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Analysis of Free Space Optical Communication System for Different Atmospheric Conditions & Modulation Techniques

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Abstract: *The free space optical communication (FSO) is often used for digital communication systems because of its low cost. It is also preferred where the developing the infrastructure is difficult. It also provides the security because of its line of sight nature and very small detectable area, but besides the given advantages it's having serious problem because the performance of FSO is very sensitive to the channel (space) conditions, which changes continuously also the conditions are much complicated then the conditions in RF channels. Hence in this paper an analysis of the FSO communication in presented under scattering, fading & fog conditions with DPSK modulation.*

Keywords: *Free Space Optical Communication (FSO), Differential Phase Shift Keying (DPSK).*

I. Introduction

Free-space optical communication (FSO) is an optical communication technology that use slight propagating in free space to transmit data for telecommunications or computer networking. "Free space" means air, outer space, vacuum, or something similar. This contrasts with using solids such as optical fiber cable or an optical transmission line. The technology is useful where the physical connections are impractical due to high costs or other considerations.

Free-space point-to-point optical links can be implemented using infrared laser light, although low-data-rate communication over short distances is possible using LEDs. Infrared Data Association (IrDA) technology is a very simple form of free-space optical communications.
Free Space Optics is additionally used for communications between spacecraft. Maximum range for terrestrial links is in

The order of 2 to 3km [1] but the stability and quality of the link is highly dependent on atmospheric factors such as rain, fog, dust and heat.

Secure free-space optical communications have been proposed using a laser N-slit interferometer where the laser signal takes the form of an interferometric pattern. Any attempt to intercept the signal causes the collapse of the interferometric pattern [2] [3]. This technique has been demonstrated to work over propagation distances of practical interest [4] and in principle; it could be applied over large distances in space [2].

II. Related Work

In free-space optical communication links, atmospheric turbulence causes fluctuations in both the intensity and the Phase of the received light signal, impairing link performance .Xiaoming Zhu at el. [5] describe several communication techniques to mitigate turbulence-induced intensity fluctuations, i.e. signal fading.

They describe the use of maximum-likelihood detection in spatial diversity reception to reduce the diversity gain penalty caused by correlation between the fading at different receivers. In other paper Hennes HENNIGER and Otakar WILFERT [6] gives an overview of the challenges a system designer has to consider while implementing an FSO system. Typical gains and losses along the path from the transmitter through the medium to the receiver are introduced in this paper. This paper also discussed the different modulation and coding techniques for the FSO. Xiaoming Zhu, JosephM. Kahn [7] presented Mitigation of Turbulence-Induced Scintillation Noise in Free-Space Optical Links Using Temporal-Domain Detection Techniques & experimentally demonstrate the effectiveness of these techniques in a 500-m terrestrial link using ON–OFF keying, where MLSD and PSAD yield signal to-noise ratio gains of 2.4 and 1.9 dB, respectively.

Song Gao, Anhong Dang, HongGuo [8] presented a coherent differential phase-shift keying (DPSK) transmission system to improve the receiver sensitivity for wireless optical communications. The error probability expression over atmospheric channels is derived under the assumption of log-normal distributed scintillation, and then the performance of DPSK system is compared with that of a most commonly used on-off keying (OOK) system under the same channel conditions. Theory analysis and numerical results illustrate that with the same bandwidth, DPSK system has a higher sensitivity than OOK, and to a certain extent DPSK format can reduce the impairment from turbulence induced scintillation for its threshold being signal intensity insensitive, and hence, DPSK format is very suitable for atmosphere channels and has a broad prospect in wireless optical communications.

Channel Modeling

A suitable model for simulation of FSO communication channels is presented by S. Sheikh Muhammad & P. Kohldorfer, E. Leitgeb[9] their model is taken here for reference.

2.1 Scintillation Losses

Randomly distributed cells are formed under the influence of thermal turbulence inside the propagation medium; the wave fronts vary causing the focusing and defocusing of the beam. Such fluctuations of the signal are called scintillations. The amplitude and frequency of scintillations depend on the size of the cells compared to the beam diameter [10]. The intensity and the speed of the fluctuations (scintillations frequency) increase with wave frequency. For a plane wave, a low turbulence and a specific receiver, the scintillation variance can be expressed as in equation (1) where λ represent the transmitter wavelength in [nm], l the channel-length in [m] and C_n^2 the refractive index structure parameter in $\left[m^{-2/3}\right]$. C_n^2 is for low turbulence 10^{-16} for moderate turbulence 10^{-14} and for high turbulence 10^{-13} [9].

$$a_{scin} = 2\sqrt{23.17(\frac{2\pi}{\lambda}10^{9})^{7/6} c_n^{\,2} l^{11/6}} \text{ [dB]}.......(1)$$

The dependence from C_n^2 is depicted in figure (1). For strong turbulences, a saturation of the variance given by above relationship is observed. The parameter C_n^2 does not have the same value at millimeter waves and at optical waves. Millimeter waves are especially sensitive to humidity fluctuations while in optic, refractive index is a primary function of the temperature.

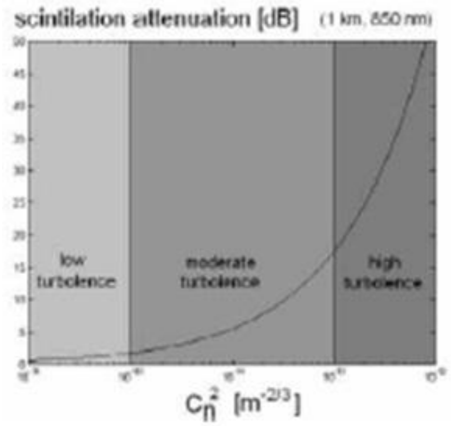

Figure 1: plot for C_n^2 Vs Scintillation Variance[9].

2.2 Fog Attenuation

The theoretical background of fog attenuation for light based on Mie Scattering can be found in [11-13] and is not being dealt with here. Several models exist which allow to calculate specific attenuation for different optical wavelengths based on visibility data. The two most widely used models that we used and implemented in our simulation are the Kruse model and the Kim model. The specific attenuation is calculated in equation (2), with the variables visibility V [km], wavelength λ [nm], visibility reference at wavelength λ 0 [nm] and for transmission of air drops to V % percent of the clear sky; and the results are shown in figure 2. The wavelength dependency in this expression is expressed by q, which is in the Kruse model given by equation (3) and in the Kim model by equation (4).

$$a_{spec} = \frac{10\log V}{V}(\frac{\lambda}{\lambda_0})^{-q}\left[\frac{dB}{km}\right]$$

…………….(2)

$$q = \begin{cases} 1.6 & if V > 50km \\ 1.3 & if\, 6km < V < 50km \\ 0.585V^{1/3} & if V < 6km \end{cases}$$

……………(3)

$$q = \begin{cases} 1.6 & if V > 50km \\ 1.3 & if\, 6km < V < 50km \\ 0.16V + 0.34 & if\, 1km < V < 6km \\ V - 0.5 & if\, 0.5km < V < 1km \\ 0 & if V < 0.5km \end{cases}$$

……………..(4)

At very high attenuations the Kim model is the better model.

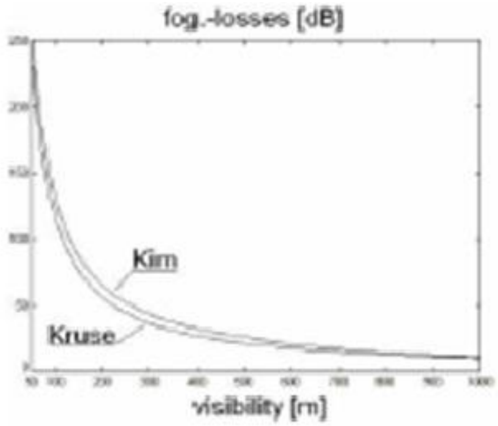

Figure 2: Plot of Visibility Vs Fog attenuation [9]

III. System Architecture

The system architecture of the simulated model contains a DPSK generator formed by the cascading of amplitude and phase modulator & the drive signal of the phase modulator is preceded by a delay-XOR pre-coder to generate the differentially encoded data sequence. Then the channel is formed by performing the noise, scintillation & fading as given by in the section 2.1 & 2.2. Then an asymmetric Mach-Zehnder interferometer (MZI) splits the signal to two paths and recombines these two signals after a path difference corresponding to the symbol duration. A balance receiver follows the interferometer as a multiplier to demodulate the differentially coded signal.

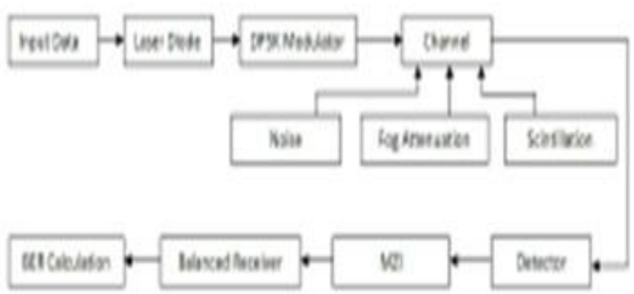

Figure 3: Block Diagram of the simulated model

IV. Simulated Results

The above discussed model is simulated for 650 nm LASER, q = 1.3 & V = 10, fog visibility 1km to 10km & analyzed for different Modulation techniques OOK, PSK & DPSK with various scintillation indexes.

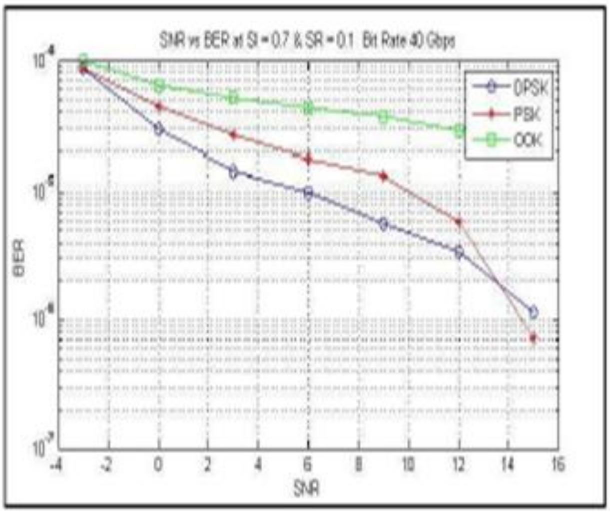

Figure 4: Effect of Scintillation Index on BER for all three modulation techniques. The scintillation rate is maintained constant 0.1 fog visibility is 10 Km and data rate is 40 GB/s. the simulation shows that DPSK has a good performance and the BER remains less than 0.1 for all values of SI (0.1 to 0.7).

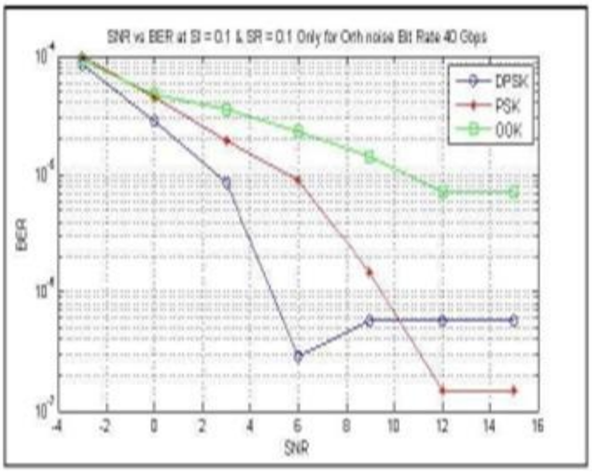

Figure 5: Effect of Additive Noise on BER for all three modulation techniques. The scintillation index and scintillation rate are maintained constant 0.1 fog visibility is 10 Km and data rate is 40 GB/s. the simulation shows that PSK and DPSK behaves similar.

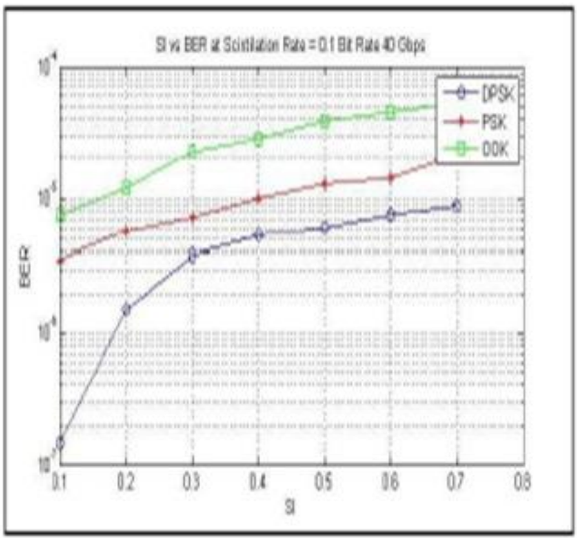

Figure 6: Effect of Additive Noise on BER for all three modulation techniques for higher SI. The scintillation index is maintained constant 0.7 and SR remain 0.1 fog visibility is 10 Km and data rate is 40 GB/s. the simulation shows that in presence of higher additive noise the SI remains ineffective.

5. Conclusion

In this work, we have analyzed the Free Space optical communication System using different modulation techniques and with different channel conditions like Fog & scintillation. The DPSK format has a better performance than OOK & PSK in atmosphere turbulence & Fog conditions for its longer symbol distance and being signal intensity insensitive. It can also be said that an appropriate coding technique will further improve the performance for the wireless optical transmission system.

References

[1] Tom Garlington, Joel Babbitt and George Long (March 2005). "Analysis of Free Space Optics as Transmission Technology". WP No. AMSEL-IE-TS-05001. U.S. Army Information Systems Engineering Command. p. 3. Archived from the original on June 13, 2007. Retrieved June 28, 2011.

[2] F. J. Duarte (May 2002). "Secure interferometric communications in free space". Optics Communications 205 (4): 313–319. doi:10.1016/S0030-4018(02)01384-6.

[3] F. J. Duarte (January 2005). "Secure interferometric communications in free space: enhanced sensitivity for propagation in the metre range". Journal of Optics A: Pure and Applied Optics 7 (1). doi:10.1088/1464-4258/7/

[4] F. J. Duarte, T. S. Taylor, A. M. Black, W. E. Davenport, and P. G. Varmette, N-slit interferometer for secure free-space optical communications: 527 m intra interferometric path length , J. Opt. 13, 035710 (2011).

[5] Xiaoming Zhu and Joseph M. Kahn, Fellow, IEEE "Free-Space Optical Communication Through Atmospheric Turbulence Channels", IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 50, NO. 8, AUGUST 2002.

[6] Hennes HENNIGER & Otakar WILFERT "An Introduction to Free-space Optical Communications", RADIOENGINEERING, VOL. 19, NO. 2, JUNE 2010, p203.

[7] Xiaoming Zhu, Joseph M. Kahn, Fellow, IEEE, and Jin Wang, Student Member, IEEE "Mitigation of Turbulence-Induced Scintillation Noise in Free-Space Optical Links Using Temporal-Domain Detection Techniques", IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 15, NO. 4, APRIL 2003.

[8] Song Gao, Anhong Dang & Hong Guo "Performance of Wireless Optical Communication Systems Using DPSK Modulation" Feb. 15-18,2009 ICACT 2009.

[9] S. Sheikh Muhammad & P. Kohldorfer, E. Leitgeb "Channel Modeling for Terrestrial Free Space Optical Links", ICTON 2005.

[10] R.L. Philips, L.C. Andrews: Laser Beam Propagation through Random Media, in SPIE publications, Washington, 1998.
[11] F. de Fornel, M. Al Naboulsi, H. Sizun: Fog attenuation prediction for optical and infrared waves, in Journal SPIE, 2003.
[12] F. de Fornel, M. Gebhart, E. Leitgeb, M. Al Naboulsi, H. Sizun: Availability prediction for free space optic communication systems from local climate visibility data, in Short Term Scientific Report 4. COST 270, 2003.
[13] E. Korevaar, I.I. Kim, B. McArthur: Comparison of laser beam propagation at 785 nm and 1550 nm in fog and haze for optical wireless communications, in SPIE proceedings, vol. 4124, 2001