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# Modeling and Simulative Analysis of High-Speed FSO Link using Different System Parameters

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***Abstract***

*In this paper, modeling and simulative analysis of a Free Space Optical (FSO) communication link has been performed using different system parameters. Analysis has been performed by observing the Q Factor and SNR of the received signal under different data transmission rates, link length, divergence angle, and transmitted power levels of the information signal using OPTISYSTEM simulation software. It has been observed from the results that as the FSO link distance increases, the Q Factor of the received signal decreases and thus BER value increases. Also, as the data transmission rate of the system in increased, the Q Factor of received signal decreases. On increasing the value of divergence angle, the Q Factor of received signal decreases and thus degrades the performance of the system.*

***Keywords***: *FSO, Q Factor, SNR, transmission power levels, divergence angle, bit rate, Link length*

## 1. Introduction

Free Space Optical (FSO) communication also known as Optical Wireless Communication (OWC) is a cost effective and an attractive alternative in order to achieve high data transmission rates, large capacity and secure transmission of voice and image signals [1]. FSO communication links can be considered as an effective solution to solve bottleneck of connection problem in traditional microwave communication links [2]. The basic principle of FSO communication link involves the transmission of information signal through free space/vacuum as the transmission medium in the form of narrow beam light signal and then collecting the same signal at the receiver end with the use of telescope placed at a certain distance [3]. FSO is considered as an effective alternative to traditional RF/microwave communication links due to various reasons such as narrow light beam width, and availability of unlicensed spectrum. Due to the availability of narrow width of the light signal, spatial multiplexing is possible in FSO communication links and number of connections can be established in any location. The data transmission rates available for FSO links are comparable to that in optical fiber communication links, but the cost involved in FSO links are a fraction of that required for optical fiber links [2, 5]. The effect of snow and rain on the performance of FSO link is insignificant but the performance is badly affected by the presence of atmospheric turbulence and fog weather. The range of atmospheric attenuation lies between few dB/Km in normal conditions to 300 dB/Km in dense fog weather conditions [4]. Three of the most important factors that affect the performance of data transmission in FSO communication links are absorption, scintillation and scattering [6, 7]. These factors when present can reduce the total amount of received energy by the receiver. The main reason of absorption is the presence of water vapors and carbon dioxide in the free air along the path of data transmission [8]. The presence of water vapors and carbon dioxide depends on the altitude and the amount of humidity present in the air. The presence of water vapors and humidity results in the

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decrease in power density of information signal (attenuation) and thus degrades the performance of the FSO communication link. However, by deploying appropriate transmission power level depending upon the atmospheric condition and by deploying multiple transmission beams within FSO (spatial diversity) can improve the performance of FSO communication link and maintain required availability of network [5].

In this paper, simulative analysis of an FSO transmission link has been performed using OPTISYSTEM simulation software. The performance of the link has been analyzed by varying the link distance, transmission power level, divergence angle and data transmission rates. Performance has been analyzed by evaluating the Q Factor and SNR of the received signal for different system parameters. Rest of the paper is organized as follows- In Section 2, system description in presented and the simulation parameters used in the proposed link are given. In Section 3, results are presented and discussed. The conclusion to this investigative study is given in Section 4.

## 2. System Description

The basic design of FSO communication link used in this paper has been designed and simulated for analysis of performance by using OPTISYSTEM simulation software tool. Several system parameters are manipulated to obtain optimum performance of the transmission system. The main system parameters being considered in this paper are link distance, transmission power level, divergence angle, and bit rate. The FSO model used in this simulative study is shown in Figure 1.

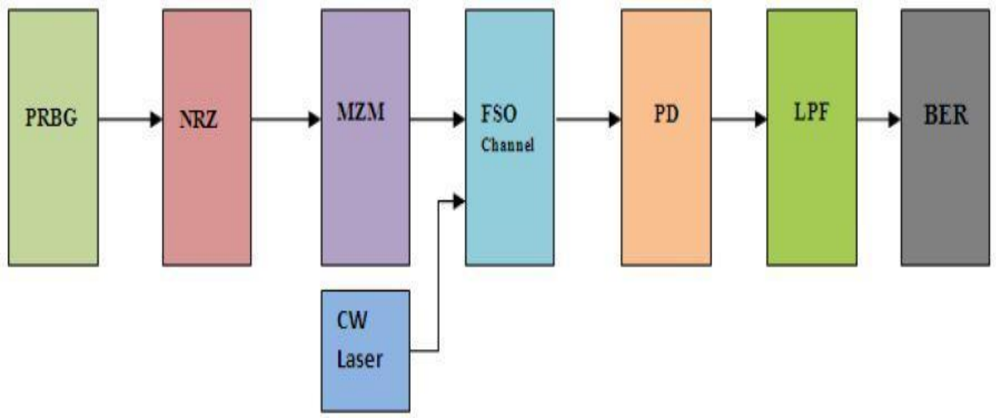


**Figure 1. Block Diagram of FSO Communication Link**

In this paper, the optical transmitter section in the proposed design consists of three subsystems. Pseudo Random Binary Sequence (PRBS) generator comprises of the first subsystem. PRBS generator generates the information signal to be transmitted in the form of a stream of binary digits in random sequence. The output from PRBS generator is then directed towards Non-Return to Zero (NRZ) electrical pulse generator. The NRZ pulse generator converts the binary signal at its input terminal from PRBS generator to corresponding electrical signals in NRZ modulation format. In NRZ modulation format, 1 is represented by a particular condition and 0 is represented by another condition. The third subsystem in the proposed design consists of continuous wave laser operating at 1550 nm central wavelength. The light signal from the CW Laser is directed toward Mach-Zender (MZ) pulse modulator which modulates the electrical signal from NRZ pulse generator with continuous wave output from the laser. In FSO communication link, the transmission channel consists of free air/vacuum as the signal propagation medium. The information signal transmitted from the optical transmitter travels through free air as propagation medium to reach the optical receiver. The optical receiver section consists of an Avalanche photodiode (APD) which converts the optical information signal to the corresponding electrical signal. A Bessel LPF removes any high-frequency noise present in the received electrical signal. The received signal is then further analyzed by BER analyzer. The different simulation parameters used in this simulation are given in Table 1.

**Table 1. Simulation Parameters**

| Parameter | Description/ Value |
|---|---|
| Transmitting Wavelength | 1550 nm |
| Transmitting Optical Power | 6- 12 dBm |
| Transmitter aperture diameter | 30 cm |
| Link Distance | 1500 m |
| APD multiplication factor | 1 |
| Data rate | 2.5-5 Gbps |
| APD quantum efficiency | 0.8 |
| Filter Type | Bessel Filter |
| APD dark current | $1\mu A$ |
| Divergence angle | 1-3 mrad |

## 3. Results and Discussions

The performance of FSO communication link, proposed in this paper has been analyzed under different simulation parameters such as transmission power levels, divergence angle, link distance, and bitrates. The performance has been analyzed on the basis of Q Factor and SNR value of the received signal.

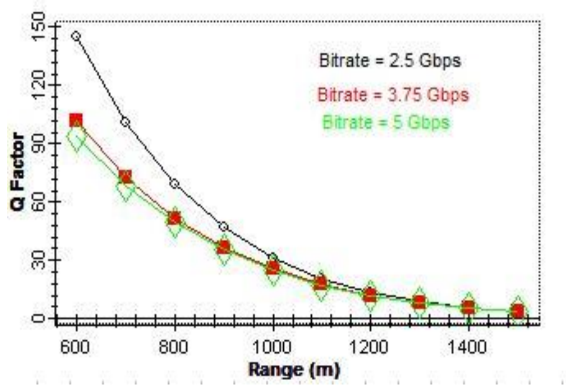


**Figure 2(a) Q Factor v/s Link Range for Different Data Transmission Rates**

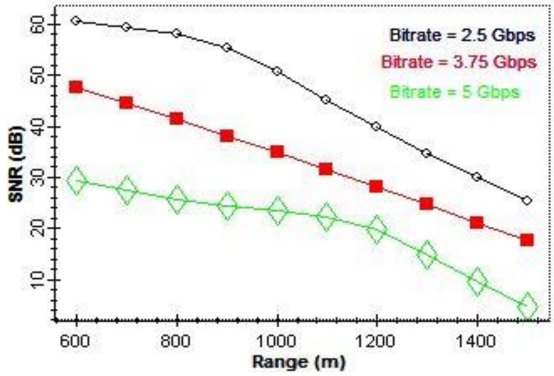


**Figure 2(b) SNR v/s Link Range for Different Data Transmission Rates**

Figure 2(a) and 2(b) indicate the graph between Q Factor and SNR for varying link distance at different data transmission rates respectively. It can be observed from the results that there is decrease in Q Factor values which change from [140, 99, 87] to [11, 9, 7] dB for link distance of 1.5 Km in case of 2.5 Gbps, 3.75 Gbps and 5 Gbps data transmission rates respectively and SNR lie in the range [60, 48, 30] to [28, 20, 9] dB for link distance of 1.5 Km in case of 2.5 Gbps, 3.75 Gbps and 5 Gbps data transmission rates respectively. In this paper, the performance of received signal has also been evaluated by varying the transmission power levels of the information signal for a 1.5 Km link under different data transmission rates.

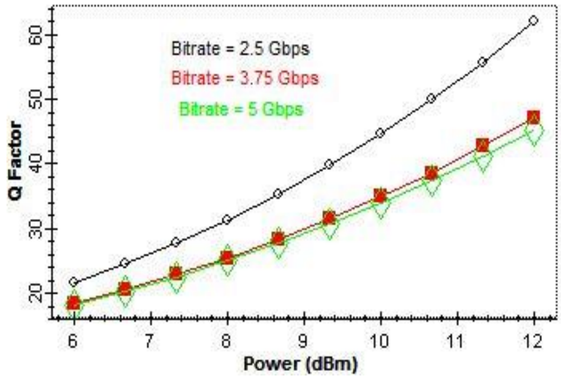


**Figure 3(a) Q Factor v/s Transmitted Power for Different Data Transmission Rates**

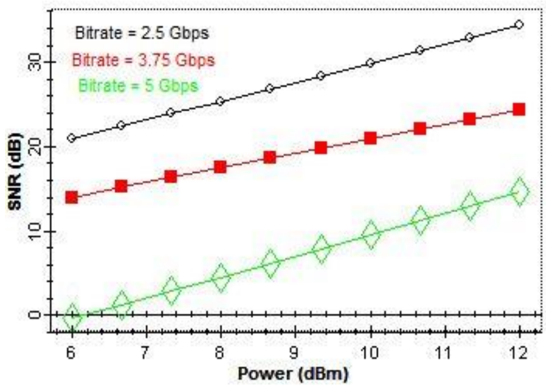


**Figure 3(b) SNR v/s Transmitted Power for Different Data Transmission Rates**

 

Figure 3(a) and 3(b) indicate the graph between Q Factor and SNR for varying transmission power levels at different data transmission rates respectively. It can be observed from the results that there is increase in Q Factor values which change from [20, 10, 8] to [67, 47, 42] dB for transmission power level of 6-12 dBm in case of 2.5 Gbps, 3.75 Gbps and 5 Gbps data transmission rates respectively and SNR lie in the range [21, 15, 01] to [37, 20, 12] dB for transmission power level of 6-12 dBm in case of 2.5 Gbps, 3.75 Gbps and 5 Gbps data transmission rates respectively.

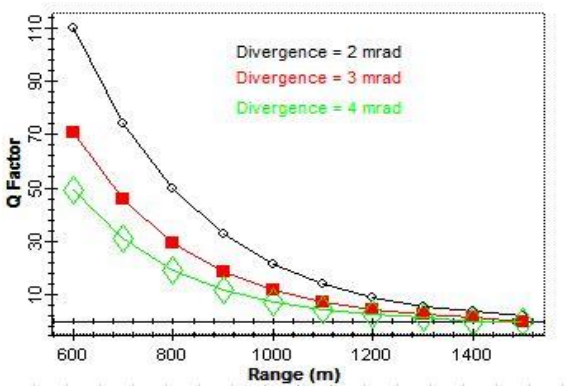


**Figure 4(a) Q Factor v/s Link Range for Different Divergence Angle**

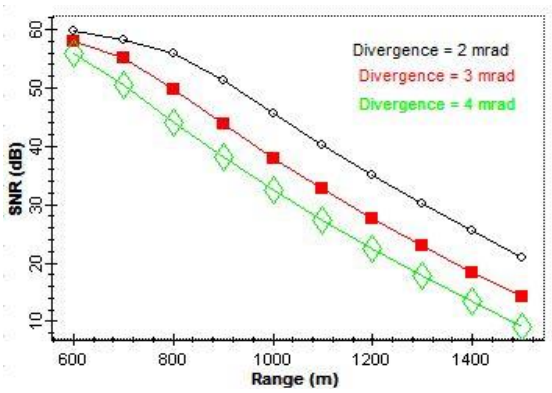


**Figure 4(b) SNR v/s Link Range for Different Divergence Angle**

Figure 4(a) and 4(b) indicate the graph between Q Factor and SNR for varying link distance at different divergence angle respectively. It can be observed from the results that there is decrease in Q Factor values which change from [110, 71, 50] to [11, 9, 7] dB for link distance of 1.5 Km in case of 2 mrad, 3 mrad, and 4 mrad divergence angle respectively and SNR lie in the range [60, 57, 55] to [28, 20, 9] dB for link distance of 1.5 Km in case of 2 mrad, 3 mrad, and 4 mrad divergence angle respectively. In this paper, the performance of received signal has also been evaluated by varying the transmission power levels of the information signal for a 1.5 Km link under different divergence angles.

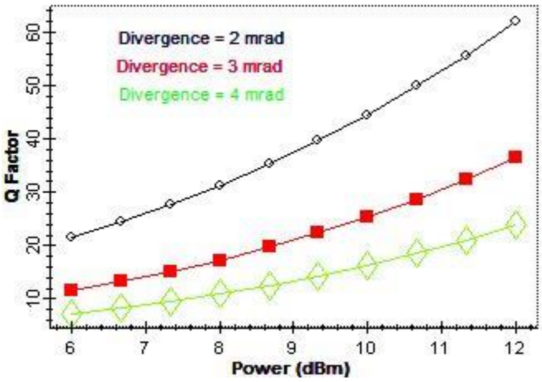


**Figure 5(a) Q Factor v/s Transmitted Power for Different Divergence Angle**

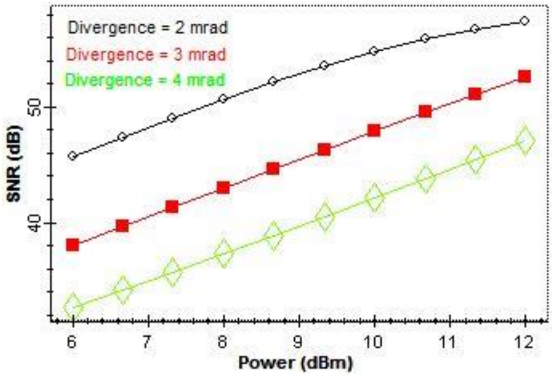


**Figure 5(b) SNR v/s Transmitted Power for Different Divergence Angle**

Figure 5(a) and 5(b) indicate the graph between Q Factor and SNR for varying transmission power levels at different divergence angle respectively. It can be observed from the results that there is increase in Q Factor values which change from [20, 12, 8] to [67, 37, 22] dB for transmission power level of 6-12 dBm in case of 2 mrad, 3 mrad, and 4 mrad divergence angle respectively and SNR lie in the range [42, 37, 31] to [57, 52, 45] dB for transmission power level of 6-12 dBm in case of 2 mrad, 3 mrad, and 4 mrad divergence angle respectively.

## 4. Conclusion

This paper has analyzed the performance of Free Space Optical communication link in terms of Q Factor and SNR values of received signal. The results show that the performance of FSO link depends upon the data transmission rates and divergence angle values over 1550 nm of operating wavelength. It can be concluded form the results that as the FSO link length increases the Q Factor decreases and hence the BER increases. Q Factor also decreases when the data transmission rates increase. Also, as the transmission power levels increase, the Q Factor value increases. In another case, it has been seen that as the value of divergence angle increases the Q Factor and SNR value of received signal decrease. Therefore, it can be concluded that in order to achieve longer link distance in FSO communication links at high data transmission rates, divergence angle should be decreased and transmission power levels should be increased but power levels should not exceed a certain safe value to prevent harm to human skin and eyes.

## References

[1] H. Henniger and O. Wilfert, 2010, "An Introduction to Free Space Optical Communications", Radio engineering, vol. 1, **(2010)** June.
[2] B. Barua, 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, **(2011)** May.
[3] W. O. Popoola, 2009, "BPSK Subcarrier Intensity Modulated Free-Space Optical Communications in Atmospheric Turbulence", JOURNAL OF LIGHTWAVE TECHNOLOGY, vol. 27, **(2009)** April 15.
[4] L. Nadeem, M. S. E. Awan, 2009, "Optical Wavelengths Comparison for Different Weather Conditions", IEEE **(2009)**.
[5] B. Epple, 2010, "Simplified Channel Model for Simulation of Free-Space Optical Communications", vol. 2, **(2010)** May.
[6] K. Kiaseleh, 2006, Performance of Coherent DPSK Free Space Optical Communication System in Distributed Turbulence, IEEE Transactions Communication, vol. 54, no. 4, **(2006)** April.
[7] Info-Communications Development Authority (IDA) of Singapore, 2002, "A Trial-Based Study of Free-Space Optics Systems in Singapore", **(2002)** October.
[8] I. I. Kim, B. McArthur and E. Korevaar, 2001, "Comparison of Laser Beam Propagation at 785nm and 1550nm in Fog and Haze for Optical Wireless Communications", SPIE Proceedings 4214, pp. 26-37.