Performance Analysis of Free Space Optics Link at Different Link Distance

Akansha Solanki[1], Nikita Ishpunniani[2] and Nitin Garg[3*]
[1 & 2]Student, EECE Department, Northcap University, Gurgaon, India
[3]Assistant Professor, EECE Department, Northcap University, Gurgaon, India

Abstract: We refer to the term optical wireless communication, when we use optical carriers as transmission media in different bands such as infrared, ultraviolet (UV) or visible. And when such communication takes place at outdoor terrestrial area to establish communication between various buildings within line of sight (LOS), then it is called Free Space Optical (FSO) Communication. FSO can be used for high rate communication for MAN extension, LAN to LAN connectivity or just to provide simple link between two distant points. This paper shows the design model for FSO link from one point to another separated by some distance. The link would be simulated virtually through software to attain maximum speed or high data rate up to maximum range possible, irrespective of all the atmospheric turbulences that the FSO channel could face during transmission of data. We would use optical sources at transmitter side and optical detectors as the receiver side to design the link.

Keywords : Bit Error Rate, Free Space Optical, Line Of Sight, Local Area Network, Metropolitan Area Network, Radio Frequency

I. INTRODUCTION

Free space optical communication refers to the transmission of data from source to destination via unguided optical medium that propagates in free space. The optical carriers through which the data is transmitted in free space could be visible, infrared or ultraviolet bands.

FSO has many advantages over conventional RF links. FSO allows transmission of data at high data rates up to 10Gbps due to availability of high optical bandwidth in comparison to RF links which can only scale up to only hundreds of Mbps [1]. FSO systems makes use of narrow laser beams which provides high reuse factor and immunity to electromagnetic interference. Thus, the frequency utilized in FSO communication is above 300GHz which is an unlicensed spectrum and is not easy to intercept [2]. FSO is highly economical, portable and is even the solution to the last mile bottleneck that is present in communication through copper cables which is the incapability to provide high bandwidth [3].

Various applications of FSO communication are [4]:

- Campus connectivity- FSO technique can be used to spatial network between multiple buildings in campuses providing high speed communication.
- Video monitoring and transmission- Conventional technologies in wireless communication are unable to provide required throughput for videos streams but this could be provided by FSO technology.
- Security- cryptography techniques are considered in nexus with optic fiber link. However, FSO links can also be considered as the option to secure communication where optic fiber is not feasible.
- Disaster recovery- FSO communication tends to be the most efficient communication technique in disaster hit areas as immediate FSO links can be formed in short time where other communication methods are not possible.

- Broadcasting- FSO systems can even fulfill the throughput requirements of high definition television broadcasting applications and can broadcast high quality videos through FSO link.

The signal through the FSO channel undergoes various losses. As the laser beam travels along FSO channel, its spreads resulting in the loss of optical power known as the Geometrical Losses. Another type of loss is Atmospheric Loss which is the result of many atmospheric factors. Fog, dust, aerosols, smoke etc affect the visibility of the laser light as they absorb the energy to cause attenuation and broadening of optical pulses [4]. Another factor that causes atmospheric loss is scintillation. Atmospheric pressure and temperature variations results into changes in the refractive index of air due to which the light intensities vary in time and space at the receiver and thus is called scintillation or fading. Besides all the losses that decay the power on the FSO link, Bit Error Rate or BER is considered to be an important parameter that analyzes the performance of an FSO link which is known as the number of bits received at the receiver to the total number of bits transmitted from the transmitter. Another parameter that describes performance of optical link is Q Factor which is a function of signal to noise ratio.

The relation between BER and Q Factor is given as:

$$BER = \frac{1}{2}\,\text{erfc}\,\frac{Q}{\sqrt{2\pi}}$$

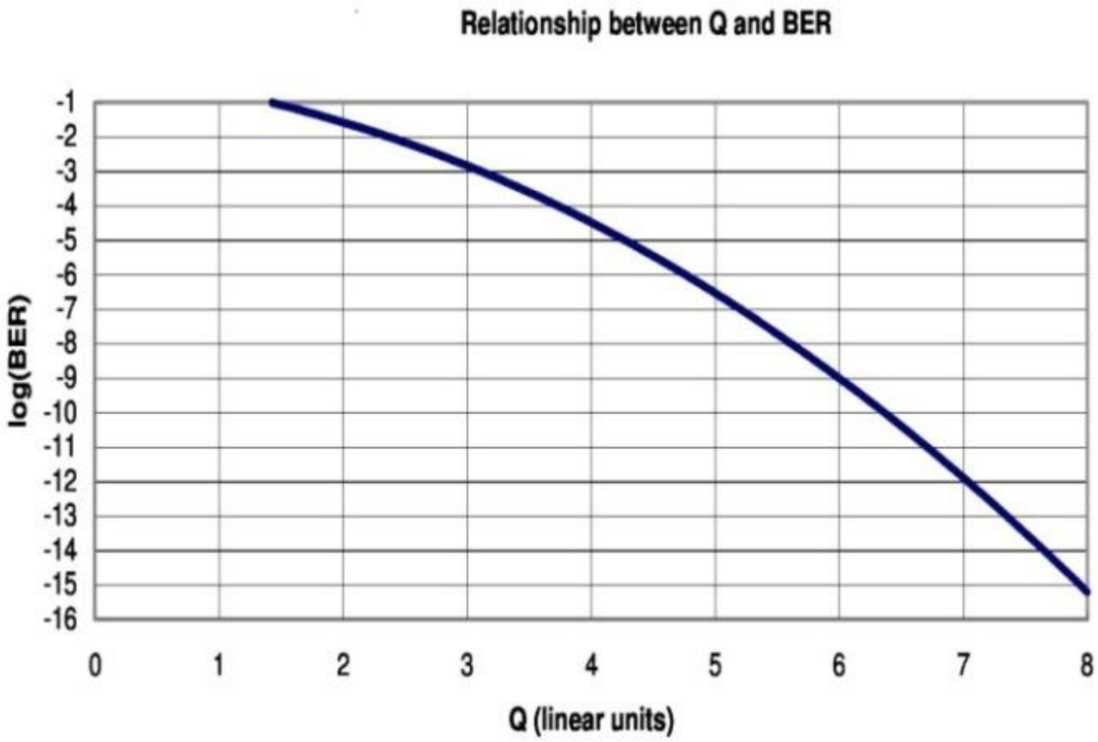

Fig 1: BER vs Q factor

The remaining part of the paper is as follows: In Section 2, block diagram is introduced. In Section 3, results and followed by the conclusion.

I. BLOCK DIAGRAM

A. Transmitter

The transmitter consists of:

- Bit sequence generator generates pseudo random sequence of bits 0 and 1 and this sequence of bits is given to the next subsystem
- Line encoded pulse generator- This generates pulses that could be encoded according to various line coding techniques such as: RZ, NRZ, bipolar RZ, bipolar NRZ or Manchester encoding. The purpose of line coding is pulse shaping and to reduce errors to tune the pulses according to the properties of the transmission channel.
- Optical source- The most common optical source in FSO communication is laser diode, though high power LEDs could also be used. But the important factor is that the laser is operated at a wavelength of 1550nm. The reason is that wavelengths above 1400nm tend to get absorbed by the eye and does not penetrate the eye which could lead to damaging of retina.

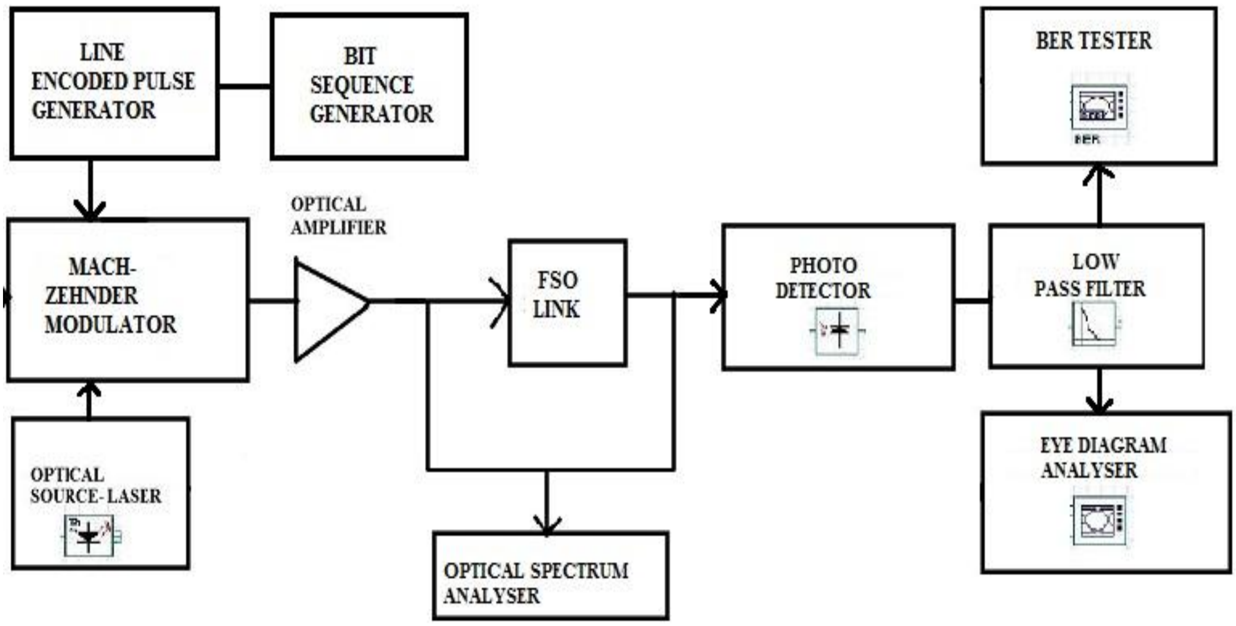

Fig 2: Block diagram of FSO system

- Mach-Zehnder modulator- The working of mach-zehnder depends upon intensity modulation of optical signal based on the phase difference produced at the output of the modulator. The optical signal travels through the two arms of the modulator and combine at output to give an in-phase or phase differentiated resultant output that could lead to ON or OFF state.
- Optical amplifier- It is used to increase the gain of the signal.

B. Transmission Channel

Free space optical link is used to transmit signal from transmitting end to the receiving end. Two optical spectrum analyzers are used before the reception of signal through FSO channel and after the reception through the FSO channel to analyze the variations in spectrum when it travels along the transmission channel.

C. Receiver

The receiver constitutes:

- Optical detector- the detector used is avalanche photo diode which is used to detect the incoming optical signal and convert it into equivalent electrical signal. APDs are preferred more over other optical detectors because it provides high current gain and increases the performance at the receiver end and thus, could be used in case of longer links.
- Low pass filter- it is used to remove or filter excess high frequency signals for error free output signal
- The resultant output signal is given to the BER tester and Eye Diagram analyzer to show the values of bit error rate and Q factor of the signal at the given range of the channel.

II. RESULTS

The design for the FSO communication was analyzed for NRZ and RZ type modulation scheme on OPTISYSTEM. The following are the eye diagrams for NRZ and RZ modulator. The opening of eye determines the performance of the system if the eye opening is wide the system performance is good and if it becomes narrower the performance is poor.

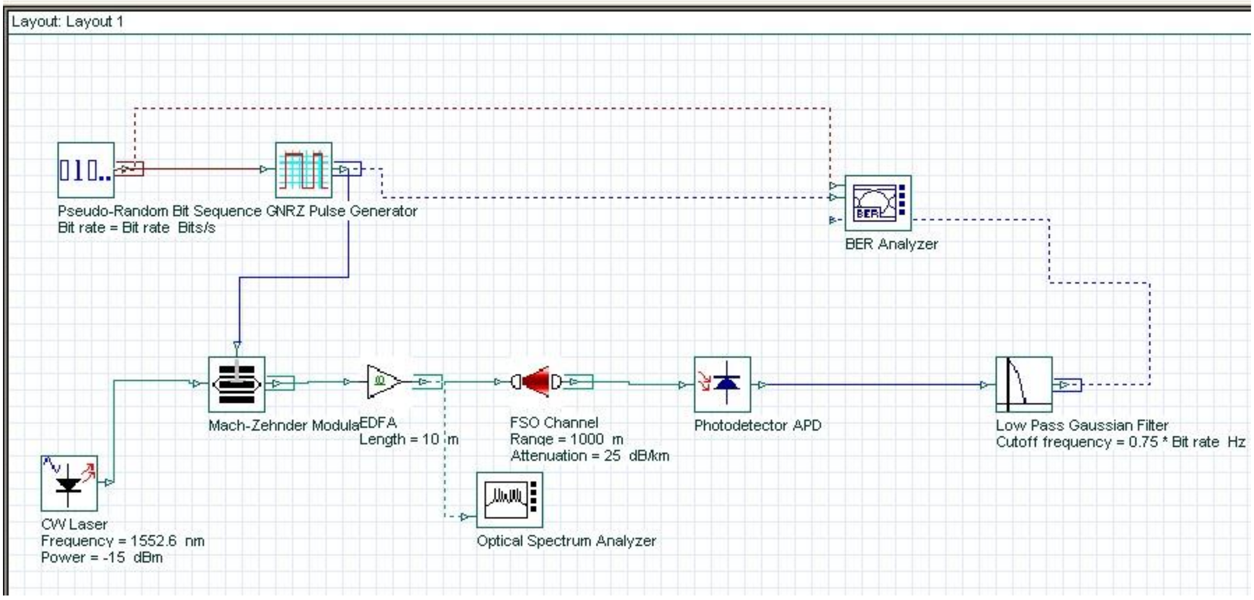

Fig 3: Block diagram for NRZ modulation

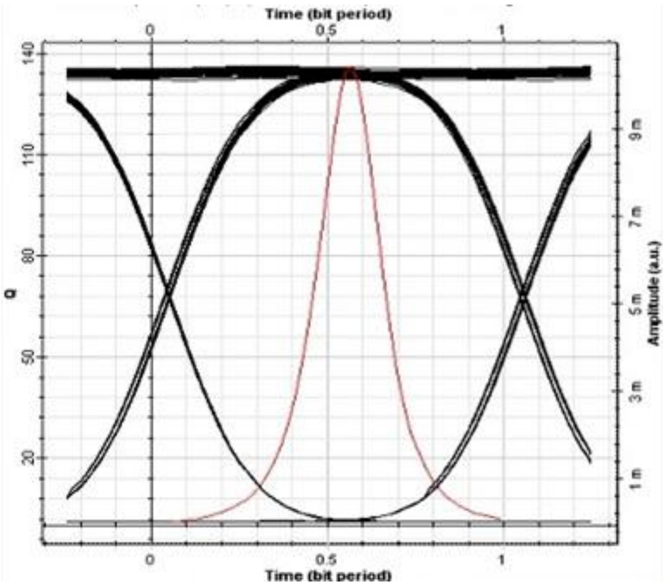

Fig 4: Eye diagram at 2.5 Gbps for link length = 200m for NRZ modulation.

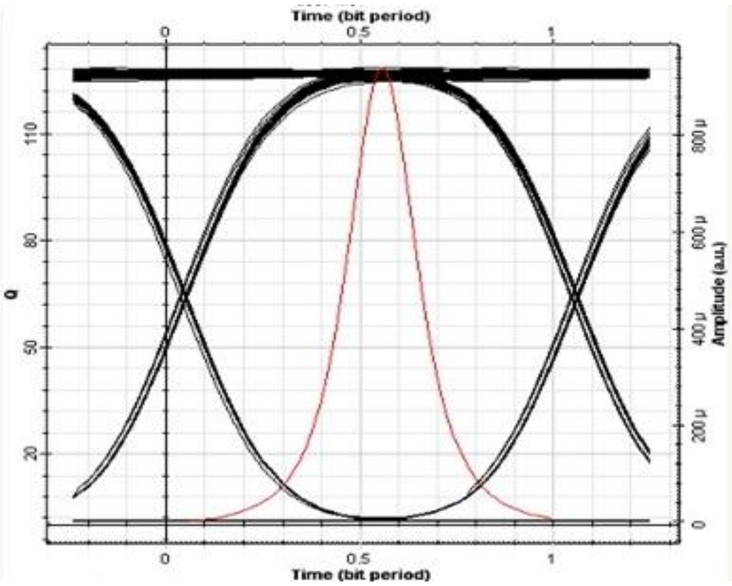

Fig 5: Eye diagram at 2.5 Gbps for link length = 400m for NRZ modulation.

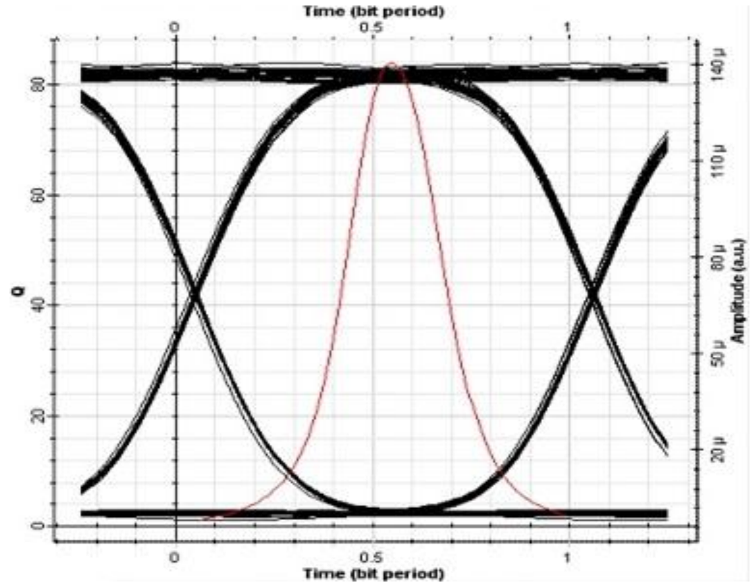

Fig 6: Eye diagram at 2.5 Gbps for link length = 600m for NRZ modulation.

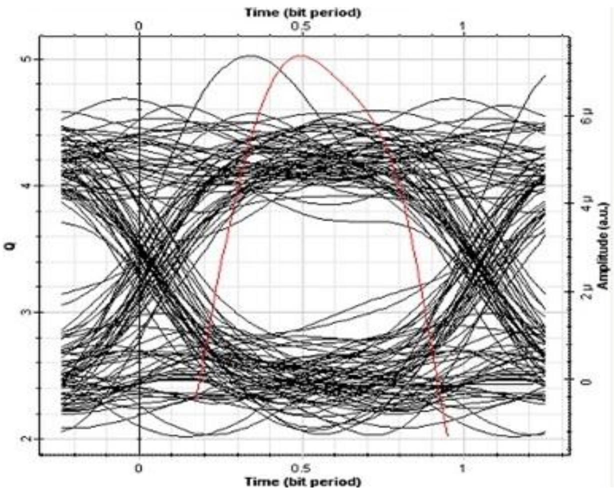

Fig 7: Eye diagram at 2.5 Gbps for link length = 800m for NRZ modulator.

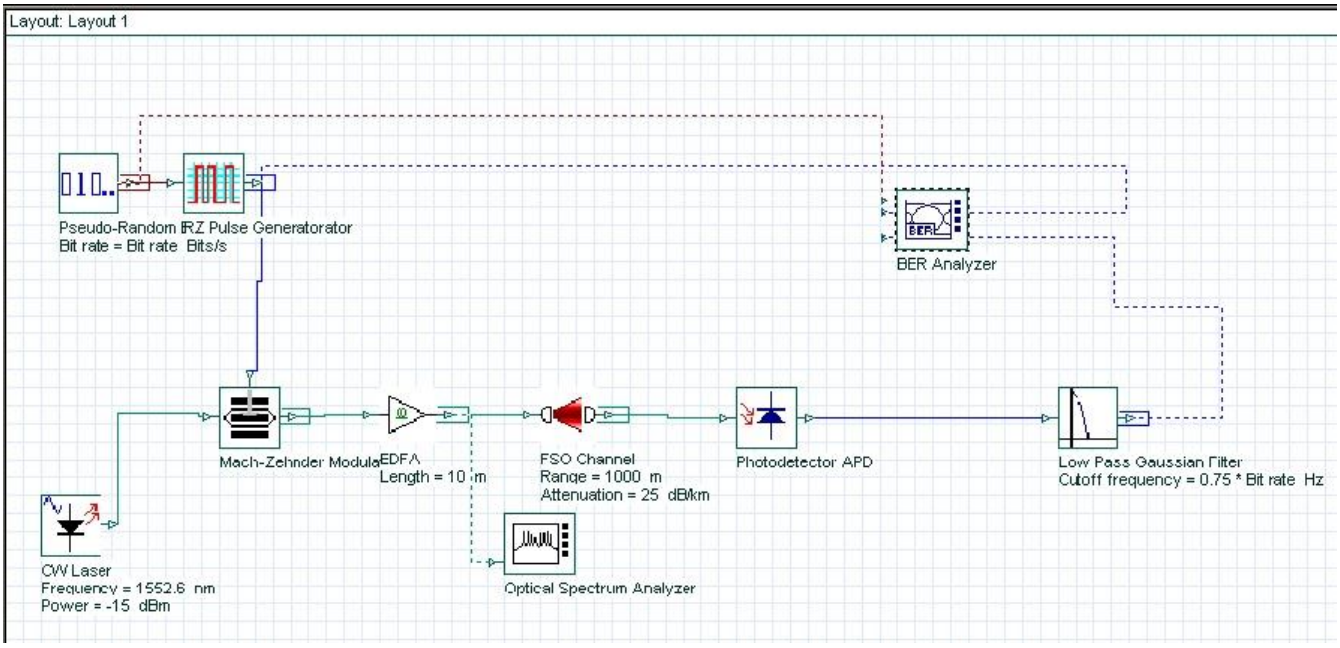

Fig 8: Block diagram for RZ modulator

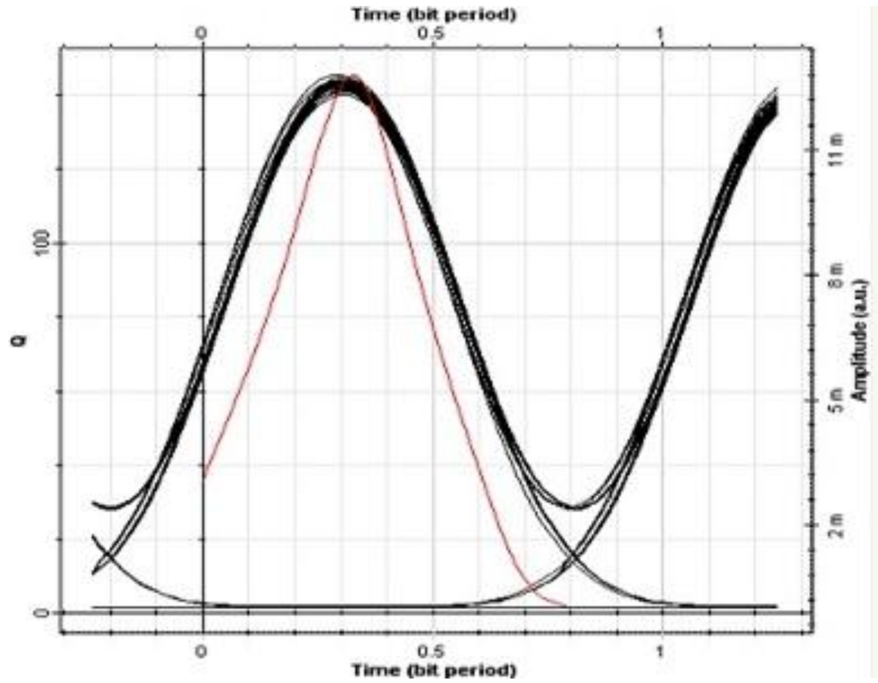

Fig 9: Eye diagram at 2.5 Gbps for link length = 200m for RZ modulator

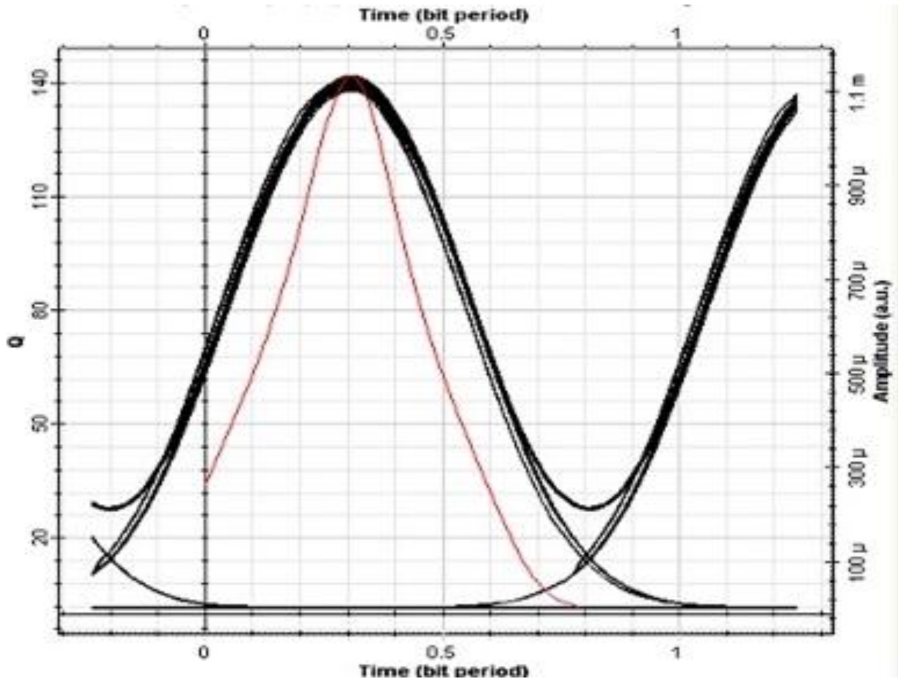

Fig 10: Eye diagram at 2.5 Gbps for link length = 400m for RZ modulator.

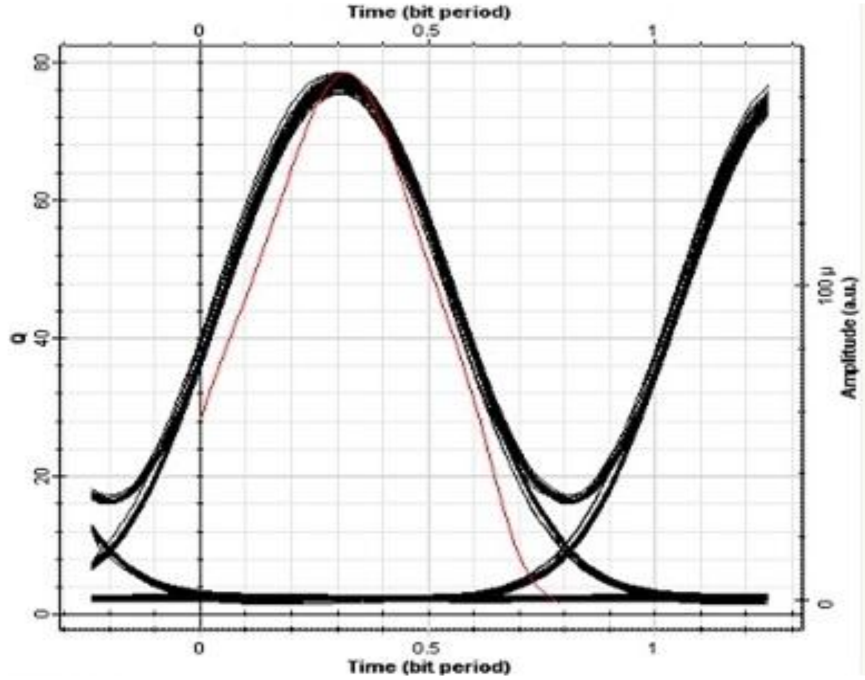

Fig 11: Eye diagram at 2.5 Gbps for link length = 600m for RZ modulator.

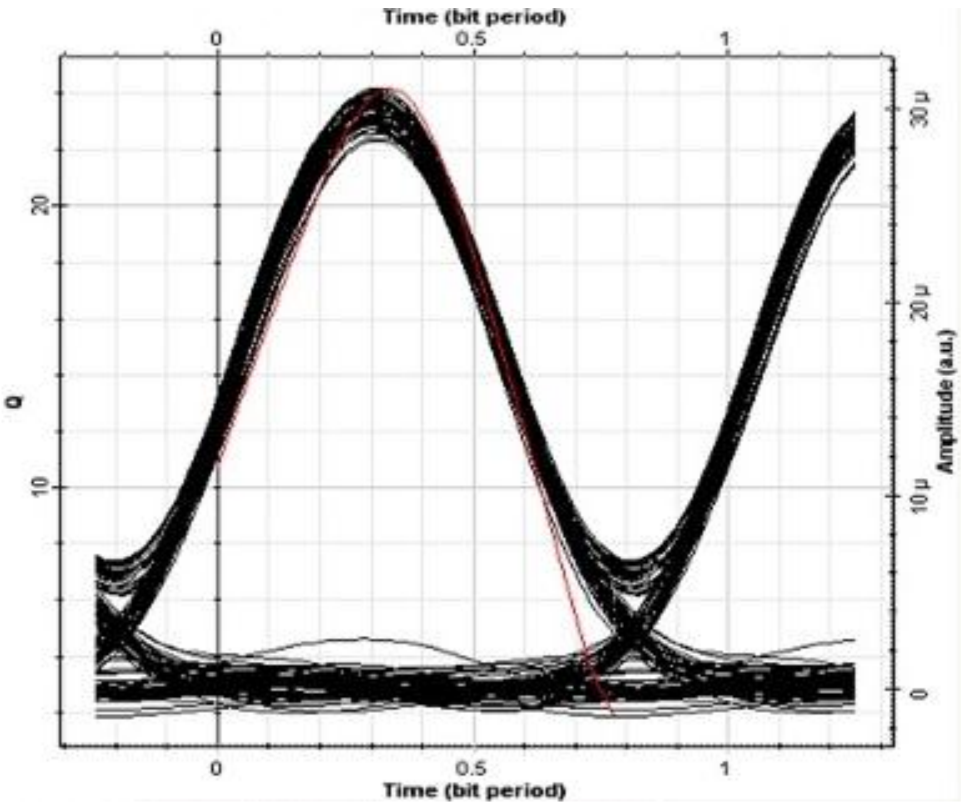

Fig 12: Eye diagram at 2.5 Gbps for link length = 800m for RZ modulator

The above outcomes for both RZ and NRZ modulation schemes shows how the quality factor decreases and the eye diagram distorts as we increase the distance from 200m to 800m considering the bit rate to be constant which is 2.5Gbps

III. CONCLUSION:

As the distance increases, the quality factor gradually decays. Thus, the information is best transferred at 200m distance with least distortion and the received information is highly distorted at 800m due to which the transmitted signal could be interpreted wrong at receiver side.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical statement: The authors declare that they have followed ethical responsibilities.

REFERENCES

[1] I. Jawhar, N. Mohamed and J. Al-Jaroodi, "Data communication in linear wireless sensor networks using Unmanned Aerial Vehicles," International Conference on Unmanned Aircraft Systems (ICUAS), Orlando, pp 43-51, May 2014.

[2] I. Jawhar, N. Mohammed, J. Al-Jaroodi and S. Zhang, "A framework for using unmanned aerial vehicles for data collection in linear wireless sensor networks," International Conference on Unmanned Aircraft Systems (ICUAS), Atlanta, pp 492-499, May 2013.

[3] V. W. S. Chan, "Free-space optical communications," Journal of Lightwave Technology, vol 24, no. 12, pp 47504762, December 2006.

[4] M. A. Khalighi and M. Uysal, "Survey on Free Space Optical Communication: A Communication Theory Perspective," in Communications Surveys and Tutorials, IEEE, vol 16, no. 4, pp 2231-2258, June 2014.

[5] A. A. Huurdeman, "The Worldwide History of Telecommunications," Wiley-Interscience Conference, USA, pp 269-293 2003.

[6] D. J. Phillipson, "Alexander Graham Bell," The Canadian Encyclopedia.[Online]. Available: *http://www.thecanadianencyclopedia.com/articles/alexander-grahambell.*
[7] M. Groth, "Photophones Revisited," [Online]. Available: *http://www.bluehaze.com.au/modlight/GrothArticle1.htm*
[8] M. C. Jeung et al, "8 10-Gb/s terrestrial optical free-space transmission over 3.4 km using an optical repeater," in Photonics Technology Letters, IEEE, vol 15, pp 171173, South Korea, January 2003.
[9] M. Grabner, V. Kvicera, "Multiple scattering in rain and fog on freespace optical links," in Journal of Lightwave Technology, vol 32, no. 3, pp 513520, February 2014.
[10] Ronald L Fante, "Electromagnetic beam propagation in turbulent media," Proceedings of IEEE, Bedford, pp 1669-1692, December 1975.
[11] L. B. Pedireddi, B. Srinivasan, "Characterization of atmospheric turbulence effects and their mitigation using wavelet-based signal processing," IEEE Transactions in Communications, Chennai, India, vol 58, no. 6, pp 1795-1802, June 2010.
[12] L. C. Andrews, R. L. Phillips, C. Y. Hopen, M. A. Al-Habash, "Theory of optical scintillation," Journal on Optical Image Science, vol 16, no. 6, pp 14171429, June 1999.
[13] D. Kedar and S. Arnon, "Urban optical wireless communications networks: the main challenges and possible solutions," IEEE Commun. Mag., vol. 42, no. 5, pp. 2-7, Feb. 2003.
[14] S. Navidpour, M. Uysal, and M. Kavehrad, "BER performance of free space optical transmission with spatial diversity," IEEE Trans. Wireless Commun., vol. 6, no. 8, pp. 2813-2819, Aug. 2007.