PERFORMANCE OF FSO LINKS USING VARIOUS MODULATION TECHNIQUES AND CLOUD EFFECT

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ABSTRACT - Free space optical technology uses light wave travelling in free space to wirelessly transmit data for telecommunication. FSO is used in such places where physical optical wire usage is not possible or it is too costly. In this study the performance of the differentially coherent detected signal based FSO communication system is investigated considering the effect of cloud caused Inter Symbol Interference (ISI).To mitigate the effect of fading, the differential coherent detection technique is employed. BER performance is analysed in both absence and the presence of ISI. BER performance is also analysed with BPSK-SIM ,DPSK, DPSK-SIM, M-ary PPM and PolSK modulation schemes. Graphs taken with the help of MATLAB/OPTISIM at different carrier wavelength is analysed.

KEYWORDS - Free Space Optical (FSO) ,Inter Symbol Interference (ISI) , Differential Phase Shift Keying (DPSK), BER Performance, Optisim , Carrier Wavelength

INTRODUCTION

The recent surge in the research of free-space-optics (FSO) are due to its advantages over radio frequency (RF) communication, viz. much larger capacity, license free bandwidth, lower power consumption, more compact transceiver architecture, excellent security, low cost and better protection against interference[1] . FSO systems are widely used in inter-satellite and deep space communications. Un fettered bandwidth and very high speed of FSO makes it an apt technology for delivering broadband wireless services for certain applications like metropolitan area network (MAN), local area network (LAN), optical fiber backup , last mile access network and high definition television (HDTV) broadcasting services. However, as FSO links undergo random change in the refractive index due to the variations in air, temperature and pressure, a temporal and spatial variation in light intensity (called scintillation) similar to the fading effect on wireless communication occurs [2]. It can be shirked through spatial diversity, aperture averaging, modulation techniques and error control coding.

An important factor on the selection of modulation technique for FSO systems is the receiver sensitivity as there is always a trade -off between the receiver sensitivity and complexity. Though amplitude shift keying (ASK) is the simplest and widely reported, it does not offer immunity to the turbulence induced

Fading [3]. Differential phase shift keying (DPSK) with coherent phase -diversity system offers the best sensitivity in optical fiber systems. However, there is an additional power penalty caused by the frequency offset because of delayed and not-delayed bits not being in phase[4]. Furthermore, there is a further power penalty due to the phase noise of the semiconductor lasers sources[5]. The inter symbol interference (ISI) due to multipath propagation is considered because of cloud.

The deterministic and random factors, which are involved to decide the overall performance of FSO communication systems are scattering, absorption, propagation distance, turbulence, weather conditions, pressure, temperature variations, wind speed, laser wavelength, pointing error effects and data rate etc [6]. The obvious solution to lessen the impairments on the performance of FSO systems and also cover large distances is to employ relay assisted and/or multi hop transmission techniques primarily three major statistical models to describe the atmospheric turbulence channel, viz. the log-normal distributed channel model, K-distributed channel model and the gamma–gamma distributed channel model .

CIRCUIT DIAGRAM

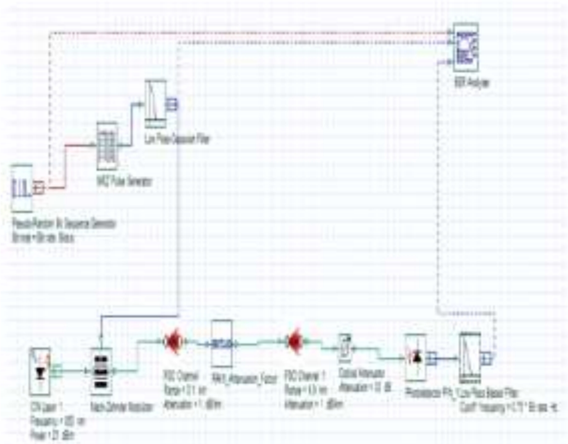

FIG 1 FSO-NRZ Stimulation with cloud effect

TRANSFER FUNCTION OF CLOUD

Clouds cause temporal widening and attenuation of optical pulse power as a part of optical communication channel. In all practical cases, part of the optical channel passes through the earth's atmosphere that contains clouds[7] .One important distortion effect imposed by the atmosphere is the signal temporal broadening. This produces inter symbol interference which limit s maximum transmission band width Using transmission with a wider temporal frequency band width will cause significant degradation in received signal quality because of the narrow information band width per mitted by clouds. Usually, in open optical communication severe bandwidth limitation occur s particularly when clouds are present. In order to imp rove performance, adaptive method s may be used according to atmospheric conditions. A theoretical model is presented [8]. It is followed by calculations of the electro-optical properties of the cloud s. This includes solving the Mie equations of scattering and absorption coefficients and the scattering phase function for the poly dispersion case. All calculations were carried out at three different wavelengths in the visible and near infrared (IR) spectral range, i.e. 0.532 µm , 0.8 µm and 1.3 µm wavelengths. These wavelengths are those under consideration for optical satellite communication. Longer wavelengths in the IR atmospheric windows exhibit very high absorption. Mid -IR wavelengths exhibit much more scattering than shorter ones because of the size distribution of cloud particulates. Mathematical models were developed for temporal impulse response at the three wavelengths listed above for the visible and near IR.

Table 1: Double Gamma function Constants: cloud thickness=250 m

Gamma function constant	Wavelengths		
	0.532µm	0.8µm	1.3µm
k_1	12.4	5.2	2
k_2	1.1×107	0.83×107	0.71×107
k_3	0.66	0.41	0.3
k_4	2.4×106	1.9×106	1.8×106

DIFFERENTIAL COHERENT

Differential coherent detection offers the simplest way of achieving carrier synchronization with phase - shift keying (PSK), and, thus, represents an attractive solution for systems where error in signal is caused by the channel itself. However, differentially coherent detection is based the premise that there is no inter symbol interference (ISI) in the received signal [9]. When a frequency selective multipath channel introduces ISI, differentially coherent detection must be combined with equalization. In fact, when carrier phase noise effect s are not severe Coherent detection performs better than non - coherent detection. In non coherent detection, a receiver computes decision variables based on a measurement of signal energy. In differentially coherent detection, a receiver computes decision variables based on a measurement of differential phase between the symbol of interest and one or more reference symbol(s). In differential phase -shift keying (DPSK), the phase reference is provided by the previous symbol.

BIT ERROR PERFORMANCE ANALYSIS

Bit error rate of the received signal is determined after propagation through cloud . It is observed from the transfer function of cloud that high attenuation of transmitted signal occurs while it passes through cloudy environment. Therefore there is higher probability of error due to inter symbol interference which is occurred by pulse broadening in cloud. The inherent non -linear frequency response of cumulus cloud causing successive symbols to blur together. The presence of ISI in the system introduces errors in the decision device at the receiver output [10].

RESULTS

The possibility that the endwise output SNR falls less than a specified threshold is known as outage probability. Threshold is a smallest value of the SNR above which the quality of service is acceptable. The outage probability over slow fading channel is expressed as:

$$P_{\text{out}} = P(\text{SNR}(h) \leq \text{SNR}_{th})$$

where SNR this the threshold SNR value below which the signal strength of the receiver is less than acceptable limits. For a various modulation techniques BPSK-SIM , DPSK, DPSK-SIM, M-ary PPM and PolSK, it can be estimated as follows

$$P_{\text{out, BPSK-SIM}} = P\left(h \leq \sqrt{\frac{2\sigma_n^2 \text{SNR}_{th}}{\gamma^2}}\right) = F_h\left(\sqrt{\frac{2\sigma_n^2 \text{SNR}_{th}}{\gamma^2}}\right)$$

$$P_{\text{out,DPSK}} = P\left(h \leq \frac{P\nu \text{SNR}_{th}}{\eta AT}\right) = F_h\left(\frac{P\nu \text{SNR}_{th}}{\eta AT}\right)$$

$$P_{\text{out, DPSK-SIM}} = P\left(h \leq \sqrt{\frac{2\sigma_n^2 \text{SNR}_{th}}{\gamma^2 A^2}}\right) = F_h\left(\sqrt{\frac{2\sigma_n^2 \text{SNR}_{th}}{\gamma^2 A^2}}\right)$$

$$P_{\text{out, MPPM}} = P\left(h \leq \frac{\text{SNR}_{th} P_R}{P_T}\left(\frac{\lambda L}{\eta A}\right)^2\right) = F_h\left(\frac{\text{SNR}_{th} P_R}{P_T}\left(\frac{\lambda L}{\eta A}\right)^2\right)$$

$$P_{\text{out, PolSK}} = P\left(h \leq \frac{\sigma_n^2 \text{SNR}_{th}}{\gamma^2 P_{LO}}\right) = F_h\left(\frac{\sigma_n^2 \text{SNR}_{th}}{\gamma^2 P_{LO}}\right)$$

GRAPHS FOR VARIOUS MODULATIONS

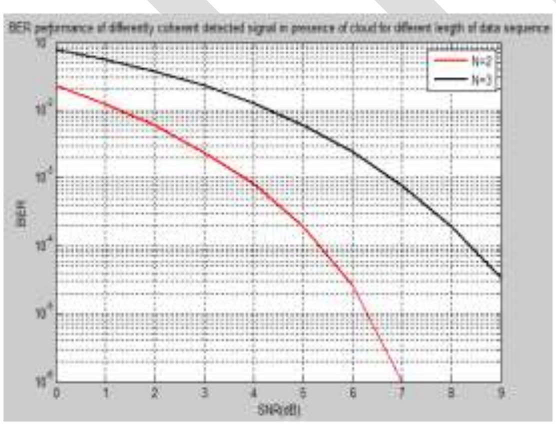

FIG 2 BER performance of differently coherent detected signal in presence of cloud for different length of data sequence (Data sequence length is 2N, where N=2, 3)

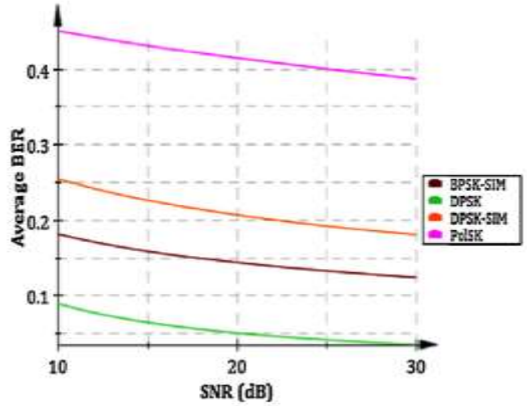

FIG 3 BER against SNR for various modulation schemes with α=4, β= 1.

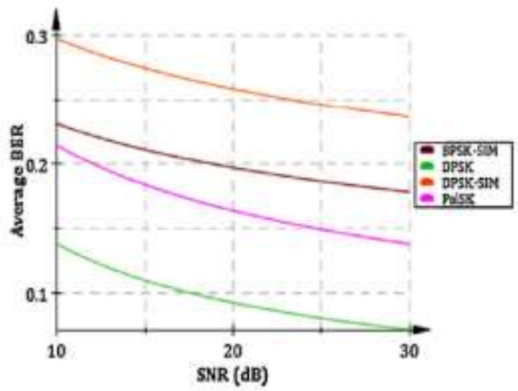

FIG 4 BER against SNR for various modulation schemes with α= 1, β = 1.

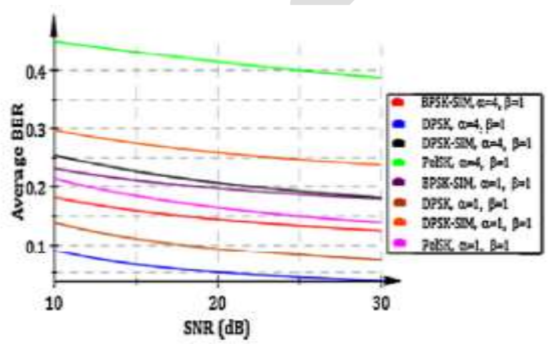

FIG 5 BER against SNR for various modulation schemes with α = 4, β = 1 and α = 1, β = 1

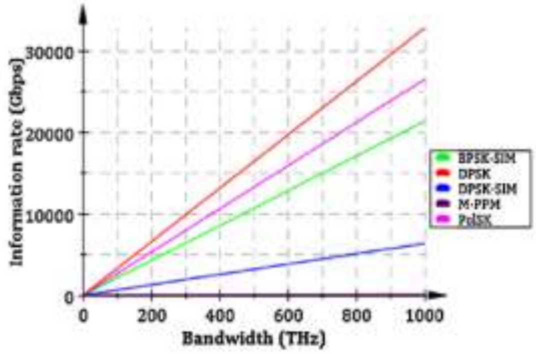

FIG 6 Information rate versus bandwidth with α = 4, β = 1.

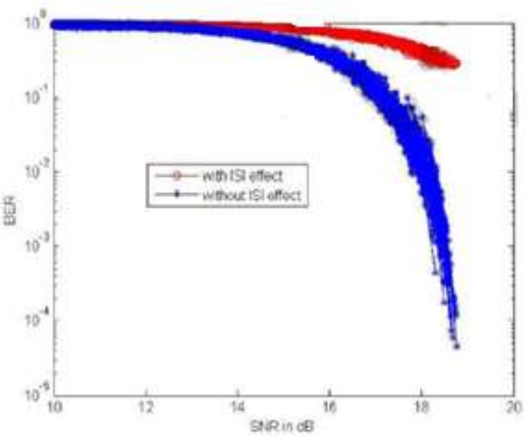

FIG 7 BER performance of received signal with and without the effect of ISI caused by cloud. Cloud thickness=250m

CONCLUSIONS

We studied different modulation formats using FSO. Novel closed-form expressions for the average BER, channel capacity and outage probability of the various modulation techniques such as, BPSK-SIM, DPSK, DPSK-SIM, M-ary PPM and PolSK were derived. The channel capacity, BER and outage performance of the FSO system using various modulation formats were analyzed and compared. It is also shown that PolSK offers the best outage probability performance and high channel capacity is achieved by the DPSK modulation formats. It is evident from analysis that there is signal power and signal quality both degrades a lot for cloud effect. As a result of pulse broadening in cloudy media ISI effect is severe in received signal so that high SNR (nearly 7 8 dB) is needed to achieve a BER at the scale of 10 -8. However with the increase of received data sequence length and combination of adaptive algorithm with differentially coherent detected signal better BER performance can be achieved than conventional OOK detection.

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