CODED ON OFF KEYING SYSTEM FOR FREE SPACE OPTICAL LINK OVER STRONG TURBULENCE AND MISALIGNMENT FADING CHANNELS

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ABSTRACT

The performance of optical wireless systems deteriorates to a large extent from the presence of turbulence and pointing error effects. To meet the typical bit error rate (BER) targets for reliable communications within the practical ranges of signal-to-noise ratio, error control coding schemes are often proposed. We are investigates the error performance for convolutional coded on-off keying free-space optical systems through symbol by symbol interleaved channels characterized by strong turbulence and/or pointing error effects. We consider several channel types and derive exact analytical expressions for the pair wise error probability. These expressions are applied to obtain upper bounds on the BER performance using the transfer function technique.

Keywords- Free-Space Optical Communications, Atmospheric Turbulence Channel, Pair Wise Error Probability, Error Performance Analysis.

I. INTRODUCTION

Free-space optical (FSO) systems can be used as an effective method for a variety of applications involving, among others, a promising solution for the last mile problem. Various impairments complicate, however, the design of FSO links and deteriorate the error performance [1]. Optical wireless signals are attenuated by the distance between transmitter and receiver and are subject to atmospheric turbulence. Another issue affecting the performance has to do with the appropriate alignment between transmitters and receivers. Since FSO systems are usually installed on high buildings, building sway causes vibrations in the transmitted beam leading to misalignment (pointing error (PE) effects) between the transmitter and receiver [2]. To satisfy the typical bit error rate (BER) targets for reliable communications within the practical ranges of signal-to-noise ratio (SNR), error control coding has been employed. In Zhu and Kahn derived an approximate upper bound on the pair wise error probability (PEP) of coded FSO links with intensity modulation/direct direction (IM/DD) and provided upper bounds on BER for various coding schemes including block, convolutional, and turbo codes. Uysal and Li used the same assumptions as and investigated the performance of convolutional coded FSO systems for turbulence channels modelled by the negative exponential (NE), *K*, *I-K*, and gamma-gamma channels, respectively. However, they used approximations on the derived PEP due to the difficulty of mathematically handling these specific turbulence probability density functions (pdf) [1]. Free-space optical communication (FSO) systems (in space and inside the atmosphere) have developed in response to a growing need for high-speed and tap-proof communication systems. Links involving satellites, deep-space probes, ground stations, unmanned aerial vehicles (UAVs), high altitude platforms (HAPs), aircraft, and other nomadic communication partners are of practical interest. Moreover, all links can be used in both military and civilian contexts. FSO is the next frontier for net-centric connectivity, as bandwidth, spectrum and security issues favour its adoption as an adjunct to radio frequency (RF) communications [5]. **C**ontinuous alignment between transmitter and receiver is an important issue for a successful signal transmission in optical wireless systems. However, thermal expansion, dynamic wind loads, and weak earthquakes result in the sway of high-rise buildings, which causes vibrations of the transmitter beam and, therefore, misalignment (pointing error) effects between the transmitter and receiver. To overcome this problem and keep line-of-sight between the transmitter and receiver, the designers should increase the beam width and power. However, a wide beam width increases the required signal-to-noise (SNR) ratio leading to increased cost and complexity, whereas a narrow one may result in outage appearance [1]. Hence, proper optimization techniques should be followed [2]. The effect of misalignment fading has been studied for inter satellite laser communications, as well as for terrestrial links of short distance. In [1], Arnon developed a mathematical model to minimize the transmitter power and optimize the divergence angle for a given bit-error rate (BER) using a small detector model. However, he has not provided closed form expressions, nor has he examined the outage probability, which is a dominant metric particularly for FSO links. Based on Arnon's work, Liu in [2], presented two optimization problems for FSO systems using quantum cascade lasers. In [3], Farid and Hranilovic have provided a FSO channel model for fading due to atmospheric turbulence and pointing error effects considering beamwidth, pointing error variance, and detector size. Their model for misalignment fading is much simpler than the one in [1]. Particularly, they considered lognormal and gamma-gamma distributed turbulence, and examined the system performance in terms of capacity and outage probability. Although they tried to optimize the beamwidth in order to increase the channel capacity subject to outage using test and trial methods, they have not investigated the BER performance. In [4], Sandalidis et al. derived the average BER expression for an intensity-modulation/direct detection (IM/DD) FSO system with on-off keying (OOK) assuming strong turbulence fading and pointing error effects.

II. PROPOSED SYSTEM

We have investigated for first time the error performance for coded on-off keying (OOK) by optical wireless communication systems through symbol by symbol interleaved channels characterized by strong turbulence and pointing error effects. Turbulence is modelled by K or NE distributions. Specifically, we consider various combinations of channels assuming the existence of turbulence and/or pointing error effects and derive exact mathematical expressions for the PEP. These expressions are then applied to obtain upper bounds on the BER performance using the transfer function technique. To meet the typical bit error rate (BER) targets for reliable communications within the practical ranges of signal-to-noise ratio, error control coding schemes are often proposed [1].It is shown by following figure.

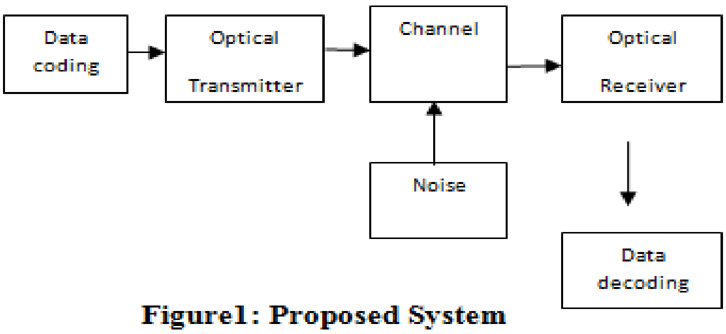

Figure1: Proposed System

Advantages of Proposed System:

1. By using OOK coding, we can attain low BER targets for small SNR values
2. This analysis can be easily extended to other turbulence models

A) Scope

1) The proposed method can be used with huge modulation bandwidth. The frequency range of an optical carrier spans from 10^{12}-10^{10} to 2000 THz data bandwidth [3].

2) The proposed system can be used with narrow beam size. A typical laser beam has a diffraction limited divergence in between 0.01-0.1 mrad [3].

3) Our proposed system is quick to deploy and redeploy.FSO technology offers portability and quick deployment. It also only takes a short time to redeploy the FSO link easily to another location [5]

III. PROPOSED METHODOLOGY

1. Data Coding:

Input data is giving to data coding process. It may be giving analog as well as digital data .Data encoding take place at this step. We are using here bipolar encoding process [3].

2. Optical Transmitter:

Coded data is giving to optical transmitter. It converts coded data in to optical signal. At the transmitter side, each block of data bits is first modulated by an electrical OOK modulator [3].

3. Channel:

Optical data is transmitted over channel. Whenever we are transmitting data from transmitter to receiver over channel noise gets mix with it. Coded On-Off keying system is used for minimization of strong turbulence and fading of channel [4]. It is used for reliable data communication [13].

4. Optical Receiver:

It is used towards receiver side of communication system. It is used for reduction of noise. It converts optical signal in to original data [3].Demodulation take place at the receiver side [6].

5. Data Decoding:

We can use any type of decoding algorithm. We are using here bipolar decoding process [3].

6. System Models:

We consider a single-input single-output (SISO) FSO system using IM/DD with OOK. The transmitter contains a light source and the laser beam propagates along a horizontal path. The received antenna has lens to focus the received beam to an optical receiver. A point receiver is used and therefore, no aperture averaging is possible. We also assume that the receiver utilizes ML soft decoding [1].

7. Channel models:

a) Turbulence Channel Models:

A number of statistical models have been proposed to describe turbulence-induced fading for different degrees of turbulence severity. Under weak irradiance fluctuations and long propagation distances, one of the most widely used models is the log-normal. Discrepancies, however, occur as the strength of the turbulence increases. In that case, irradiance statistics can be modelled using the *K* or the NE distribution [1, 4].

b) Misalignment Fading Model:

The appropriate alignment between transmitters and receivers is a difficult problem in FSO transmission particularly for long-range systems. A tractable pdf to describe misalignment fading is also introduced [5].

IV. ERROR PERFORMANCE

For coded systems, the PEP has been the basic method for the union bounds calculation and is used as the main criterion for code design [1]. This metric represents the probability of choosing the coded sequence $\mathbf{X}^{\wedge}$ = ($x1^{\wedge}$,….,$xN^{\wedge}$) when $\mathbf{X}$ = (x, ..., xN) is transmitted [5]. Assuming the assumptions in [3], i.e., maximum likelihood soft decoding with perfect CSI and OOK transmission, the conditional PEP subject to fading coefficients $\mathbf{I}$ = ($I1$, $I2$, ..., IM) is given as

$$P\left(\mathbf{X}, \hat{\mathbf{X}} \,|\, \mathbf{I}\right) = Q\left(\sqrt{\frac{E_s}{2N_0} \sum_{k \in \Omega} I_k^2}\right)$$

where $Q(\cdot)$ is the Gaussian Q function, Es is the total transmitted energy, and $\mathbf{X}$ and $\mathbf{X}^{\wedge}$ differ from each other. We have obtained error performance using K and NE channel. The expression of D(Θ) for K and NE channel is given as

Channel	$D(\theta)$
K	$\frac{2^{\alpha-1}}{\pi\Gamma(\alpha)} G_{4,1}^{1,4}\left[\frac{4\gamma}{\sin^2\theta\alpha^2} \middle\vert \begin{matrix} \frac{1-\alpha}{2}, \frac{2-\alpha}{2}, 0, \frac{1}{2} \\ 0 \end{matrix}\right]$
NE	$\sqrt{\frac{\pi \sin^2\theta}{\gamma}} \exp\left(\frac{\sin^2\theta}{\gamma}\right) \operatorname{erfc}\left(\sqrt{\frac{\sin^2\theta}{\gamma}}\right)$
PE	$\frac{\gamma^2}{2} G_{1,2}^{1,1}\left[\frac{\gamma A_0^2}{4\sin^2\theta} \middle\vert \begin{matrix} \frac{2-\gamma^2}{2} \\ 0, -\frac{\gamma^2}{2} \end{matrix}\right]$
K + PE	$\frac{2^{\alpha-2}\gamma^2}{\pi\Gamma(\alpha)} G_{5,2}^{1,5}\left[\frac{4\gamma\left(\frac{\alpha}{A_0}\right)^{-2}}{\sin^2\theta} \middle\vert \begin{matrix} \frac{2-\gamma^2}{2}, \frac{1-\alpha}{2}, \frac{2-\alpha}{2}, 0, \frac{1}{2} \\ 0, -\frac{\gamma^2}{2} \end{matrix}\right]$
NE + PE	$\frac{\gamma^2}{2\sqrt{\pi}} G_{3,2}^{1,3}\left[\frac{A_0^2\gamma}{\sin^2\theta} \middle\vert \begin{matrix} \frac{2-\gamma^2}{2}, 0, \frac{1}{2} \\ 0, -\frac{\gamma^2}{2} \end{matrix}\right]$

V. NUMERICAL RESULTS AND DISCUSSION

Several numerical results are provided in this section to examine the performance of the interleaved symbol by symbol channel through turbulence and/or misalignment fading conditions. At first, we consider turbulence effect only. Fig. 2 shows the derived PEP expressions for the K and NE channels given by (1), respectively, in terms of the electrical average SNR, μ. In that figure we assume an error event of length 2, i.e., $|\Omega|$ = 2, and use several values of parameter α.The derived results show that as the turbulence gets weak (α increases), the system performance is not significantly improved. This happens because the K distribution is less sensitive at high values of α. Moreover, it is observed that the PEP when α = 20 is very close to that for the NE channel. This is expected since the K distribution tends to the NE one for $\alpha \to \infty$.Coded on off keying is obtained by two modulation techniques such as Non Return to zero(NRZ) and Return to zero(RZ). It is shown by figure 3.

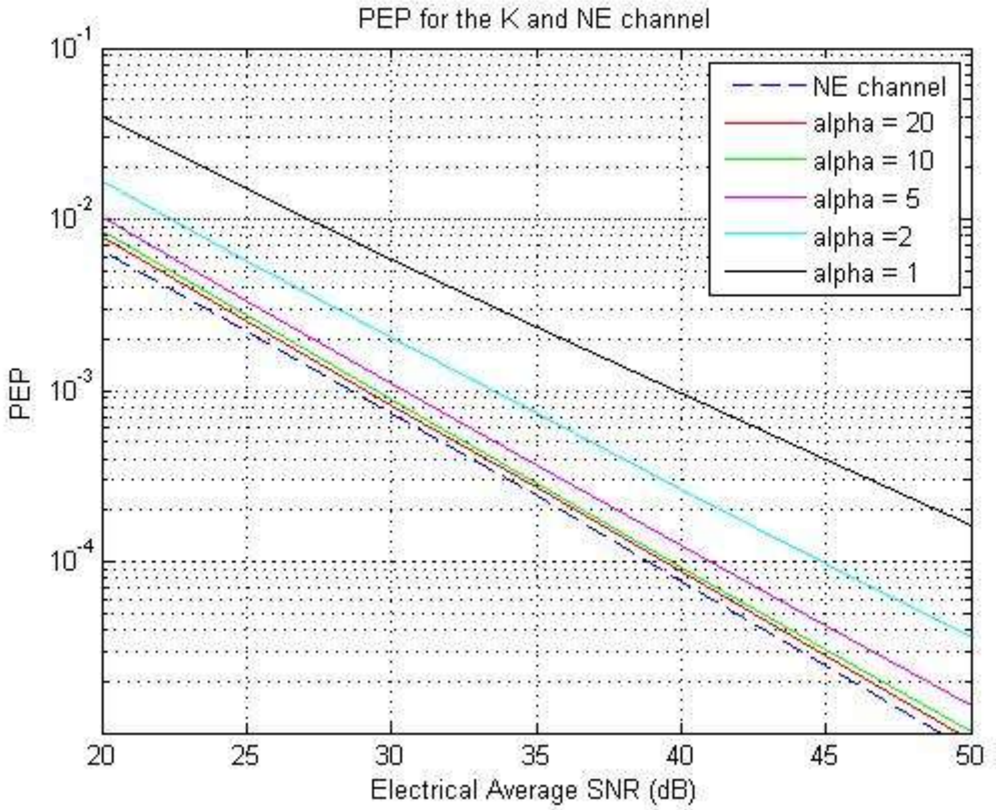

Figure2: PEP for the K and NE channel

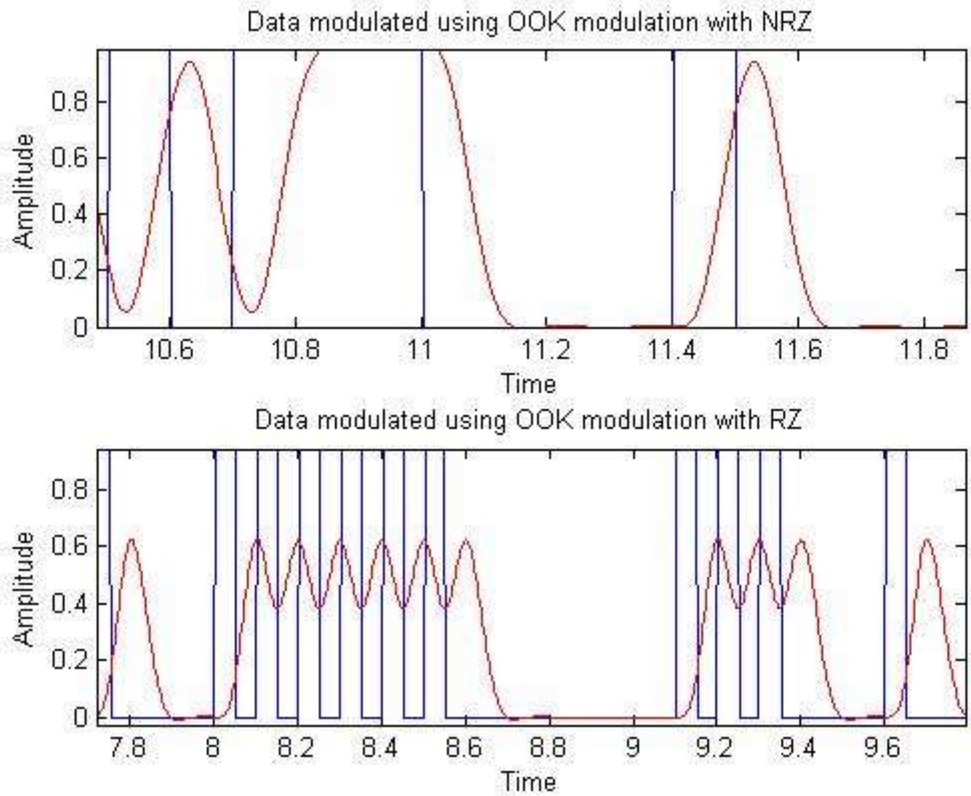

Figure3: Coded on off keying using NRZ AND RZ modulation technique

VI. CONCLUSION

We have investigated the error rate performance for an IM/DD with OOK optical wireless system using convolutional error control coding schemes. We have assumed symbol by symbol interleaved channels characterized by strong turbulence and/or misalignment fading. We have derived exact PEP expressions and obtained upper bounds on the BER performance using the transfer function method.

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