# Design and Analysis of High Speed Free Space Optical Communication Link with Different Parameter

Jitendra Singh
Department of ECE
NIT Hamirpur- India

Vinod Kapoor
Department of ECE
NIT Hamirpur- India

## ABSTRACT
In this paper, Performance evaluation of Free Space Optical Communication Link with Different Parameters has been observed. It has been observed that BER of received data increases when path length is increases, also increase when data rate increases. In other case it observed that BER of received data increases when path length is increases, also increase when divergence angle increases and Q factor decreases with increase in distance and divergence angle. We have achieved BER 10-7 at 1600 m with bite rate of 2.50 Gbps and BER 10-12 at 2000 m with divergence angle 2 mred in free space optical communication link.

## Keywords
Optical Wireless Communication, DML, APD, Bit Error Rate, Bit Rates, Optical Received Power, Divergence angle.

## 1. INTRODUCTION
Optical wireless communications also know as Free Space Optics (FSO) is a cast effective and attractive solution for high data rate, image, and voice transmission [1]. It has received significant possible alternative to solve the bottleneck connectivity problem and as an alternative to more conventional RF/microwave links [2]. The FSO technique is fundamentally based on transmitting data laden light through the atmosphere and collecting the data laden light by telescope at a remote distance [3]. FSO communication is attractive due to the number of reason including narrow beam width and an unlicensed spectrum. Due to the narrow beam width it offers spatial multiplexing and more number of links capabilities in a given location. It offers data rate comparable to optical fiber communication but fraction of it deployment cost [2, 15]. FSO is less affected by snow and rain, but can be more affected by the atmospheric turbulence and fog. The attenuation coefficient typically ranges from a few dB/Km in clear atmosphere to 270dB/Km in dance fog region [3]. The three most significant factor that effect the optical transmission are absorption, scattering and scintillation.[10, 11]. All these can reduce the amount of energy received by receiver. Absorption is caused primarily by carbon dioxide and water vapor in the air along the transmission path. Their presence is a function of both humidity and altitude. This causes a decrease in the power density (attenuation) of the FSO beam and directly affects the availability of a system. However, the use of appropriate power based on atmospheric conditions and the use of spatial diversity (multiple beams within a FSO based unit) helps maintain the required level of network availability [5]. The transmittance T of laser radiation that has propagate over a distance L is given by the Bear's low

$$T = \exp(-\alpha_e(\lambda).L[Km]) \quad (1)$$

The $\alpha_e$ is the extinction coefficient describes the extinction level of the medium.

Scattering is caused when the wavelength collide with scatter. When the scatter size is comparable size of wavelength this is known as Mie scattering, when the scatter is smaller than the wavelength this is known as Rayleigh scattering [12, 13]. The scattering coefficient $\beta n$ in clear weather can be expressed according to visibility and wavelength by the following expression [15].

$$\beta_n = \frac{3.91}{V}\left(\frac{\lambda}{550nm}\right)^{-Q} \quad (2)$$

Where V is the visibility in km and λnm is the wavelength (in nm), *Q* is a factor which depends on the scattering particle size distribution [15]:

1.6 for large visibility (V > 50 km), 1.3 for mean visibility (6 < V < 50 km), $0.585\,V^{1/3}$ for low visibility (V < 6 km). A recent study [17] proposes another expression for the parameter *Q*. This expression, not yet proven experimentally, is:

Q = 1.6 if V > 50 km, Q = 1.3 if 6 km < V < 50 km, Q = 0.16*V + 0.34 if 1 km < V < 6 km,Q = V − 0.5 if 0.5 km < V < 1 km, Q = 0 if V < 0.5 km.

When molecular and aerosol absorption coefficients as well as the Rayleigh scatter coefficient have low values, the extinction coefficient can be given by the following equation [15]:

$$\alpha \cong \beta_n = \frac{3.91}{V}\left(\frac{\lambda}{550nm}\right)^{-Q} \quad (3)$$

Corresponding atmospheric attenuation is given by following Beer's Law in Equation 4 [14].

$$\tau(R) = \frac{P(R)}{P(O)} = \exp(-\beta_n R) \quad (4)$$

Equation 4 can be converted to logarithms scale in Equation 5.

$$\tau(R) = -10\log\frac{P(R)}{P(O)} = -10\log e^{(-\beta_n R)} = 10\log e^{(-\beta_n R)} \quad (5)$$

## 2. SYSTEM MODELING

FSO system basic design has modeled and simulated for performance characterization by using OptSim 4.6 which is a powerful software design tool that enables to plan, test and simulate almost every type of optical link in the transmission layer of a broad spectrum of optical networks from LAN, MAN to ultra long haul. It can minimize time requirement and decrease cost related to the design of optical systems, links and even components. There are several parameters of the system varied to obtain the optimum system performance. The main parameter that considered the laser propagation distance between the specific FSO channel. The FSO design model is illustrated in Fig 1.

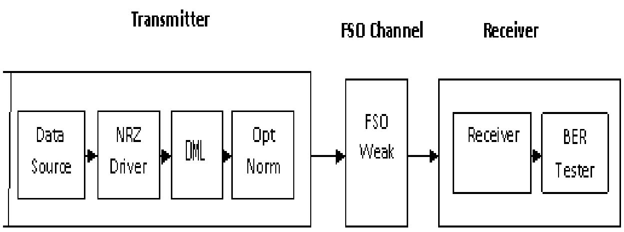



**Fig 1. Block diagram of FSO.**

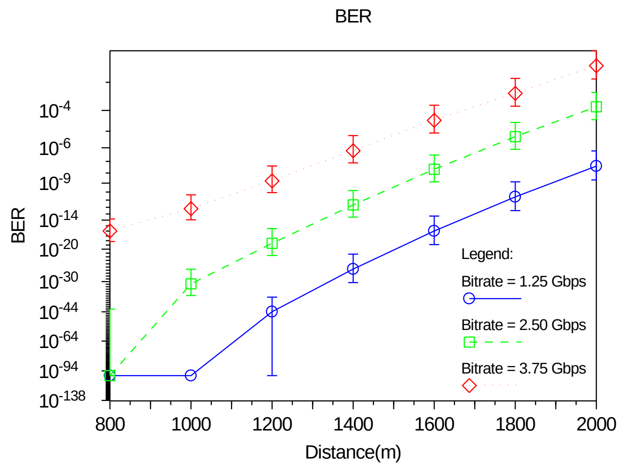
In our proposed design, the optical transmitter consists of three subsystems. The first subsystem is the Pseudo-Random Binary Sequence (PRBS) generator. This subsystem is to represent the information or data that wants to be transmitted. The output from a PRBS generator is a bit stream of binary pulses; a sequence of "1"s (ON) or "0"s (OFF), of a known and reproducible pattern. The second subsystem is the Non-Return-to-Zero (NRZ) electrical pulse generator. This subsystem encodes the data from the PRBS generator by using the NRZ encoding technique. A NRZ line code is a binary code in which 1's are represented by one significant condition and 0's are represented by some other significant condition. The third subsystem in the optical transmitter is the direct modulated lasers. Direct modulated lasers based on InGaAs semiconductor technology with operating wavelengths around 1550 nm [7] were developed specifically for fiber optic communications systems because of the low attenuation characteristics of optical fiber in this wavelength range. The free space between transmitter - receiver is considered as FSO channel which is a propagation medium for the transmitted light. In this design OptSim 4.6 software used, the FSO channel is between an optical transmitter and optical receiver with aperture diameter of 180cm$^2$ at each end respectively. Meanwhile, the beam divergence angle is set to 3 mrad. The optical receiver consist of an avalanche photodiode (APD) followed by a front-end amplifier, a low pass filter. The InGaAs APD must be capable of meeting the system bandwidth requirements. Therefore, a Trans-Impedance Amplifier (TIA) is used after the detector because it is preferred for use in wideband optical communication receivers. A Low Pass Filter (LPF) after the front-end amplifier is used to filter out the unwanted higher frequency signals. Bessel LPF is used with a cut-off frequency of 0.75 x bit rate of the signal. The receiver is use to regenerate electrical signal of the original bit sequence and the modulated electrical signal as in the optical transmitter to be used for BER analysis. Table I shows the parameter and their specification taken in to consideration during the simulation.

**Table I**
**Technical specification for owc link**

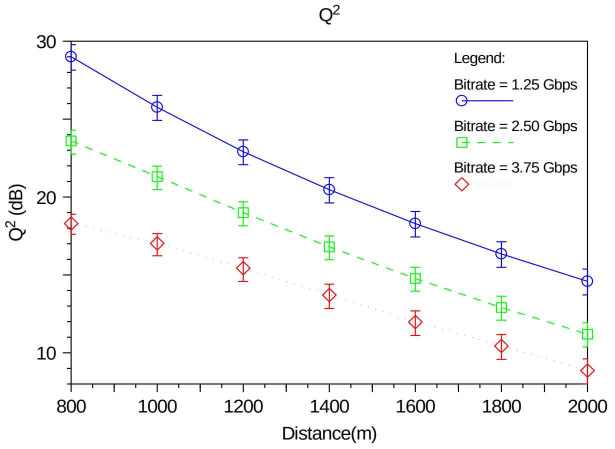
| Parameters | Description/Values |
|---|---|
| Transmitter Type | DMLaser |
| Tx Wavelength | 1550nm |
| Transmitter optical power | 8dBm |
| Tx aperture area | 180cm$^2$ |
| Link distance | 1500 meter |
| Pd_APD Multiplier | 1.0 |
| APD ionization Coefficient | 1.0 |
| APD Quantum Efficiency | 0.8 |
| Filter Type | LPBessel |
| APD Dark Current | 1μA |
| Sigma Add | 1.9 |
| Divergence Angle | 3mrad |

## 3. RESULT ANALYSIS

In our proposed design, by varying the data rate and the path length between the two transceivers, the system performance in terms of BER and Q factor has obtained by using laser Wavelength of 1550 nm. Then, the system performances have plotted in Fig. 2(a) and 2(b) and 3(a) and 3(b) respectively. The path length has set from 800 meter to 2 km while the transmit power has set at a constant value of 8 dBm, attenuation through transmission path 25dB/Km (Normal attenuation), the data rates From Fig. 2(a) shows that BER of received data increases when path length is increases, also increase when data rate increases. In results of Fig 2(b) it shows that Q factor decreases with increase in distance and data rate and it also shows that with higher data rate, Maximum achievable Q factors are also reduced.

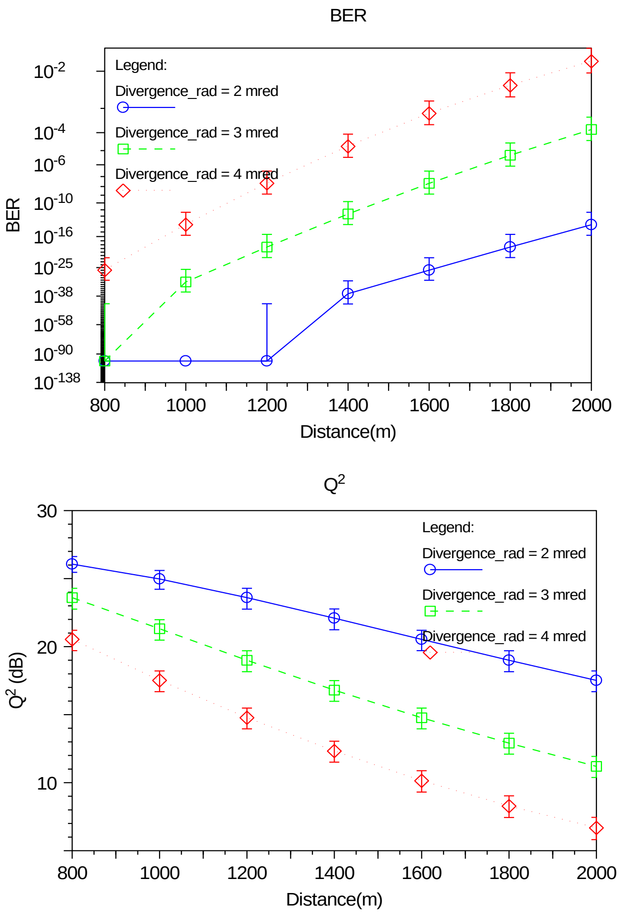



(a)




(b)

**Fig 2. (a) and (b) BER and Q factor for variable length at different bite rate**




(b)

**Fig. 3(a) and (b) BER and Q factor for variable length at different divergence angle.**

From Fig. 2(a) shows that BER of received data increases when path length is increases, also increase when data rate increases. In results of Fig 2(b) it shows that Q factor decreases with increase in distance and data rate and it also shows that with higher data rate, Maximum achievable Q factors are also reduced. From Fig. 3(a) shows that BER of received data increases when path length is increases, also increase when divergence angle increases. In result of Fig. 3(b) shows that Q factor decreases. With increase in distance and with divergence angle and it also shows that with high divergence angle, Maximum achievable Q factors are also reduced.

Fig. 3(a) and 3(b) shows that BER and Q value versus distance for different value of divergence angle. For this analysis the transmit power 8 dBm, attenuation through transmission path 25dB/Km ( normal attenuation), Bit rate 2.50 Gbps and the divergence angle vary from 2 mred to 4 mred.

## 4. CONCLUSIONS

This paper has studied the BER and Power performance of the free-space optical Link and experiencing that the Bit Error Rate and Q value both are the function of the Data Rates and divergence radius over a defined window 1550nm. It is concluded that BER of received data increases when path length is increases, also increase when data rate increases. From result it observed that 1.25Gbps can transmit upto 1800 meter and at 2.50 Gbps transmit upto 1500 meter and at 3.75 Gbps transmit up to 1200 meter at BER is less than 10-6 at divergence angle 3 mred. But it get higher for higher distance that is not acceptable. In other case it obeseved that BER of received data increases when path length is increases, also increase when divergence angle increases and Q factor decreases with increase in distance and divergence angle. We can achieve longer distance at higher bit rate by decreasing the divergence angle of the transmitter.

## 5. REFERENCES

[1] Henniger, H. Wilfert, O. 2010 An Introducttion to Free Space Optical Communications. Radioengineering, Vol. 19 , June 2010.

[2] Barua, B. 2011. Comparison the Performance of Free-Space Optical Communication with OOK and BPSK Modulation under Atmospheric Turbulence. International Journal of Engineering Science and Technology (IJEST). Vol. 3 May 2011

[3] Popoola, W. O. 2009. BPSK Subcarrier Intensity Modulated Free-Space Optical Communications in Atmospheric Turbulence. JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 27, APRIL 15, 2009

[4] Nadeem, Leitgeb, E., Awan, M. S. 2009. Optical Wavelengths Comparison for Different Weather Conditions. IEEE 2009.

[5] Epple, B. 2O10. Simplified Channel Model for Simulation of Free-Space Optical Communications. VOL. 2, MAY 2010

[6] Kiaseleh, K. 2006. Performance of Coherent DPSK Free Space Optical Communication System in Distributed Turbulence. IEEE Transactions Communication, Vol. 54,. 4, April 2006.

[7] Info-Communications Development Authority (IDA) of Singapore. 2002. A Trial-Based Study of Free-Space Optics Systems in Singapore. October 2002

[8] Kim, I. I., McArthur, B., Korevaar, E. 2001. Comparison of Laser Beam Propagation at 785nm and 1550nm in Fog and Haze for Optical Wireless Communications. SPIE Proceedings 4214:26-37.

[9] Nistazakis, H., Tsiftsis, T. A, Tombras, G. S. 2008. Performance Analysis of Free Space Optical

Communication Systems over Atmospheric Turbulence Channels. IET Communication 3(8):1402-1408.

[10] Manor, H., Arnon, S. 2003. Performance of an Optical Wireless Communication System as a Function of Wavelength. Applied Optics 42(21): 4285-4293.

[11] Mohd Supa'at, A. S., Mohammad, A. B., Tong, Y. T., and Idrus S. M. 1999. Unguided Optical Communication: Design a Mndewa, S. M., Huang, D., Yuan, X. 2008. A Survey of Atmospheric Turbulence on Laser Propagation. Asian Journal of Information Technology 7(7): 307-312.

[12] Mndewa, S. M., Huang, D., Yuan, X. 2008. A Survey of Atmospheric Turbulence on Laser Propagation. Asian Journal of Information Technology 7(7): 307-312.

[13] Naimullah, B. S., Othman, M., Rahman, A. K., Sulaiman, S.I., Ishak, S., Hitam, S., Aljunid, S. A. 2008. Comparison of Wavelength Propagation for Free Space Optical Communications. International Conference of Electronic Design. 1-5.

[14] Kim, I. I., Stieger R., Koontz J. A., Moursund C., Barclay M., Adhikari P., Schuster J., and Korevaaret E. 1998. Wireless Optical Transmission of Fast Ethernet, FDDI, ATM and ESCON Protocol Data Using the TerraLink Laser C

[15] Olivier Bouchet, Hervé Sizun, Christian Boisrobert, Frédérique de Fornel, Pierre-Noël Favennec, " Free-Space Optics:Propagation and Communication" publisher Hermes Science in France, 2004nd Evaluation in Malaysia Atmosphere. 269-271