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Characterization of Free Space Optical communication system for Diverse Atmospheric Conditions At Different Wavelengths

Manpreet Singh[1] | Puneet Chopra[1] | DrMintuTyagi[2]

[1]Electrical Engineering, BGIET Sangru, Punjab, India
[2]Physics Department, Desh Bhagat University, Punjab

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ABSTRACT

Free space optical communications system is characterized for three optical windows i.e. 850 nm, 1064 nm, 1550 nm at different temperature conditions and link range. Signal to noise ratio and Bit Error Rate are the major parameters taken into major consideration.

Keywords *: Bit Error Rate ,Free Space Optics, Signal to Noise Ratio, Turbulence*

I. INTRODUCTION

The optical communication system gaining high popularity and seems to be more promising as compared to the radio frequency communication in the last decades and emerging as the replacement for the radio frequency communication link. It uses a modulated light source that transmits an optical signal and a photo-detector thatmake a replica of the transmitted signal received end and is further converts to an electrical signal. The fiber optical communication utilizes optical fiber to transmit the light through the path. This system offers to carry information through light signals across larger distances with less loss with contrast to the metal wires and are immune to electromagnetic interference.The fiber optic communication systems are commonly used in the telecommunications industry and have approximately replaced copper wire communications due to their numberof advantages over electrical transmission. This technique has considerablyhas less attenuation and prone to interference compared to existing copper wire in larger distance and high speed applications. Intended for wireless communication technology optical system provespotential that can complement the rapid growth of wireless network devices.The FSO communication link could be developed basically with the help of infrared laser lightyet iflow data rate communication over short distances is possible using LEDs. To increase the link rangeup to terrestrial difference such as for few kilometers,however the stability and quality of the link is highly dependent on atmospheric factors such as rain, heat, fog & dust. The link range in free space communication i.e. free-space-optical communication is currently in the order of several thousand kilometers and function in large swathes of different unlicensed spectrum agreeable to wavelength division multiplexing. FSO requires clear lineofsight (LOS) alignment between the transmitter and receiver for communication. To maintain the line of sight between the transmitter and receiver during anlasting transmission is an major concern,while FSO transmitters are highly directional. The gap in bandwidth between Radio Frequency wireless and optical fiber network speeds is enormous because of the limited accessibility of the RF spectrum. A high capacity gap with highspeed, line of sight and free-space-optical communication to overcome the received attention particularly for sky scraping altitudes such as space communications and building-top metro-area communications. Different methods has been developed for such fixed deployments of FSO to tolerate small variations, swaying of the buildings using beam steering or mechanical auto tracking but none of these techniques target mobility. The major concentration of FSO link has been on reaching long communication distances with highly expensive FSO components such as lasers with higher bandwidth link. Free Space Optic offersspatial reuse and angular diversity, thatmake FSO even more attractive once combined with its optical transmission speed. As Free Space Optical communication needs clear line of sight that is different to Radio Frequency.

II. EFFECT OF ATMOSPHERIC TURBULENCE

Atmospheric turbulence is usually categorized in regimes depending on the magnitude of index of refraction variation and in homogeneities present in atmosphere. These regimes are a function of the distance travelled by the optical radiation through the atmosphere and are classified as strong, moderate, weak.The turbulence outcome in signal fading further impairing the FSO link performance severely.Different models describing the pdf statistics of the irradiance fluctuation. Unluckily, due to the extreme complexity involved in mathematically modelling of atmospheric turbulence, a single model valid for all the turbulence regimes does not currently exist. These different models are the gamma–gamma, log-normal and negative exponential models. Their relevant ranges of validity of these models as reported in the literature are in the weak, moderate and saturate regimes. The effect of atmospheric turbulence is the fluctuation of the atmospheric refractive index n along the path of the optical field or radiation traversing the atmosphere. The refractive index fluctuation is the direct end product of random variations in atmospheric temperature from point to point. These random temperature changes are a function of the atmospheric pressure, wind speed and altitude. The smallest and the largest of the turbulence eddies are termed as the inner scale l_0 and the outer scale $L_0$of the turbulence, respectively, the values of l_0 and L_0 are typically of the order of a fewmillimetres and several metres correspondingly [3]. The temporal coherence time τ0 of atmospheric turbulence is stated to be of the order of milliseconds and this value is very large compared to the duration of a typical symbol data rate, thus the turbulent atmospheric channel could be described as a "slow fading channel" since it is static over the duration of a data symbol. Equation 1 shows the relationship between the temperature of the atmosphere and its refractive index. Whereas for many of engineering applications the rate of change of the refractive index with respect to channel temperature is represented by

$$n_{as} = 1 + 77.6(1 + 7.52 \times 10^{-3} \lambda^{-2}) \frac{P_{as}}{T_e} \times 10^{-6} \quad (1)$$

$$\frac{-dn_{as}}{dT_e} = 7.8 \times 10^{-5} \frac{P_{as}}{T_e^2} \quad (2)$$

where Pas is the atmospheric pressure in millibars, λ the wavelength in microns and Te is the effective temperature in Kelvin Near the sea level, $-dn_{as}/dT_e \cong 10^{-6} K^{-1}$. The involvement of humidity to the refractive index fluctuation is not accounted for in Equation 1 because this is negligible at optical wavelengths . Further on the position and time-dependent index of refraction denoted by nas(r, t) can be represented as the sum of its free-space value nas0, and a turbulence induced random fluctuation component nas1 (r, t) Therefore

$$n_{as}(r,t) = n_{as_0} + n_{as_1}(r,t) \quad (3)$$

In accordance with the Taylor's frozen-flow assumption, which implies that the temporal variations of the index of refraction of the channel are mainly due to the transverse component of the atmospheric wind, the randomly fluctuating part of Equation 3 can then be written as

$$n_{as_1}(r,t) = n_{as_1}(r - v_w t) \quad (4)$$

wherevw(r) is the local wind velocity perpendicular to the field direction of travel in atmospheric turbulence and an important parameter for characterizing the amount of refractive index fluctuation is the index of refraction structure parameter C_n^2 introduced by Kolmogorov. According to which is a function of the wavelength, temperature and atmospheric altitude. A commonly used model to describe C_n^2 in terms of altitude is the Hufnagel–Valley model given below as

$$C_n^2(h) = 0.00594\,(v_w/27)^2\,(10^{-5}h)^{10}\exp(-h/1000) + 2.7\times10^{-16}\exp(-h/1500) + \hat{A}\exp(-h/100) \quad (5)$$

where Â is taken as the nominal value of Cn 2(0) at the ground level in m−2/3 and λ is the altitude in meters. The normally used values for vw is 21 m/s. The value of the index of refraction structure parameter varies with altitude, however for a horizontally propagating field it is usually implicited constant.

III. RESULTS & DISCUSSIONS

The paper presents an analysis of Free Space Optical Communication system, for different wavelength i.e. 850 nm, 1064 nm, 1550 nm. The atmospheric turbulence was considered to be week and the parameters used to evaluate the performance of the FSO communication system are Signal to Noise Ratio and Bit Error Rateare considered. The evaluation of the system is also done by varying the link range for different temperature conditions.Mat lab was used to develop the simulation setup of the Free Space Optical Link. Graphs are plotted for the different values of the Signal to Noise ratio versus Bit Error Rate at different atmospheric temperature. Further on the range of the link is also changed from 1 Km to 5 Km for each value of temperature i.e. 0 °C, 20°C and 40 °C for the three different optical windows i.e. 85 nm, 1064 nm and 1550 nm and the table 1 show the parameters used for the link developed for the evaluation free space optical communication system.

Table 1 Parameters used for characterization of FSO link at moderate atmospheric turbulence .

Parameter	Value
Symbol rate Rb	155 Mbps
Spectral radiance of the sky N(λ)	$10^{-3} W/cm^2 \mu m Sr$
Spectral radiant emittance of the sun W(λ)	$0.055 W/cm^2 \mu m$
Optical band-pass filter bandwidth Δλ at λ = 850 nm	1 nm
PIN photodetector field of view (FOV)	0.6 rad
Radiation wavelength λ	850nm, 1064 nm & 1550 nm
Number of subcarriers N	1
Link range L	1 km, 2 km, 3 km, 4km, 5 km
Index of refraction structure parameter C_n^2	$0.75\times10^{-14} m^{-2/3}$
Load resistance RL	50Ω
PIN photodetector responsivity R	1
Operating temperature Te	0 °C, 20 °C, 40 °C
Optical modulation index ξ	1

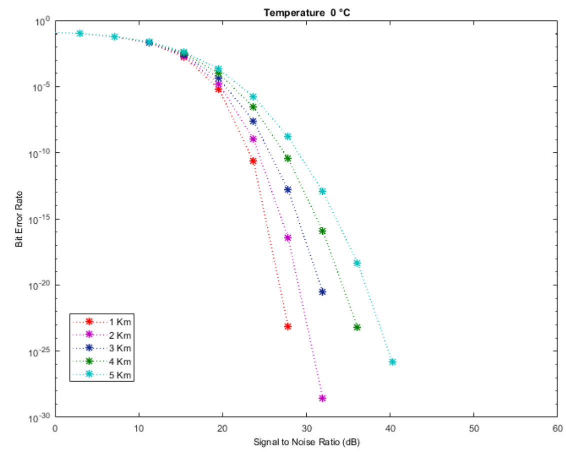

Figure 1: Shows the performance of FSO communication System at 850 nm for 0° C at different link Range

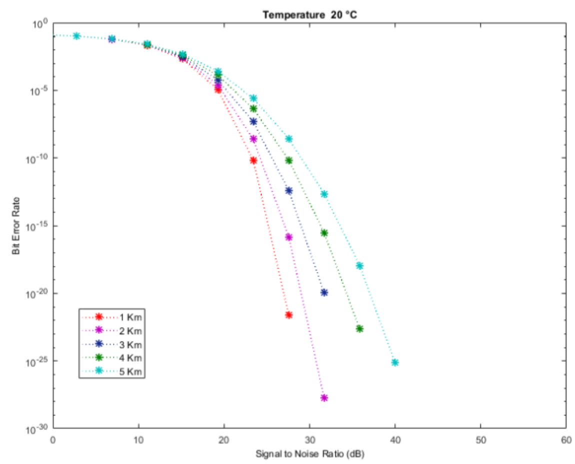

Figure 2: Shows the performance of FSO communication System at 850 nm for 20° C at different link Range

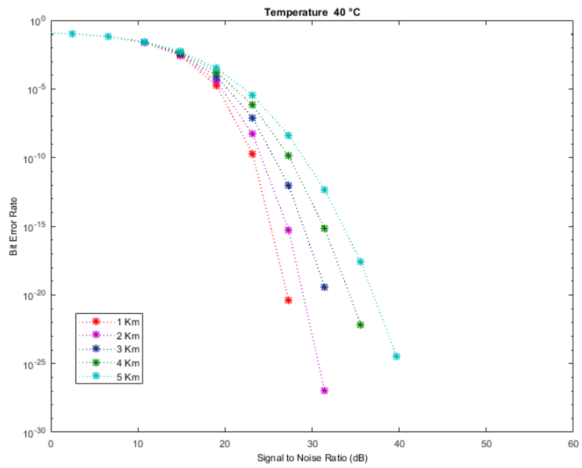

Figure 3: Shows the performance of FSO communication System at 850 nm for 40° C at different link Range

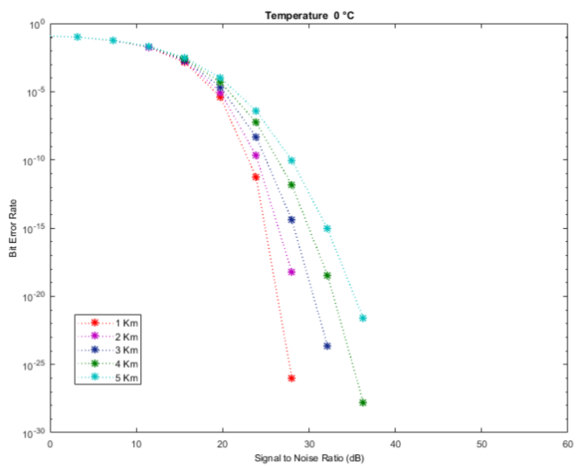

Figure 4: Shows the performance of FSO communication System at 1064 nm for 0° C at different link Range

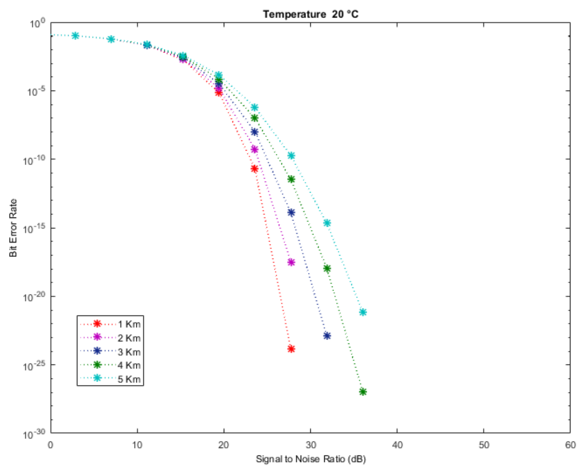

Figure 5: Shows the performance of FSO communication System at 1064 nm for 20° C at different link Range

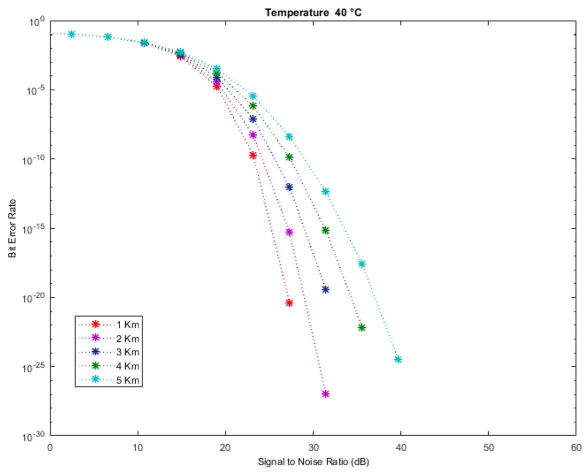

Figure 6: Shows the performance of FSO communication System at 1064 nm for 40° C at different link Range

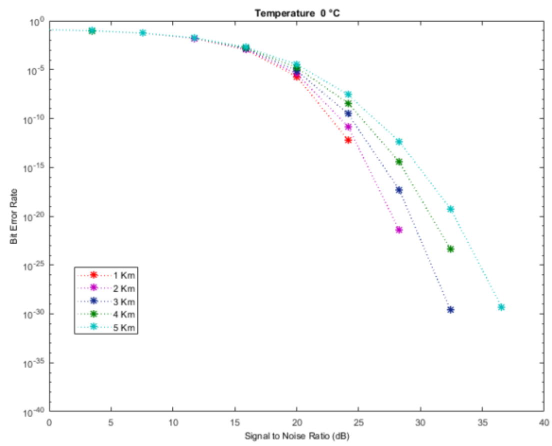

Figure 7: Shows the performance of FSO communication System at 1550 nm for 0° C at different link Range

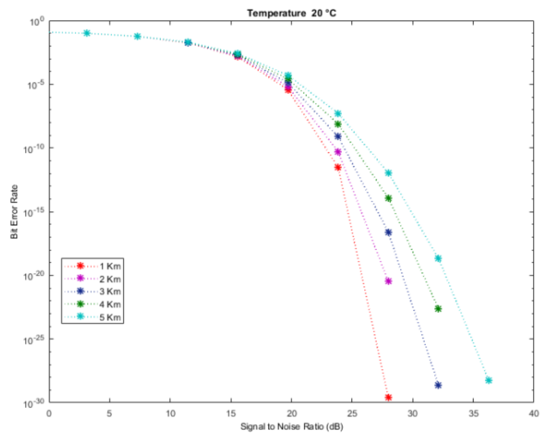

Figure 8: Shows the performance of FSO communication System at 1550 nm for 20° C at

different link Range

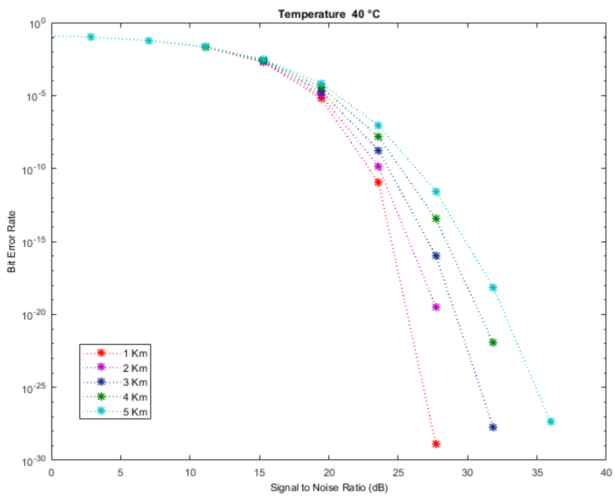

Figure 9: Shows the performance of FSO communication System at 1550 nm for 40° C at different link Range

IV. CONCLUSION

This paper presents a characterization of Free Space Optical Communication system at 850 nm, 1064 nm & 1550 nm for different temperature condition and variation of link range. It is aynalized from the results that the performance of the system is very good at the wavelength of 850 nm as comparing to the two oteroptical windows i.e. 1064 nm & 1550 nm. Further on the Bit Error Rate is very small in shorter distance and the effect change in atmosphere plays vital role for the performance to the system.The paper is focused for characterization of the system in the lower atmospheric turbulence. Two major parameters i.e. Signal to Noise Ratio and Bit Error Rate are observed to characterize the Free Space Optical System. Further research could be carried to analyze the system in different atmospheric turbulence.

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