EFFECT OF OPERATING WAVELENGTHS AND DIFFERENT WEATHER CONDITIONS ON PERFORMANCE OF POINT-TO-POINT FREE SPACE OPTICAL LINK

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ABSTRACT

Free Space Optical (FSO) communication is a very recent and emerging technology to establish broadband wireless data transmission system using modulated optical beams. The adoption of FSO system is mainly needed when any physical connection between the transmitter and receiver is practically impossible and where high bandwidth data transmission is expected. The performance of FSO communication technology is highly dependent on atmospheric attenuation which is related to the visibility of the different weather conditions as well as operating wavelengths. This paper presents our study about the effect of visibility as well as operating wavelengths on atmospheric attenuation in different weather conditions for point-to-point free space optical link. Moreover, it also discusses the methodology to find out the optimum link distance for point-to-point FSO link which will be operated in different weather conditions. It is found that, atmospheric attenuation is changed with the change in weather condition as well as operating wavelengths.

KEYWORDS

Free Space Optical Communications, Link Distance, Atmospheric Attenuation, Visibility, OptiSystem 7.0.

1. INTRODUCTION

Free space optical (FSO) communication is the technology to establish broadband wireless communication system to transmit data using infrared light beam as carrier and free space as communication channel [1, 2]. This is a very recent, exciting and an upgraded means for short distance broadband communication [3-5]. It is generally operated between the 780 – 1600 nm wavelengths bands [4]. This system requires a line of sight, point-to-point link between the transmitter and receiver. The link can be implemented using infrared laser light and infrared data association (IrDA) technology [6, 7]. FSO communication is useful when it is practically impossible to establish any physical connection between the transmitter and receiver and where high bandwidth data transmission is expected [6]. FSO communication is a very effective technology due to its many significant advantages especially there is no need for any physical connection between the transmitter and receiver [3, 4]. It provides wide ranges of services and ensures higher bit rate up to few Gbps. Currently, it is capable of providing services up to 2.5 Gbps of data, voice and video communications [2]. Some other important advantages of this technology are: no need for licensed frequency band allocation, no cost of digging roads, easy to install, absence of radiation hazards of radio frequency, immunity to electromagnetic interference, large bandwidth, low power consumption, low bit error rates, protocol transparent, full duplex operations, no necessary of Fresnel zone [8, 9] etc.

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Recent studies have shown that to achieve an acceptable performance for a practical FSO link, it requires to overcome some major challenges. The challenges are: determination of modulation techniques, suitable light sources, source power, transmitter-receiver alignment and transmitting wavelengths. Moreover, the types of detectors, various sources of noise and error correction techniques are also the factors that should be considered in the installation of practical FSO link [2]. However, the quality of FSO link is strongly dependent on the performance of FSO channel (free space) [6]. There are several challenges facing the channel performance, from which the effect of weather variations on channel is one of them. Moreover, visibility is one of the most important weather factors affecting the channel performance. With the change in weather conditions, visibility changes, which consequently changes the atmospheric attenuation experienced by the FSO channel [5]. The change in operating wavelength is another factor which also affects the atmospheric attenuation of the channel [2]. The change in attenuation changes the link performance [5, 6]. Hence, it is important to consider the effect of visibility for different weather conditions as well as operating wavelength on FSO communication channel before installing any FSO link.

In our study, we considered the effects of different weather conditions on point-to-point FSO link at different visibilities for 850, 1250 and 1550 nm wavelengths of optical signal. In this regard, firstly we found the atmospheric attenuations of free space (FSO channel) for those wavelengths using the standard “Kim Model” with MATLAB simulation in different weather conditions. Secondly, with these attenuations, the communication channel performance is also investigated using the simulation package “OptiSystem 7.0”. In our research it is found that for a particular visibility or atmospheric attenuation, quality of the received signal is changed with the change in link distance and operating wavelengths. The maximum link distances vary with visibilities as well as operating wavelengths. It is also found that, the atmospheric attenuation is changed with the change in visibility and they are inversely proportional to each other [10]. Additionally, atmospheric attenuation changes with the change in operating wavelengths and they are also inversely proportional to each other. However, when the visibility is less than or equal to 0.5 km, it is independent of wavelengths. In clear weather condition with maximum visibility, our proposed FSO link is found to be about 4 km. Considering the practical situation it is obtained that the optimum distance of that link is about 400 m for different weather variations [10].

2. SYSTEM MODEL

Free space optical (FSO) communication requires a line of sight, point-to-point wireless link between the transmitter and receiver [1, 7]. Figure 1 shows the generalized block diagram of a point-to-point FSO link.

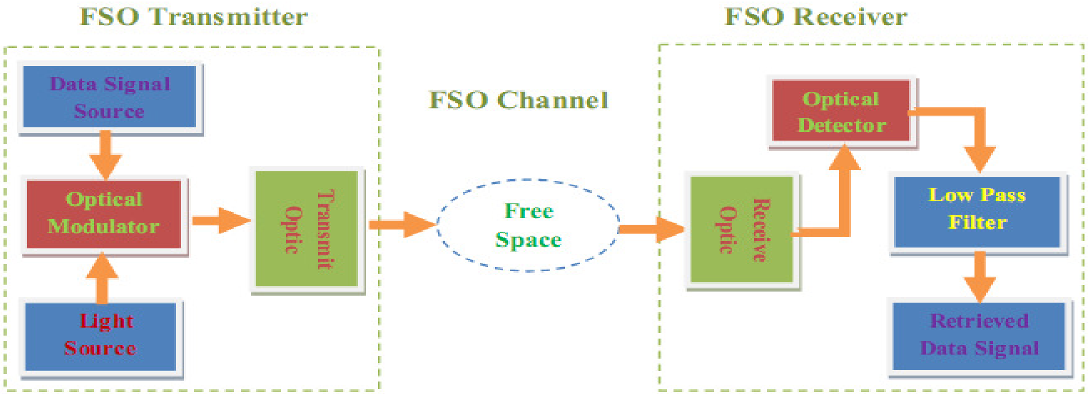


Figure 1. Generalized block diagram of point-to-point FSO link.

In transmitter system, the data signal to be transmitted is modulated with light signal by optical modulator. The modulated signal transmitted by the transmitter optic to the receiver over the free space. In receiver system, the receiver optic received the transmitted signal. This signal is detected and filtered by the optical detector and low pass filter, respectively. Finally, an estimate of the transmitted data signal is obtained. Figure 2 visualizes the schematic representation of a point-to-point FSO link between the transmitter and receiver. The FSO transmitter, located on Building 1 and connected to a local area network (LAN) situated in that building, transmits the optically modulated signal through the free space. The FSO receiver, located on Building 2 and connected also to a LAN situated in that building, receives the transmitted signal.

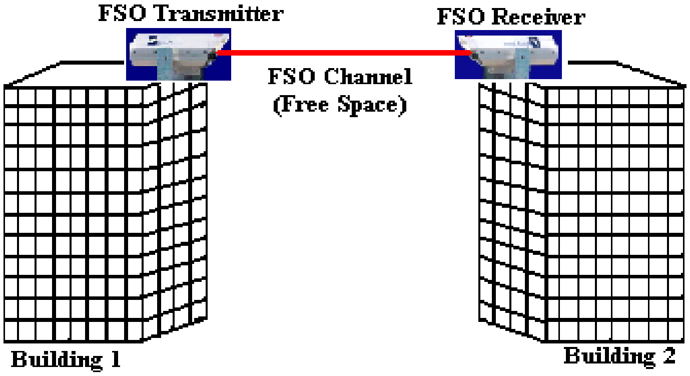


Figure 2. Point-to-Point FSO Link between the two Buildings.

3. MATHEMATICAL MODEL

The performance of point-to-point free space optical (FSO) link is strongly dependent on the atmospheric attenuation experienced by the FSO channel. At the same time, atmospheric attenuation is influenced by the weather visibility and link distance [4]. This attenuation can be modelled mathematically for different weather conditions [9]. According to the Beers-Lambert law, the relationship between the transmitted signal power (P_T) and the received signal power (P_R), in the presence of atmospheric attenuation, can be represented by the following exponential relation [2, 9]:

$$P_R = P_T \exp(-\sigma Z) \tag{1}$$

Where, Z is the link distance (distance between the transmitter and receiver) of point-to-point FSO link in km and σ is the atmospheric attenuation coefficient given by the following equation:

$$\sigma = \frac{3.91}{V}\left(\frac{\lambda_{nm}}{550}\right)^{-q} \tag{2}$$

Where, V is the visibility (maximum distance at which an object or light can be clearly discerned) in km, λ_{nm} is the transmission wavelength in nm. The parameter q refers to the size distribution of the scattering particles, and according to the standard “Kim Model” [2] q is given by:

$$q = \begin{cases} 1.6 & \text{if } V > 50 \text{ km} \\ 1.3 & \text{if } 6 \text{ km} < V < 50 \text{ km} \\ 0.16V + 0.34 & \text{if } 1 \text{ km} < V < 6 \text{ km} \\ V - 0.5 & \text{if } 0.5 \text{ km} < V < 1 \text{ km} \\ 0 & \text{if } V < 0.5 \text{ km} \end{cases} \tag{3}$$

Where, 6 km<V<50 km, 1 km<V<6 km and 0 km<V<1 km specify the visibility ranges for clear, hazy and foggy weather conditions, respectively [2, 9]. Additionally, the foggy weather condition can be divided as dense, thick, moderate and light foggy with visibility ranges of 0 km<V<0.05 km,0.05 km<V<0.2 km, 0.2 km<V<0.5 km, and 0.5 km<V<1 km, respectively [9]. According to the definition of attenuation and from Eq.1, total atmospheric attenuation throughout the free space path can be represented in dB [11], as follows:

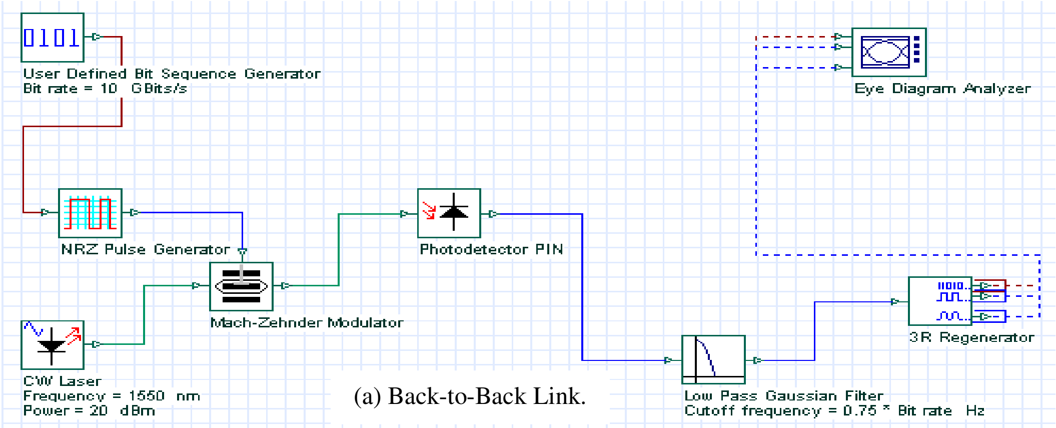
$$\begin{aligned}\alpha_{dB} &= 10\log\left(\frac{P_T}{P_R}\right)\\ &= 10\log\left(\frac{1}{\exp(-\sigma Z)}\right)\\ &= 10\log(\exp(\sigma Z)) \qquad (4)\end{aligned}$$

Hence, the atmospheric attenuation in (dB/km) can be given by as follows:

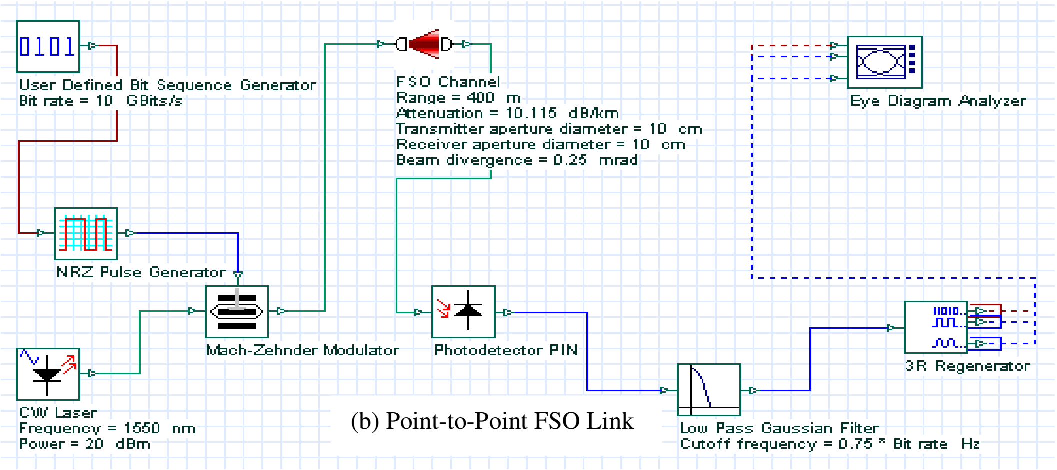
$$\begin{aligned}\alpha_{dB/km} &= \alpha_{dB}/Z\\ &= [10\log(\exp(\sigma Z))]/Z \qquad (5)\end{aligned}$$

4. SIMULATION MODEL

The simulation setup for proposed point-to-point free space optical (FSO) link using optical communication system design simulation package OptiSystem 7.0 is visualized in Figure 3.



(a) Back-to-Back Link.



(b) Point-to-Point FSO Link

Figure 3. Simulation Model for Back-to-Back and Point-to-Point FSO Link using OptiSystem.

The link parameters with their symbols and corresponding values are presented in table-1.

Table 1.FSO link parameters

Parameter	**Symbol**	**Value**
Transmission Rate	Bit Rate	10 Gbps
Link Distance	Z	Up to 5 km
CW Laser Power	P_T	20 dBm
Transmission Wavelength	λ_{nm}	850, 1250 and 1550 nm
Transmitter's Apertures	D_T	10 cm
Receiver's Aperture	D_R	10 cm
Beam Divergence	θ_{BD}	0.25 mrad
Attenuation	α	Up to 339.6183 dB/km

5. RESULTS AND DISCUSSIONS

The simulation results will be discussed into four sections. They are the, maximum link distance measurement at different visibilities with wavelength dependency, effect of visibility and wavelength on atmospheric attenuation of free space optical (FSO) channel, effect of visibility and wavelength on received signal quality, optimum link distance measurement for point-to-point FSO link. All the measurements for atmospheric attenuation are done using MATLAB 7.5. All the Q-factors and eye patterns are measured using OptiSystem 7.0.

5.1. MAXIMUM LINK DISTANCE MEASUREMENT

From equation 3, it is seen that for three weather conditions of clear, hazy and foggy, the maximum visibilities are 50 km, 6km and 1 km respectively. Hence, in this section, observation is done with these respective maximum visibilities at different link distances with different operating wavelengths. The Quality factor called Q-factor of received signal specifies the quality of the received signal. Figure 4 presents the graph of received signal Q-factor vs. link distance of point-to-point FSO link for 850, 1250 and 1550 nm wavelengths, respectively with maximum visibility (50 km) at clear weather condition.

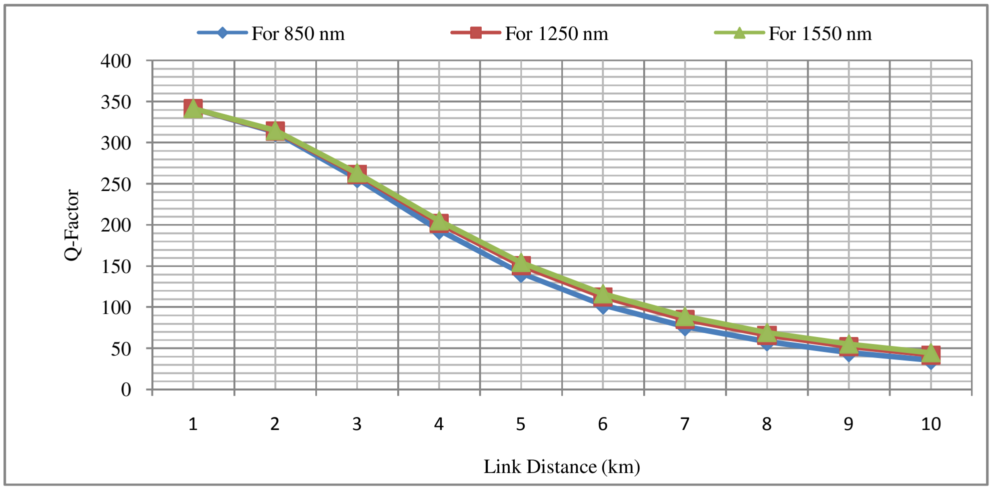
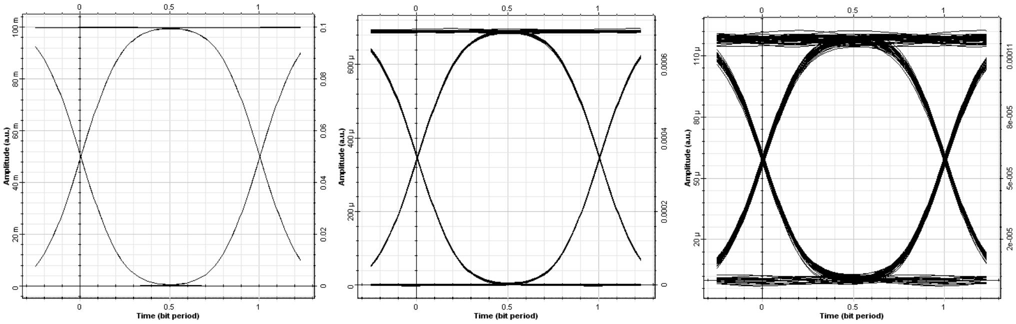


Figure 4. Received signal Q-Factor vs. Link distance at 50 km Visibility for 850, 1250 and 1550 nm wavelengths, respectively.

From Fig.4, it is observed that for each wavelength, quality of received signal decreases with the increase in link distance and vice-versa. Figure 5 showed the eye patterns for back-to-back and received signals at 4 and 5 km link distances, respectively for operating wavelength of 850 nm.



(a) For back-to-back link (b) For 4 km link (c) For 5 km link

Figure 5. Eye patterns for back-to-back and received signals for link distances of 4 and 5 km, respectively at clear weather condition.

It is observed from Fig. 5 that for 4 km link distance, an acceptable quality of received signal (Q-factor: 200) with almost same eye pattern and eye opening compared to that of the back-to-back one is obtained. However, a significant degradation in the received signal quality (Q-factor: 150) with noisy eye pattern is obtained when the link distance is 5 km. Similarly, for 1250 and 1550 nm wavelengths, a satisfied quality of received signal is obtained for 4 km link distance and a significant degradation is obtained at 5 km link distance. From the quality factor perspective, it is observed that whenever, the value of Q-factor goes below 200, significant degradation of the received signal is obtained. Hence, in this study, the value of 200 for Q-factor of received signal can be taken as the Q-factor margin, above which link performance is satisfactory and below which received signal quality is degraded significantly. Based on the above discussion, for all the respective wavelengths, received signal quality is degraded rapidly, when link distance exceeds 4 km at clear weather condition. Hence, at clear weather condition for all the respective wavelengths, the maximum link distance should not exceed 4 km. Additionally, it is observed from Fig. 4 that operating wavelength of 1550 nm showed better performance than other wavelengths. Figure 6 presents the graph of Q-factor vs. link distance for received signal of point-to-point FSO link for 850, 1250 and 1550 nm wavelengths, respectively with maximum visibility (6 km) at hazy weather condition.

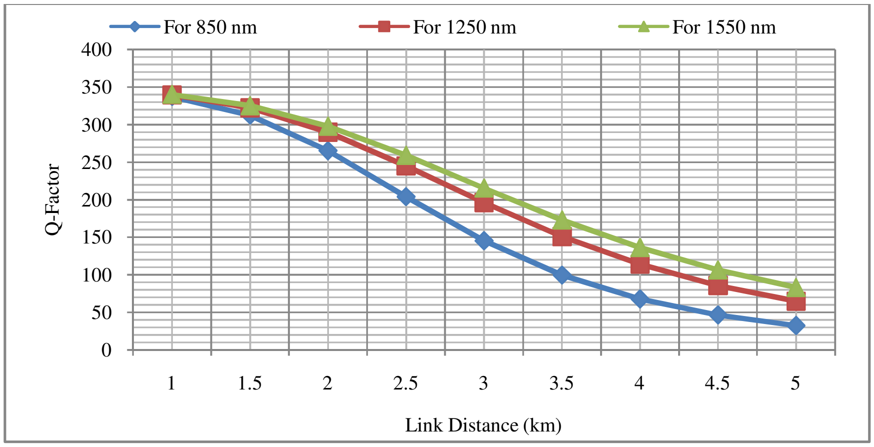
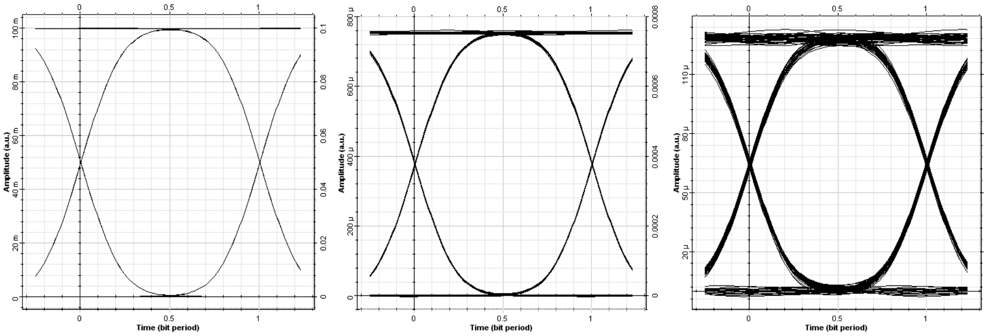


Figure 6. Q-Factor vs. Link distance at 6 km Visibility for wavelengths of 850, 1250 and 1550 nm, respectively.

From Fig. 6, it is observed that for each wavelength, quality of received signal decreases with the increase in link distance and vice-versa. Figure 7 shows the eye patterns for back-to-back and received signals at 2.5 km and 3 km link distances, respectively for 850 nm operating wavelength.



(a) For back-to-back link (b) For 2.5 km link (c) For 3 km link

Figure 7. Eye patterns for back-to-back and received signals for link distances of 2.5 and 3 km, respectively at hazy weather condition.

It is observed from Fig. 7 that, for 2.5 km link distance, an acceptable quality of received signal (Q-factor: 200) with almost same eye pattern and eye opening compared to that of the back-to-back one is obtained. However, a significant degradation in the received signal quality (Q-factor: 150) with noisy eye pattern is obtained when link distance of 3 km. Similarly, for 1250 and 1550 nm wavelengths, satisfied quality of received signals (Q-factor: 210) are obtained for 3 km link distance and a significant degradation (Q-factor: 155) is obtained at 3.5 km link distance. Based on the above discussion, at hazy weather condition, received signal quality is degraded rapidly, when link distance exceeds 2.5 km for 850 nm and 3 km for 1250 and 1550 nm wavelengths, respectively. Considering all the wavelengths, link distance should not exceed 2.5 km. At this maximum visibility of 6 km, operating wavelength of 1550 nm again showed better performance compared to other wavelengths. Figure 8 presents the graph of Q-factor vs. link distance for received signal of point-to-point FSO link for 850, 1250 and 1550 nm wavelengths, respectively with maximum visibility (1 km) at foggy weather condition.

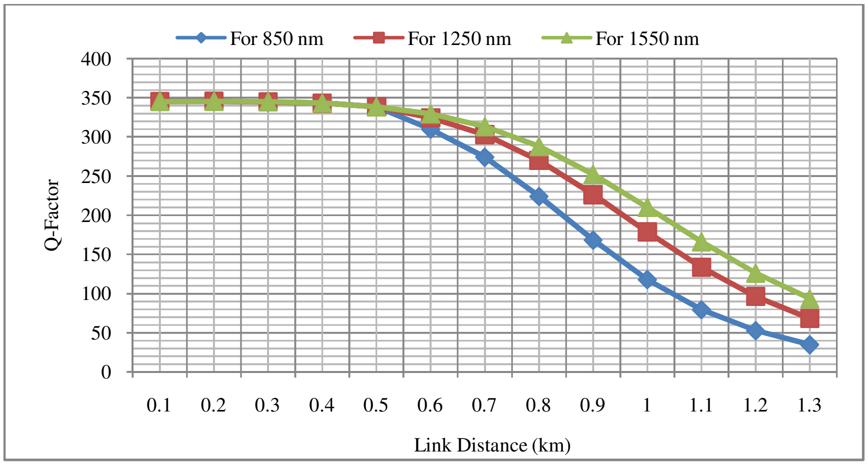
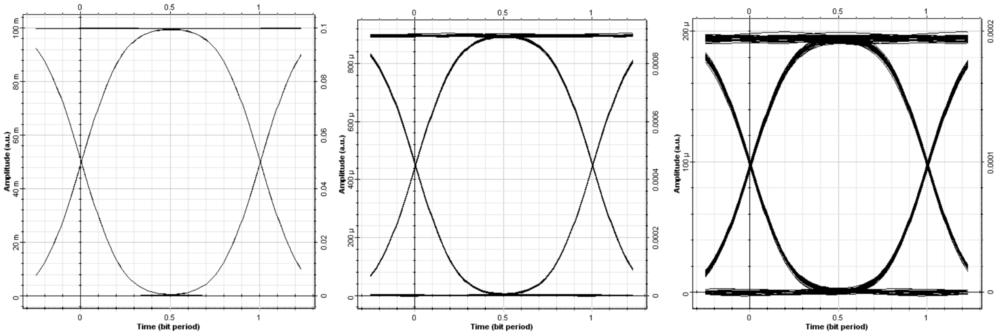


Figure 8. Q-Factor vs. Link distance at 1 km Visibility for wavelengths of 850, 1250 and 1550 nm, respectively.

Figure 9 shows the eye patterns for back-to-back and received signals at 0.8 km and 0.9 km link distances, respectively for operating wavelength of 850 nm.



(a) For back-to-back link (b) For 0.8 km link (c) For 0.9 km link

Figure 9. Eye patterns for back-to-back and received signals for link distances of 0.8 and 0.9 km, respectively at foggy weather condition

It is observed from Fig. 9 that for 0.8 km link distance, an acceptable quality of received signal (Q-factor: 225) with almost same eye pattern and eye opening compared to that of the back-to-back one is obtained. However, a significant degradation in the received signal quality (Q-factor: 160) with noisy eye pattern is obtained when link distance is 0.9 km. Similarly, for 1250 and 1550 nm wavelengths, a satisfied quality of received signals (Q-factor: 225 and 200 respectively) are obtained for 0.9, 1 km link distances and significant degradation in the received signal quality (Q-factor: 165 and 150 respectively) are obtained for 1 and 1.1 km link distances respectively. Hence, the maximum link distance, we can possibly have at foggy weather condition with maximum visibility of 1 km, is about 0.8 km for 850 nm, 0.9 km for 1250 nm and 1km for 1550 nm, respectively and above which link performance will be degraded rapidly. Considering all the wavelengths at this visibility, link distance should not exceed 0.8 km for satisfactory operation. Moreover, from Fig. 8, it is seen that the decrease in quality occurs more rapidly for 850 nm wavelength compared to that of the 1250 and 1550 nm wavelengths. Again, operating wavelength of 1550 nm showed better performance.

5.2. EFFECT OF VISIBILITY AND WAVELENGTH ON ATTENUATION OF FSO CHANNEL

From Fig. 8, it is observed that when link distance is less than 0.5 km, received signal quality is almost same for all the three wavelengths. Hence, in this section keeping the link distance fixed at 0.5 km, observations are taken with different visibilities and wavelengths. Table 2 presents the values of atmospheric attenuation experienced by the FSO channel with change in visibility for 850, 1250 and 1550 nm wavelengths, respectively in different weather conditions. These values are obtained by MATLAB simulation based on the mathematical model presented at section 3.

Table 2. Atmospheric Attenuation for Different Wavelengths and Visibilities in Different Weather Conditions

Weather	Visibility (km)	Attenuation (dB/km)		
		For 850 nm	For 1250 nm	For 1550 nm
Foggy	0.1	169.8091	169.8091	169.8091
	0.5	33.9618	33.9618	33.9618
	0.7	22.2357	20.5851	19.7183
Hazy	2	6.3702	4.9387	4.2850
	3	3.9611	2.8872	2.4203
	4	2.7709	1.8988	1.5379
Clear	10	0.9642	0.5840	0.4416
	20	0.4821	0.2920	0.2208
	40	0.2411	0.1460	0.1104

From above table, it is seen that for all the considered wavelengths, atmospheric attenuation is high at foggy, moderate at hazy and low at clear weather condition, respectively. The overall summary for the effect of visibility as well as wavelength on attenuation is visualized in Fig. 10.

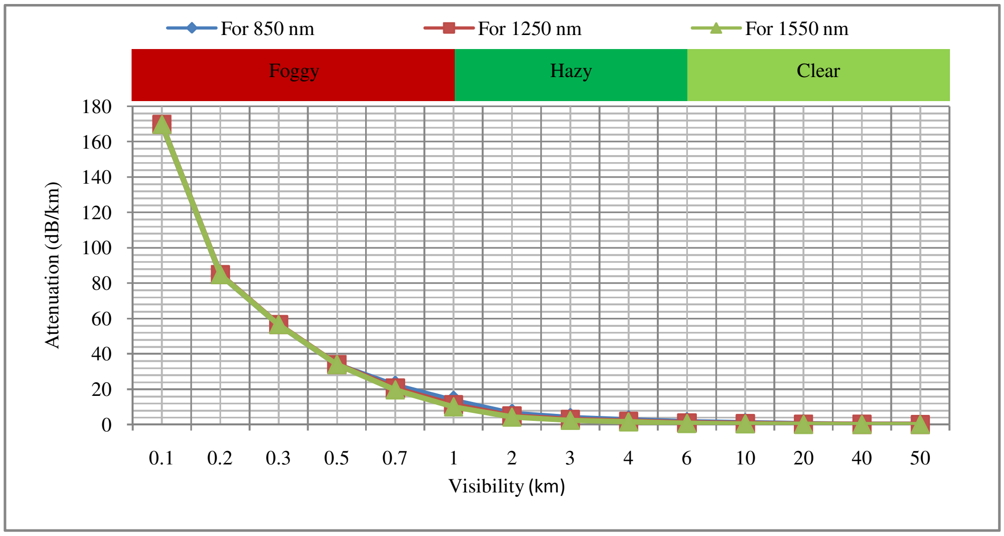


Figure 10. Atmospheric attenuation vs. visibility for 850, 1250 and 1550 nm wavelengths in different weather conditions.

It is seen that the attenuation decreases with the increase in visibility for all the respective wavelengths as well as weather conditions. The decrease in attenuation due to the change in visibility is very sharp in foggy, medium in haze and very low in clear weather conditions, respectively. Hence, for each wavelength in all weather conditions the attenuation is a decreasing function of visibility and they are inversely proportional to each other. Moreover, it is seen from table-2 that the attenuation is wavelength independent when visibility is less than or equal to 0.5 km and after that for a particular visibility, attenuation decreases with the increase in wavelengths. Hence, operating wavelength of 1550 nm performed better compared to other wavelengths.

5.3. EFFECT OF VISIBILITY AND WAVELENGTH ON RECEIVED SIGNAL QUALITY

Figure 11 shows the graph of received signal Q-factor vs. visibility for point-to-point FSO link with a fixed link distance of 0.5 km for 850, 1250 and 1550 nm wavelengths, respectively in three different weather conditions.

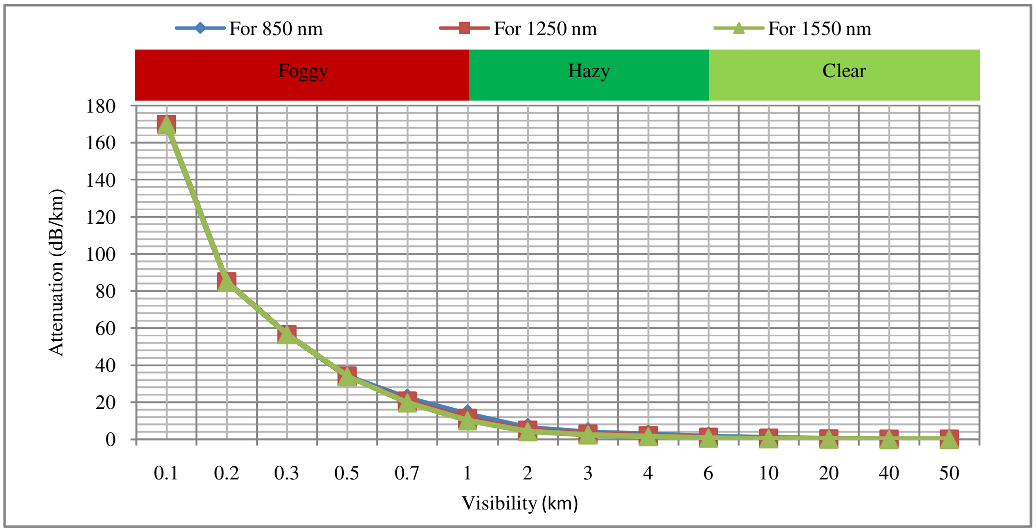


Figure 11. Received signal Q-factor vs. visibility with 0.5 link distance for 850, 1250 and 1550 nm wavelengths in different weather conditions.

It is observed from Fig. 11 that with the increase in visibility received signal quality increases rapidly at foggy and slowly at hazy and is almost flat at clear weather condition, respectively for all the respective wavelengths. Hence, the performance of FSO link is the best at clear, moderate at hazy and the worst at foggy weather condition, respectively. However, the received signal quality is independent of wavelength when visibility is smaller than or equals to 0.5 km and with higher visibilities, higher the value of wavelength better the quality of received signal. Hence, again operating wavelength of 1550 nm showed better performance than other two wavelengths.

5.3. OPTIMUM LINK DISTANCE MEASUREMENT

According to the discussion of subsection 5.1, the link distance can never exceed 800 m and this is also the maximum operating distance at foggy weather condition considering all wavelengths. Hence, the optimum link distance must be smaller than or equal to 800 m and determination of this distance at foggy weather condition is enough to satisfy the link distance optimization in remaining weather conditions. Additionally, any visibility falling in the range of 0 to 0.05 km, 0.05 to 0.2 km, or 0.2 to 0.5 km specifies dense, thick, or moderate foggy weather condition, respectively. However, from a number of surveys and practical observations it is observed that, these types of heavy foggy weather conditions are very rare. Hence, visibility stays in the range of 0.5 to 1 km at foggy weather condition usually. Since, 0.5 km is the minimum visibility in that range and received signal quality is wavelength independent till to this visibility, finding out the maximum possible distance for proposed FSO link at that visibility would be the optimum link distance for which link will be operated properly under different weather conditions and wavelengths. In Figure 12, the effect of link distance variations against Q-factor for received signal of proposed point-to-point FSO link at 0.5 km visibility at foggy weather condition is given. Operating wavelength of 1550 nm is considered in this case as it showed better performance.

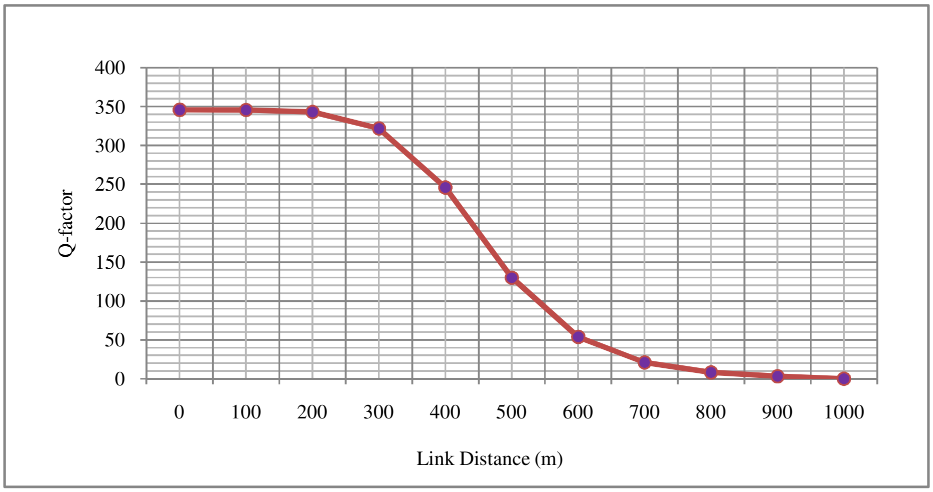
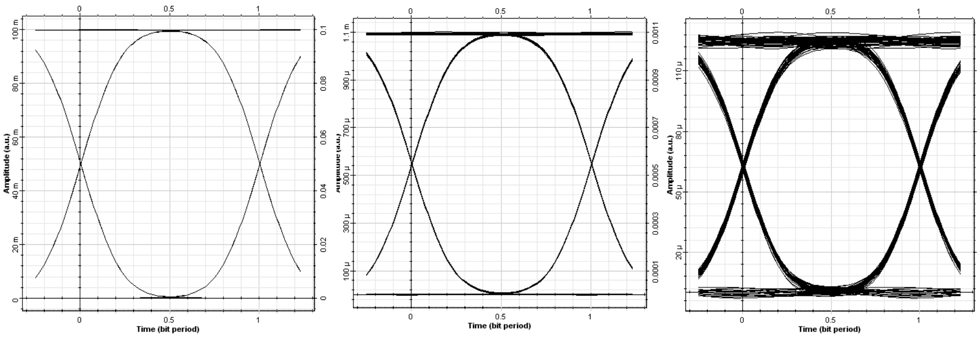


Figure 12. Q-factor of received signals for different link distances at 0.5 km visibility.

From Fig.12, it is observed that, the quality of the received signals decrease with the increase in link distance and vise-versa. With the increase in link distance up to 400 m, received signal quality is satisfactory (Q-factor: 240). When link distance is increased from 400 m, signal quality is degraded rapidly. Figure 13 shows the eye patterns for back-to-back and received signals of proposed FSO link at 0.5 km visibility for 400 and 500 m link distances, respectively.



(a) For back-to-back link (b) For 400 m link distance (c) For 500 m link distance

Figure 13. Eye patterns for back-to-back and received signals at 0.5 km visibility.

It is observed from Fig. 13 that, eye pattern for received signal of 400 m link distance is almost same as that of the back-to-back one. But, in case of 500 m link distance, the eye pattern is noisy compared to that of the back-to-back one with smaller eye opening. Therefore, for 400 m link distance with visibility greater than or equal to 0.5 km, link can work properly. Hence, the optimum link distance of the proposed point-to-point FSO link is 400 m under different weather variations.

6. CONCLUSIONS

With the change in operating optical wavelength, weather visibility and link distance, the performance of proposed point-to-point free space optical (FSO) link changes. The performance of FSO link is almost independent of wavelength in clear weather condition, somewhat dependent in hazy and foggy weather conditions. The maximum link distance varies with variations in weather visibility as well as operating wavelengths. Considering all three weather conditions, operating wavelength of 1550 nm showed better performance regarding maximum link distances at different visibilities. The performance of point-to-point FSO link is strongly dependent on the atmospheric attenuation which is influenced by weather conditions as well as operating optical wavelength. Attenuation decreases with the increase in visibility and it is low at clear, moderate at hazy and high at foggy weather condition, respectively. However, Attenuation is independent of wavelength when the visibility is less than or equal to 0.5 km and after that with respective visibilities it decreases with the increase in wavelength. The optimum link distance, which will be operated in different weather conditions, is found to be about 400 m. Our idea on the proposed FSO link and findings from this research will have great potential on future research work in the field of FSO communications.

REFERENCES

[1] Arash Komaee, P. S. Krishnaprasad, and Prakash Narayan "Active Pointing Control for Short Range Optical Communication", Communications in Information and Systems, Vol. 7, No. 2, pp. 177-194, 2007.

[2] Nazmi A. Mohammed, Amr S. El-Wakeel and Mostafa H. Aly, "Performance Evaluation of FSO Link Under NRZ-RZ Line Codes, Different Weather Conditions and Receiver Types in the Presence of Pointing Errors", The Open Electrical & Electronic Engineering Journal, Vol. 6, pp. 28-35, 2012.

[3] Ha D. Trung, Nonmember and Anh T. Pham, "Performance Analysis of MIMO/FSO Systems Using SC-QAM Signaling over Atmospheric Turbulence Channels", pp. 1-8, Presented in Part at IEEE ICC 2013.

[4] Abdulsalam Ghalib, Alkholidi and Khaleel Saeed Altowij, "Contemporary Issues in Wireless Communications" ISBN 978-953-51-1732-2, November 26, 2014.

[5] Alexander Vavoulas, Harilaos G. Sandalidis, and Dimitris Varoutas, "Weather Effects on FSO Network Connectivity", J. Opt. Commun. Netw. Vol. 4, No. 10, pp. 734-740, October 2012.

[6] Ahmed Nabih Zaki Rashed, Mohamed S. F. Tabbour, "Free Space Optics and Submarine Laser Communication Systems for Egyptian Climate Weather in the Presence of Atmospheric Turbulence", International Journal of Research in Electronics and Communication Technology, Vol. 1, No. 1, pp. 34-40, Jan-March 2014.

[7] Shalini Khare, Namrata Sahayam, "Analysis of Free Space For Different Atmospheric Conditions & Modulation Techniques", International Journal of Modern Engineering Research, Vol.2, No. 6, pp 4149-4152, ISSN: 2249-6645, November-December 2012.

[8] Dr. Ali Mahdi Hammadi, Dr. Entidhar Mhawes Zghair, "Transmission Performance Analysis of three Different Channels in Optical Communication Systems", International Journal of Scientific & Engineering Research, Vol. 5, No. 2, pp. 1615-1618, ISSN 2229-5518, February 2014.

[9] Nazmi A. Mohammed, Amr S. El-Wakeel and Mostafa H. Aly, "Pointing Error in FSO Link under Different Weather Conditions", International Journal of Video & Image Processing and Network Security, Vol. 12, No. 01, pp. 6-9.

[10] M. Nur islam, M. Nur-Al-Safa Bhuyan, "Performance Analysis and Investigation of Optimum Link Distance for Point-to-Point Free Space Optical Link in Different Weather Conditions", International Conference on Electrical Engineering and Information & Communication Technology, Page(s). 1-8, INSPEC Accession Number: 15570474, 21-23 May 2015.

[11] John M. Senior, "Optical Fiber Communications Princples and Practice", pp. 82-89., ISBN: 978-0-13-032681-2

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