywords-lognormal, Gauss-Markov model, scintillation index, turbulence.***

## I. INTRODUCTION

Free-Space Optics (FSO) system uses a line-of-sight technology with the help of laser for optical bandwidth connection. Now a day, In FSO system data, voice data and video files communications via air is reached up to 2.5 Gbps speed, with the benefit of optical connectivity with no fiber cable or not even securing spectrum licenses. Free space optics system uses light, which can be providing by either LEDs or light amplification by stimulated emission of radiation. In FSO system the main difference is the medium. Light has faster speed in air than it has in other medium like glass, so it is rational to choose free space optics system as optical communications at the light's speed.

Free space optics technology is comparatively humble. The main difference is connectivity between FSO units, which includes optical transmitter and receiver with a laser transceiver using full duplex or bi-directional capability. Each free space optic transmitter uses a high intensity power optical source like a laser, plus a lens for transmitting light through the air to another lens which is useful for receiving the info. This receiving optics lens is coupled to a high sensitivity receiver by fiber. The following are the advantages of the FSO:

- High bit rate (10 Mbps to 2.5 Gbps)
- No licensing required
- Installation cost is very low as compared to laying Fiber
- Easy to install
- Narrow light beam
- Highly secure transmission possible

In this type of communication air acts as a guiding media of the signals from transmitter to the receiver. So BER performance is largely dependent on environmental condition. Different statistical systems have been developed which define the atmospheric turbulence. Take sample, the lognormal distributed model is used in weak turbulence scenario and the negative exponential model is suited for strong turbulence scenario. The gamma-gamma distributed model is used as the irradiance PDF (probability density function) for laser beam spreading through turbulent environment like air. FSO systems' links over gamma–gamma turbulence channel fading has been calculated. Moreover, the bit error rate performance of an free space optical communication system in the attendance of gamma–gamma turbulence channel fading has also been deliberate [5].

In this article, we will examinebit error rate (BER) performance of free space optical (FSO)system links working atspecial channels, in which the turbulence-induced fading is definedusing the gamma-gamma distribution. The Structure of the paper is as follows: In Section II, we appraisal the gamma-gamma turbulence channel model under attention. It has also been assumed an OOK (on-off keying) modulation technique at the Tx and DD which is incoherenttype in the Rx in the system. So Section IIIis for an approximate of bit error rate expression is imitative for a free space optics communication system with OOK scheme.

Additive Gaussian noise with zero meanhas included the background noise, black darknoise and thermal noise.Design model and appliedoperation of best detector is usuallyfounded on maximum likelyfunction.Related to any wireless communication systemlink, free space optical channel handles fading of the data message because of spreading in air.

In section IV, there is a simulation result in form of BER vs. SNR according to the equation derived in the previous section. Here result is shown. At last, there is a conclusion of this paper.

## II. CHANNEL MODEL FOR FSO SYSTEM

### *A. Modulation Scheme and Additive White Gausian Noise*

As specified in [1],the received signal id(t) by On-Off Key modulation scheme can be statedas follow:

$$i_d(t) = h(t)s(t) + i_n(t) \quad (1)$$

Where, $s(t)$ stand for sanded signal,$h(t)$ indicate normalizedchannel fading of the strengthwhich is because of atmospheric turbulence. This turbulence is unchanged for a large number of spreaddata bits and $i_n(t)$ is entireAWG noise.

The averaged ML-based BER for channel like Gaussian is stated as:

$$P_{e,G}(\sigma_1, \sigma_0, P_t) = \frac{1}{2} erfc\left(\frac{\sqrt{2}RP_t}{\sigma_1+\sigma_0}\right) \quad (2)$$

Where, $\sigma_1$ and $\sigma_0$ areSTD of the currents of noise signalwhich stands for symbols '1' and '0', respectively [2].The receiver'sresponsively is denoted by $R$;$P_t$stats avg. of transmitted signal'spower. Complementary error function is given by*erfc*(.).

Foran free space optical channel with only AWGN, the averagesignal to noise ratio can be expressed by[3]

$$\gamma_G = \frac{4R^2{P_t}^2}{(\sigma_1+\sigma_0)^2} \quad (3)$$

Then bit error rate BER can be articulated in positions of the average signal to noise ratio

$$P_{e,G}(\gamma_G) = \frac{1}{2} erfc\left(\sqrt{\frac{\gamma_G}{2}}\right) \quad (4)$$

### *B. Fading Intensity*

The B is random variable and itis a log-normal distribution.Assume the RV (random variable A)$A$=ln$B$is a simple distribution. So, the fading channel coefficient is specified by

$$h = \frac{I}{I_m} = e^{2X} \quad (5)$$

Here $I_m$indicates the data signal light strength at the Tx, with no turbulence effect; $I$ stats the signal light strengthin the Rx.Withturbulence effect and log-amplitude $X$ is the normal RV which is identically distributed. Its mean is $\mu_x$ and standard deviation is$\sigma_x$:

$$f_x(X) = \frac{1}{\sqrt{2\pi}\sigma_x} exp\left(-\frac{(X-\mu_x)^2}{2{\sigma_x}^2}\right) \quad (6)$$

Substituting (5) in (6), the spreading of light beamstrength fadingproduced by turbulence effect is resulted in a log-normal distribution, which isderived as below:

$$f_I(h) = \frac{1}{\sqrt{8\pi}h\sigma_x} exp\left(-\frac{[\ln(h)-2\mu_x]^2}{8{\sigma_x}^2}\right) \quad (7)$$

### *C. Scintillation Index*

Performance of most offree space optical communications systems is harmfullypretentious by scintillation on bright sunny days. Beam spreading and wandering are main product of scintillation effect which resulted from light beam travelled through air pockets withvariable temperature, density, and index of refraction.Scintillation causes can be reduced by using a large aperture receiver, widely spaced Tx, excellently tuned Rx filtering, and AGC,

In scintillation effect like fadingS.I.(scintillation index), we cancreate avg. power damagebecause of special fading agreement,in such way the fading is affecting the average power, attenuate or amplifythe optical signal power. We select

$$\mu_I = 1 \quad (8)$$

that hints us to$\mu_x$=-${\sigma_x}^2$. Thus, the variance will be same as

$${\sigma_I}^2 = e^{4{\sigma_x}^2} - 1 \quad (9)$$

This parameter is known as*scintillation index*, S.I[1,4-7]. Here$\sigma_x$is given as

$$\sigma_x = \frac{\sqrt{\ln(S.I.+1)}}{2} \quad (10)$$

The instantaneous SNR from (4)for a log-normal modeled channel with AWG noise is derived as

$$\gamma_L = \frac{4h^2R^2{P_t}^2}{(\sigma_1+\sigma_0)^2} \quad (11)$$

### *D. Gauss-Markov Model*

The Gauss–Markov theorem[10], calledin the remember Carl Friedrich Gauss and Andrey Markov, which states that in a linear reversion type model of communicationwith no error expectation and totally uncorrelated and have same fluctuation, ordinary least squares estimator gives the BLUE (best linear unbiased estimator) of the constants. Here "best" stands forgenerous the lowermost possible MRE (mean squared error) of the estimation. The faults required with characteristic are unusual, IID (independent and identically distributed).Than this model can be conveyed by

$$h1=\delta h+\sqrt{1-\delta^2}w \quad (13)$$

Where, δ is the correlation factor which variation range is between 0 to 1. 0 means estimated value and actual value has no correlation in between, while 1 means purely related with actual value.W is noise of channel which is AWGN.

Based on Gauss-Markov model we can estimate transmitted bit h1 from bit h which is received at Rx. Correlating training sequences are generated based on correlation factor.

## III. BER PERFORMANCE IN GAMMA-GAMMA TURBULENCE CHANNEL MODEL IN FSO SYSTEM

Gamma-gamma channel model is suited between weak to strong turbulence. Andrew described the modified Rytov theory.This theory gives gamma-gamma pdf (probability density function) as a controllable mathematical model which suited in special turbulence condition. There are two elements distribution which is according to doubly stochastic theory. This theory takes assumption that minor irradiance changes are modulated using huge scale irradiance variations of the transmitted wave. All fluctuations are directed without dependency of gamma distributions. The gamma-gamma probability density functionmay be straightly connected to environmentcircumstances and delivers a decent fit to trialoutcomes. [7]

$$p_I(\mathrm{I})=\frac{2\alpha\beta^{(\alpha+\beta)/2}}{\Gamma(\alpha)\Gamma(\beta)}\mathrm{I}^{((\alpha+\beta)/2)-1)}K_{\alpha-\beta}\left(2\sqrt{\alpha\beta\mathrm{I}}\right) \quad (14)$$

Where,modified Bessel function$K_v(.)$ is the second order of v and Γ(.) shows the gamma function. Both α for the effective number of small scale and β for large scale eddy of the dustingatmosphere respectively. The optical field is a function of perturbations which is given by modified Rytov theory. These is resulted from large scale and small scale atmospheric properties [7].

We can find the bit error rate performance of scheme as,

$$P_b=\frac{1}{\pi}\int_0^{\pi/2}\frac{D^6(\theta)}{(1-2D^2(\theta))^2}d\theta \quad (15)$$

Here, D(θ) is denoted by,

$$\mathrm{D}(\theta)=2^{\frac{\alpha-\beta+4}{4}}c1\left(\frac{c2}{\alpha}\right)^{\frac{\alpha-\beta}{2}}\left(\frac{sin\theta}{\sqrt{\tau}}\right)^{\frac{\alpha+\beta}{2}}K_{\alpha-\beta}\left(2^{5/4}\sqrt{\frac{c2\ \alpha\ sin\theta}{\sqrt{\tau}}}\right)$$

Here; $C1=\frac{\sqrt{\pi}\alpha^{\alpha}\beta^{\beta}}{\Gamma(\alpha)\Gamma(\frac{\beta+1}{2})}$

$$C2=\beta(\sqrt{\beta-\frac{1}{2}}+\frac{1}{16}(\beta-\frac{1}{2})^{-\frac{3}{2}}$$

In above equation, α for the effective number of small scaleand β stand for large scale eddies of the scattering atmosphere and can be calculated as [7],

$$\alpha=\left[\exp\left(\frac{0.49\chi^2}{(1+0.18d^2+0.56\chi^{12/5})^{7/6}}\right)-1\right]^{-1}$$

$$\beta=\left[\exp\left(\frac{0.51\chi^2(1+0.69\chi^{12/5})^{-5/6}}{(1+0.9d^2+0.62d^2\chi^{12/5})^{5/6}}\right)-1\right]^{-1}$$

## IV. SIMULATION RESULTS

In this section,we have provided numerical simulation for the BER performance of Gamma-Gamma channel model.It provides the examination of mathematical calculationin previous section.Fig.1 shows the bit error rate possibilityby (15) and versusSNR ϒG, for altered values of alpha and beta, which are the effective number of small scale and large scale value respectively.

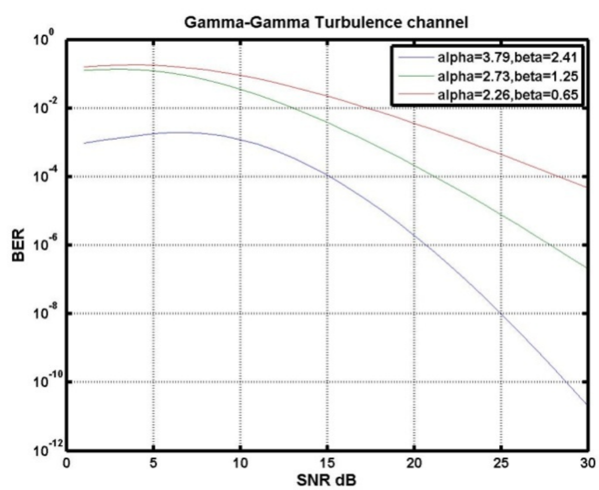


Fig.1 BER vs. SNR for Gamma-Gamma channel

In Fig.1 we can observe that the BER performance is become well as the value of alpha and beta is increases. These results match with actual experimental results for weak turbulence only. At high turbulence,it shows large deviation compared to actual results.

## V. CONCLUSION

In nearby future, FSO will become important medium of information exchange due to its advantages. In this type of communication environment condition plays an important role in transmission setup. Proper distribution model must be used while designing the channel model. For weak to stronger turbulence scenario gamma-gamma distribution is used.

## REFERENCES

[1] H. Moradi, M. Flahpour, H. H. Refai, P.G. LoPresti, M. Atiquzzaman, "*BER Analysis of Optical Wireless Signals through Lognormal Fading Channels with Perfect CSI*",IEEE Transection on Communication,2009.

[2] Navidpour, S. M., Uysal, M., and Kavehrad, M., *BER Performanceof Free-Space Optical Transmission with Spatial Diversity*, IEEE trans. Wireless Comm., Vol. 6, No. 8, pp. 2813-2819, Aug. 2007.

[3] Gagliardi, R. M., and Karp, S., *Optical Communications*, 2ndedition, John Wiley & Sons, Inc., 1995.

[4] L.C.Andrews, R.L. Philips, C.Y. Hopen, "*Aperture averaging of optical scintillations: power fluctuations and the temporal spectrum*", Waves Random Media, Vol.10, pp. 53-70, 2000.

[5] L. C. Andrews, R. L. Phillips, C. Y. Hopen and M. A. Al-Habash,"Theory of optical scintillation", *Journal of Optical Society America A*,vol. 16, no.6, p. 1417-1429, June 1999.

[6] L. C. Andrews, R. L. Phillips and C. Y. Hopen, "Aperture averaging of optical scintillations: Power fluctuations and the temporal spectrum", *Waves Random Media*, vol. 10, p. 53-70, 2000.

[7] 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", *Optical Engineering*, vol. 40, no. 8, p. 1554-1562, August 2001

[8] Tsiftsis, T. A., Sandalidis, H.G., Karagiannidis, G. K., and Uysal,M., Optical wireless links with spatial diversity over strong*atmospheric turbulence channels*, IEEE Trans. Wireless Comm., Vol.8, Issue 2, pp. 951-957, Feb. 2009.

[9] Letzepis, N., Holland, I., and Cowley, W. *The Gaussian free space*optical MIMO channel with Q-ary pulse position modulation, IEEETrans. Wireless Comm., Vol. 7, Issue 5, Part 1, pp. 1744 – 1753,2008.

[10] Wehrle, K.,Gross, J.,Modeling and tools for network simulation,1stedition,2010

[11] Hector E. Nistazakis , George S. Tombras "On the use of wavelength and time diversity in optical wireless communication systems over gamma–gamma turbulence channels", on Optics & Laser Technology, Optics & Laser Technology – International journal, Page no.: 2088–2094, 2012.