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Performance Evaluation of Free-Space Optical Communication using Linear Polarization Shift Keying Modulation

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ABSTRACT

In Free-space optical communication Transmission of data between the source and destination is done by light traveling through free space. In this paper, linear polarization shift keying modulation technique is used for propagation of light signal. FSO system is simulated using the linear polarization shift keying modulation technique under various weather conditions using Optisystem software. The performance evaluation of the system is carried out by examining qualitative parameters corresponding to variable transmission distances with different specific attenuations.

Keywords: Bit Error Rate (BER), free-space optical communication (FSO), linear polarization shift keying (LPolSK), simulation,

1. INTRODUCTION

As Free-space optical communication has a lot of potential for wireless communication and combined advantages of high bit rates, low bit error rates, immunity to Electromagnetic interference etc. Since there are atmospheric losses while propagating the signal through atmosphere [4]. Due to these losses the signal to be highly attenuated, giving in higher BER values [2]. As light has a vector characteristic so, the polarization shift keying enables us to encode and modulate the polarization states of light for binary modulation.

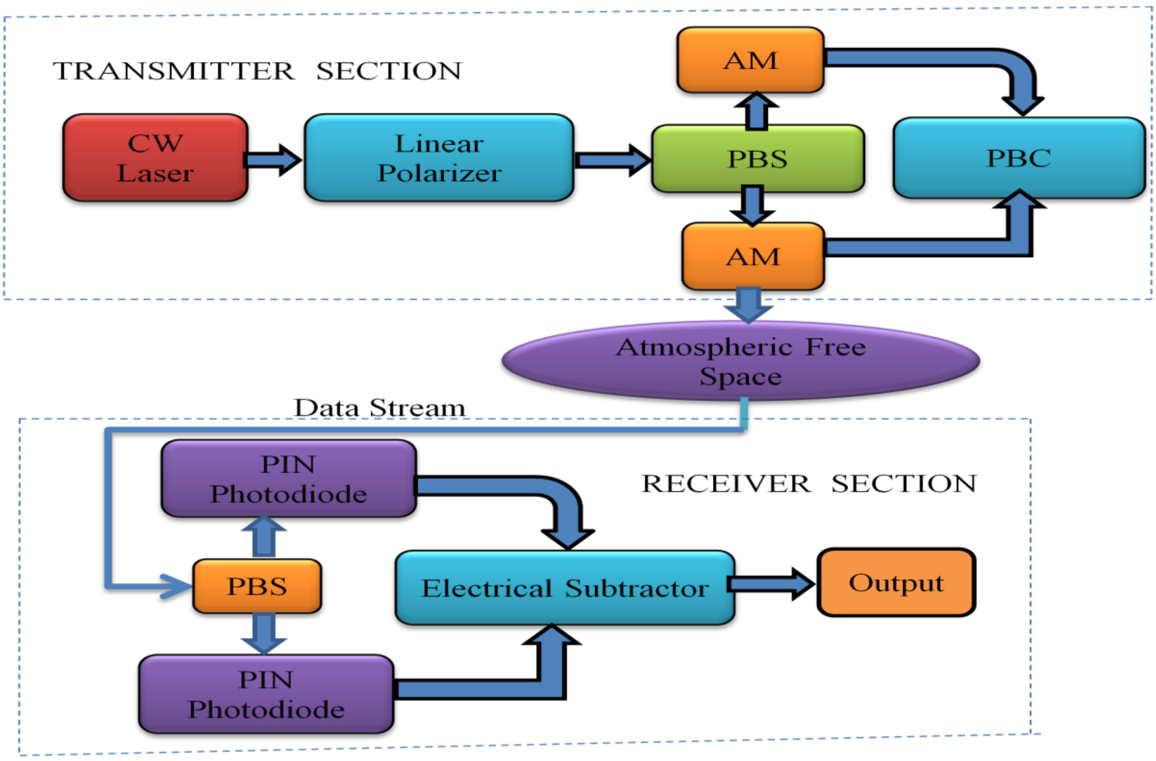


Fig. 1: Block diagram of FSO system.

Most of the techniques proposed for FSO transmission are complex which have high power and cost. Hence, we have used linear polarization shift keying that has horizontal and vertical states of polarization. These do not alter under various atmospheric disturbances thereby enhancing the reliability [3].

Working of FSO is similar to OFC (optical fiber cable) networks but the only difference is that the optical beams are sent through free air instead of OFC cores that is glass fiber. FSO system consists of an optical transceiver at both ends to provide full duplex (bidirectional) capability. FSO communication is not a new technology. It has been in existence from 8th century but now is more evolved. FSO is a LOS (line of sight) technology, where data, voice, and video communication is achieved with maximum 10Gbps of data rate by full duplex connectivity.

2. PRINCIPLE OF FSO SYSTEM BASED ON LPolSK

Linear Polarization Shift Keying

Because of the linear polarization shift keying, digital bits are encoded into vertical and horizontal polarization states [1]. The output power of the laser source can thereby be efficiently utilize. The transmitter consists of a continuous wave laser having a power of 200mW. The light from the laser is passed to a linear polarizer angled at 45 degrees. The output of this polarizer is a $+45^{o}$ linearly polarized light which then goes to a polarization beam splitter. The light is split into its vector components (x and y components). The binary data to be encoded is first given to a NRZ pulse generator that generates Non-Return-to -Zero pulses.

The amplitude modulators connected to different vector components are modulated by polar opposites of the same data stream. The resultant modulated light components are then combined to a single source of light using the polarization beam combiner. Using a polarization analyzer at the output of the transmitter, it can be shown that ‘1’ is represented by horizontal LPolSK and ‘0’ is represented by vertical LPolSK. Hence the binary data is successfully encoded in the polarization states. The standard FSO channel provided by Optisystem software is used to model the propagation medium for the simulation. It allows us to select the range of the system as well as the specific attenuation of the channel. The following table lists the specific attenuation of various atmospheric conditions used in the simulation.

The receiver consists of a polarization beam splitter that again splits the received light into its orthogonal components. The PIN photodiode detectors convert the incoming light intensity signal to electrical signal. The power of the electrical signal depends on the input signal power. An electrical subtractor gives the difference between the electrical signals produced by the two photodiodes. An oscilloscope visualizer connected to the output of the subtractor shows that the received signal is the same as the signal generated by that generated by the NRZ pulse generator.

3. ATMOSPHERIC EFFECTS IN FSO

The medium of the transmission is air for FSO and the light passes through it, some environmental challenges are unavoidable. Troposphere regions are the region where most of the atmospheric phenomenon occurred.

Atmospheric turbulence: the atmospheric disturbance happens due to weather and environment structure. It is caused by wind and convection which mixed the air parcels at different temperatures. This causes fluctuations in the density of air and it leads to the change in the air refractive index. The scale size of turbulence cell can create different type of effects given below and which would be dominant:

(i) If size of turbulence cell is of larger diameter than optical beam then beam wander would be the dominant effect. Beam wander is explained as the displacement of the optical beam spot rapidly.

(ii) If size of turbulence cell is of smaller diameter than optical beam then the intensity fluctuation or scintillation of the optical beam is a dominant one.

Atmospheric attenuation: atmospheric attenuation is the resultant of fog and haze normally. It also depends upon dust and rain. It is supposed that atmospheric attenuation is wavelength dependent but this is not true. Haze is wavelength dependent. Attenuation at 1550nm is less than other wavelengths in haze weather condition [11]. Attenuation in fog weather condition is wavelength independent.

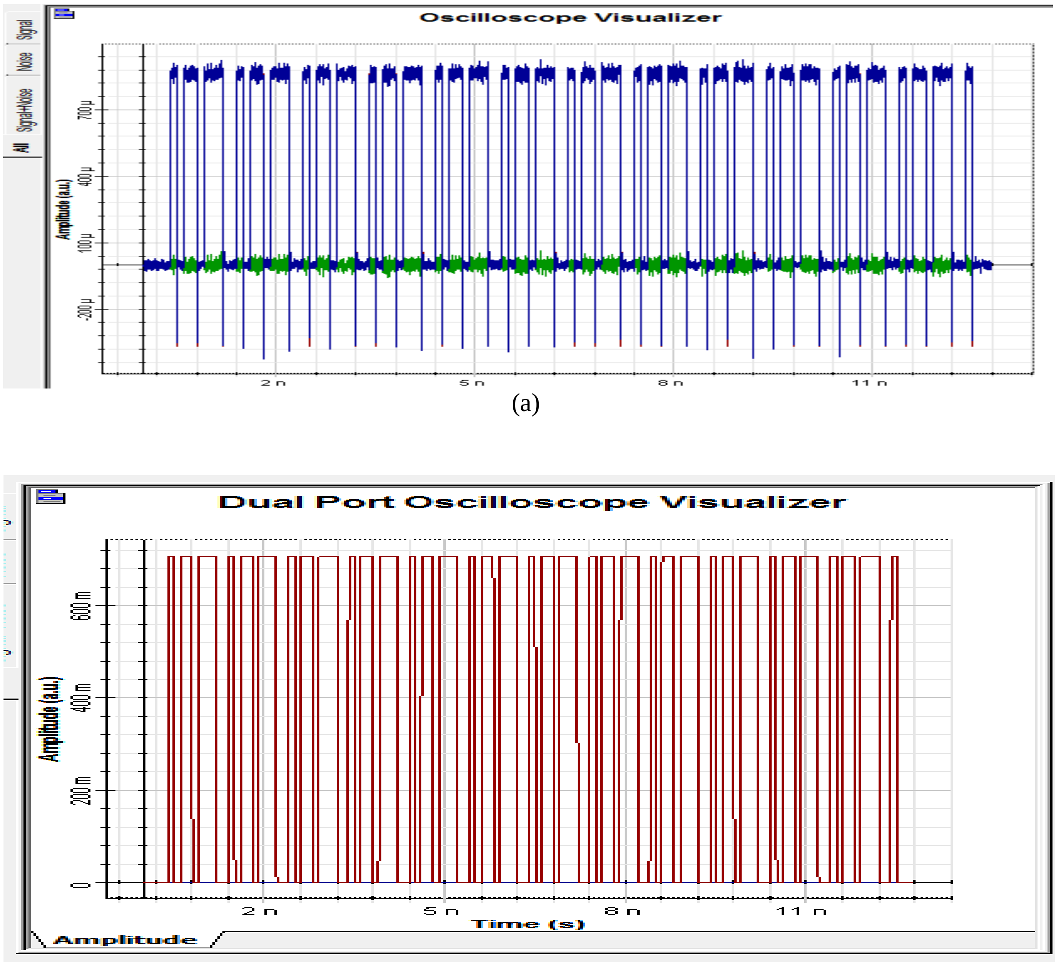
Atmospheric Weather Conditions. Atmosphere is the medium of transmission for a FSO link. Attenuation caused by it depends upon several conditions. Weather conditions are the main cause of attenuation. The region in which a link is being established has some specific weather conditions so that the preceding knowledge of attenuation can be gained; for example, fog and heavy snow are the two primary weather conditions in temperate regions. In tropical regions, heavy rain and haze are two main weather conditions and have major effect on the availability of FSO link in that region.

4. SIMULATION PROCESS

Simulation of LPolSK modulated system

This research paper uses the software Optisystem by Optiwave to establish a 2.5Gbps atmospheric optical communication system model using LPolSK. We have chosen 3 atmospheric conditions these are light haze, fog and *heavy fog.*

The source of the transmitter is a continuous wave laser emitting a 1550 nm beam of light of power 200mW. This beam is then fed to a 450 linear polarizer and then split into its orthogonal components using a polarization beam splitter. A user-defined bit sequence generator operating a bit rate of 2.5Gbps and Non-Return-to-Zero pulse generator are incorporated in the transmitter to provide a steady input binary stream. NRZ pulse generator is set to normalize the values between 1 and 0 for the amplitude modulator. A 1×2 splitter replicates the input stream so that one of the copies can be inverted using a NOT gate. A separate NRZ pulse generator is set to produce a stream of only 1's. It supplements the NOT gate in giving power to the amplitude modulator in the event of NOT gate producing a 1.



(a)

(b)

Fig. 2: (a) Input Electrical Signals (b) Output Signal

Each of the vector components are fed to an amplitude modulator which modulates the power of input optical signal based on the data stream provided to the amplitude modulators as illustrated in Figure-3. Hence, both the modulators are provided with polar opposites of the electrical signal. A polarization beam combiner combines the outputs of the modulators into a single beam of light. Using a polarization analyzer at the output of the transmitter, it can be shown that '1' is represented by horizontal LPolSK and '0' is represented by vertical LPolSK. Hence the binary data is successfully encoded in the polarization states.

The signal received from the FSO channel is passed to a polarization beam splitter. Photodiodes connected to each perpendicular component convert the optical signal into an electrical voltage. The difference in electrical voltage is calculated by an electrical subtractor. If this difference is positive then a binary '1' is inferred, else '0'. An oscilloscope visualizer connected to the output can be used to view the electrical signal received. The Bit Error Rate can be tested using a BER Analyzer as shown in Figure-3.

Performance analysis

Performance of the system is tested through simulation and detailed analysis is conducted on Q-factor and transmission distance with specific attenuation as mentioned in Table -II. Table-I summarizes the input parameters that have been used in the simulation.

Table-I: Parameters used in simulation

Parameters	Transmitted power	Wavelength	Receiver diameter aperture	Transmitter diameter angle	Receiver responsitivity
Values	200 mW	1550 nm	20 cm	2 mrad	1 A/W

Q-Factor: Q-factor is a function of signal to noise ratio. It gives the performance of receiver qualitatively. The Q-factor define the minimum signal to noise ratio require to acquire a specific BER for a given signal.

The Bit Error Rate is the ratio of the number of bits in error to the total number of bits that have arrived in a given time interval. BER is a dimensionless value and can be used as a quantitative measure of the reliability of a communication system.

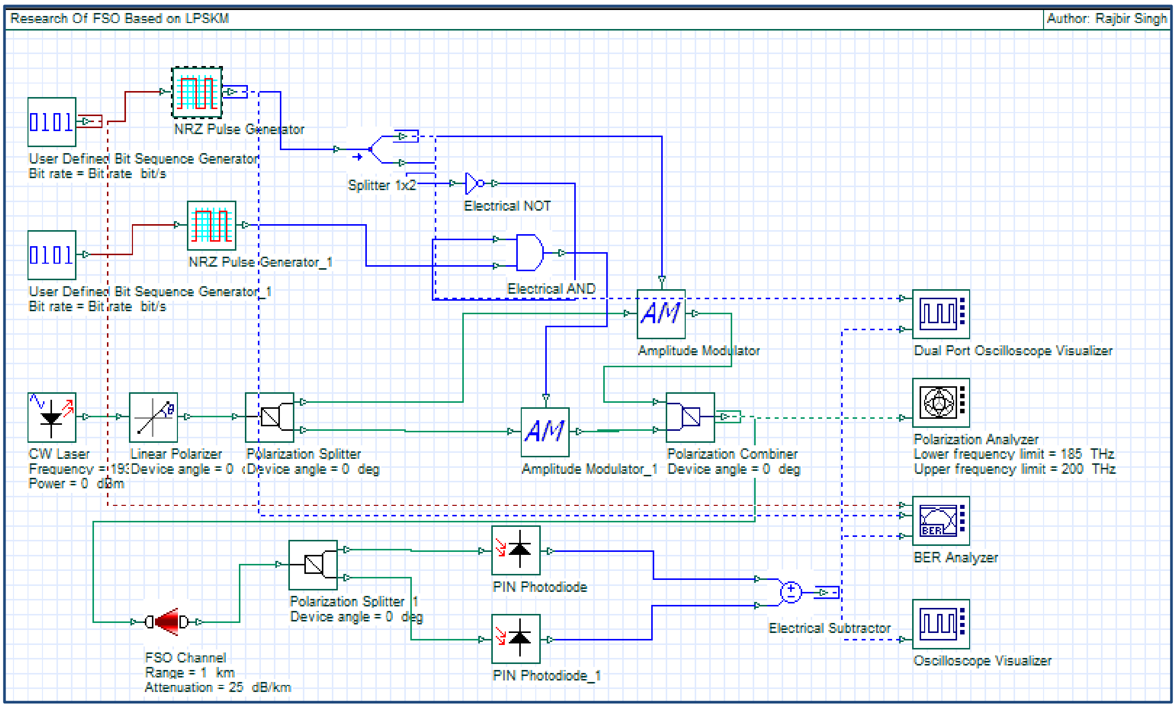


Fig. 3: Simulation layout

The output signal obtained in Figure-2(b) clearly represents the same input signal albeit at a different voltage level due to losses incurred in the channel. Table II gives the variations in Q-factor with propagation distance at attenuation 80, 100 and 120 dB.

Table II: Variation of Q factor with different propagation distance

Range (km)	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.18	0.20
Q-factor for 80dB	1061.02	841.32	526.96	388.23	340.44	185.598	120.080	32.2417	22.0094
Q-factor for 100dB	975.33	662.34	480.56	350.23	310.28	156.56	89.09	26.75	19.2170
Q-factor for 120dB	910.41	510.12	287.31	163.12	92.43	54.8623	31.7312	16.6942	9.60855

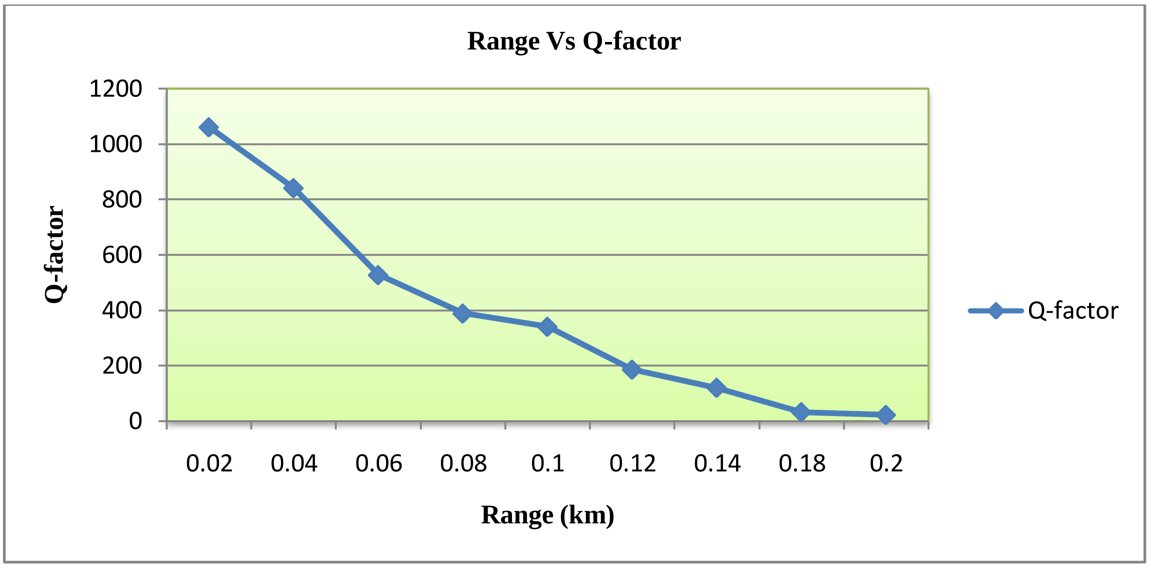


Fig. 4: Variation of Q-factor with range at Attenuation 80 dB

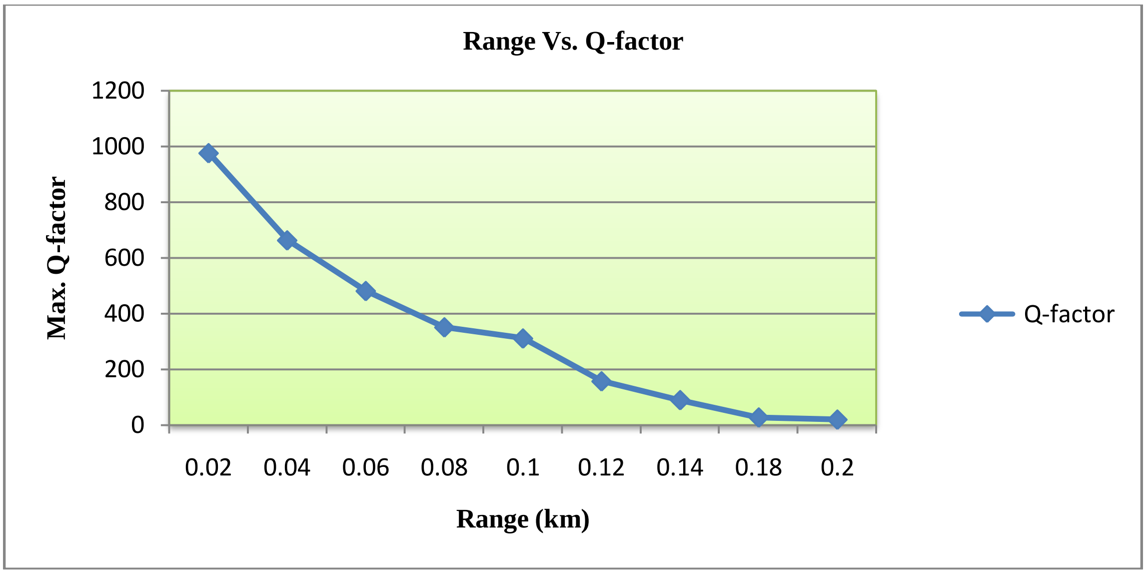


Fig. 5: Variation of Q-factor with range at Attenuation 100 dB

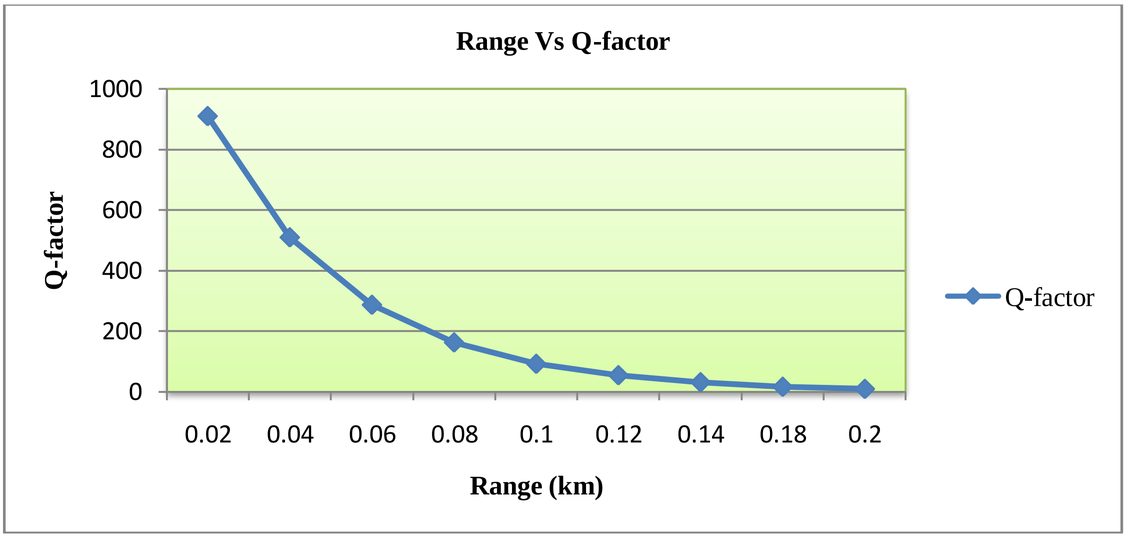


Fig. 6: Variation of Q-factor with range at Attenuation 120 dB

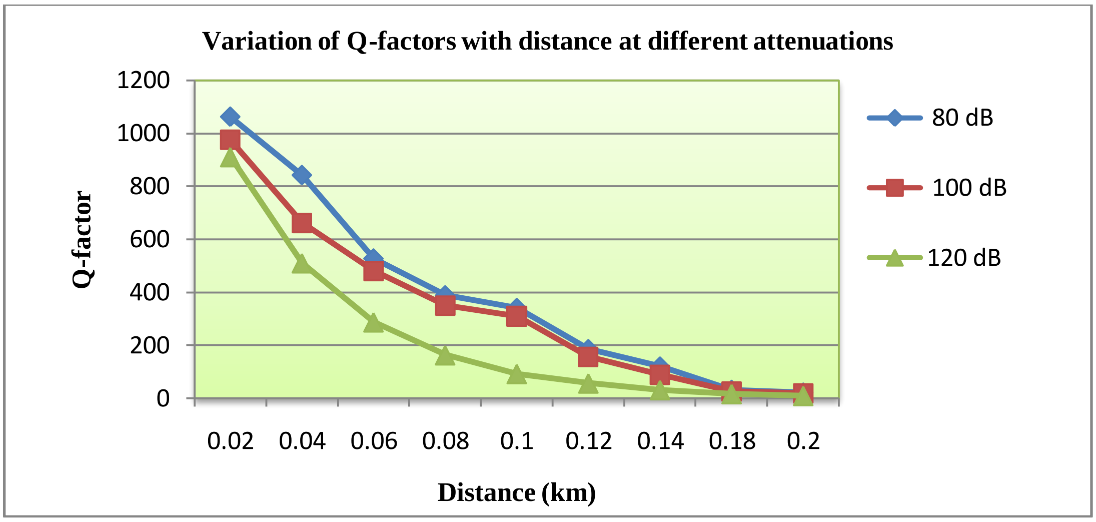


Fig. 7: Variation of Q-factor with range at Attenuation 80, 100 and 120 dB

From table II and Figure 4, 5, 6 and 7 we observed that with increase in communication distance the quality factor decreases. As the attenuation increases with changing atmospheric conditions, the quality factor also decreases. The system works optimally at low haze conditions and in clear atmospheric conditions.

CONCLUSIONS

In this research paper, we have modelled an FSO system using LPolSK method. The performance of the model was investigated by simulation and analysis was carried out for three different atmospheric conditions, namely, light haze, heavy fog and moderate fog. It was observed that the BER value increased and Q factor decreases with increase with the transmission distance. The range of visibility i.e. transmission distance decreased with increase in specific attenuation as modelled in three different scenarios. Light haze condition gave the best transmission distance while heavy fog conditions gave the least range. Hence the system has the potential for practical applications requiring low power consumption and low transmission losses.

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