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Performance analysis of terrestrial WDM-FSO Link under Different Weather Channel

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ABSTRACT

In this paper, the performance of WDM-FSO communications system is simulation analyzed, using NRZ modulation technique over different weather conditions. Based on this technique the received signal power, signal to noise ratio, Q. factor, and BER are analyzed. The characteristics of WDM was studied for free space optical communication. Simulation results indicate that the performance of WDM-FSO are more suited for strong attenuation. On the other hand, the suitability of distance link under this technique are studied, where WDM has more advantage when used in optical communication system.

***Keywords*:** WDM; FSO; optical communication; non return to zero; weather attenuation

1. INTRODUCTION

Free space optical communication (FSOC) is a technology that uses light propagating in free space optics (FSO) to transmit data between points to another [1]. FSO has similar working with fiber optic communication, the difference being the use of the atmosphere instead of optical fiber as a channel [2]. FSO technology is developed to deliver high capacity links similar to optical fiber technology but in unguided medium [3]. Comparing with (RF) system, (FSO) features are huge bandwidth, no requirement for spectrum licensing, inherent security, low cost implementations and maintenance, and free from electromagnetic interference [4]. These features offer a crucial solution for the wireless access in the recent presence of (RF) spectrum's scarcity [5].

The major challenges in (FSO) technology is fog. It is considered as a important condition that has high attenuation reaching to 480 dB/km cause reduce the visibility to few meters in worst cases [6-9]. There are different models proposed and developed to predict the effect of fog on FSO link [8,10-12]. These models were derived based on measured that were carried out under fog weather, these measurement collected from different location and applied different wavelength. There are a different works studied reported in the literatures on the impact of fog on (FSO). Most of the works based on theoretical [13,14], simulation [1,2], and experimental [15,16]. In this paper, a simulation analyzes the performance of (FSO) communication system over different weather condition. NRZ-OOK is used for modulation technique, PIN photodiode are employed as a detector in the receiver side. We discuss the impact of some metrics on FSO link such as: received signal power, signal to noise ratio S/N, Q. Factor and Bit Error Rate.

2. THEORETICAL CONSIDERATIONS

In free space optics, the link equation model is [17]:

$$P_R = P_T \cdot \frac{d_R^2}{\left(d_T + \vartheta . R\right)^2} .10^{-\alpha R/10}$$

where d_R is defines the receiver aperture diameter (m), d_T is the transmitter aperture diameter (m), θ is the beam divergence (mrad), R is the range (km) and α is the attenuation coefficient.

Attenuation coefficient based on empirical measurement data was calculated by the following empirical model [18]

$$\alpha(\lambda) = \frac{3.91}{V}\left(\frac{\lambda}{550}\right)^{-\delta}$$

where V is the visibility in (km), λ represent the wavelength in (nm). The parameter δ depends on the visibility distance range, according to Kruse model δ is given as [10]

$$\delta = \begin{cases} 1.6, \ if \ V \succ 50km \\ 1.3, if \ \ 6km \succ V \succ 50km \\ 0.58V^{1/3}, if \ \ V \prec 6km \end{cases}$$

Kim model is wavelength independent for low visibility in dense fog. The value of δ for kim model is given as [7]

$$\delta = \begin{cases} 1.6, \ if \ V \succ 50km \\ 1.3, if \ \ 6km \succ V \succ 50km \\ 0.16V + 0.34, \ \ if \ \ 1km \prec V \prec 6km \\ V - 0.5, if \quad 0.5km \prec V \prec 1km \\ 0, \ if \ \ V \prec 0.5km \end{cases}$$

Al-Naboulsi proposed expressions to predict the wavelength dependent fog attenuation coefficient for the convection and advection fogs for wavelengths from 690 to 1550 nm [11]. The attenuation coefficient for convection fog is given by

$$\alpha_{convection}(\lambda) = \frac{0.11478\lambda + 3.8367}{V}$$

The attenuation coefficient for advection fog is given by:

$$\alpha_{radiation}(\lambda) = \frac{0.18126\lambda^2 + 0.13709\lambda + 3.7502}{V}$$

The specific attenuation coefficient for both types of fog is given by

$$\alpha_{spec}(\lambda) = \frac{10}{\ln(10)}\alpha(\lambda)$$

3. SYSTEM DESIGN

Free space optical communication (FSOC) under different weather channel design has modeled and simulated for performance characterization by using opt system 7. The main components of the optical link are shown in Fig. 1. This figure shows the basic devices that have been in this study. A pseudo-random bit sequence (PRBS) is generator. This subsystem is to represent the information or date that want to be transmitted. The second subsystem is NRZ electrical pulse generator. The third subsystem is 8 CW array laser is the main source, and a mach-zehnder modulator (MZM) is used to modulated data, multiplexing (WDM), and demultiplexing (DeMUX) systems can be optimized to achieve a maximum link range. The transmitter optical signal is the transmitted over FSO link which has different weather attenuation. An Optical amplifier (EDFA) is used to amplification signals. This amplifier specially suited in a long-haul system. The optical signal is then received by the receiver, which is a PIN photodiode and is followed by low pass Bessel filter, with cut-off frequency 0.75 bit rate. The final stage is using regenerate electrical signal of the original bit sequence and the modulated electrical signal as in the optical transmitter to be used for BER tester. Some of measurements tools such as, BER analyzer, electrical power meter, Q. Factor, signal to noise ratio S/N are used as well. The system design parameters in the representative characteristic are illustrated in Table (1).

4. SIMULATION RESULTS

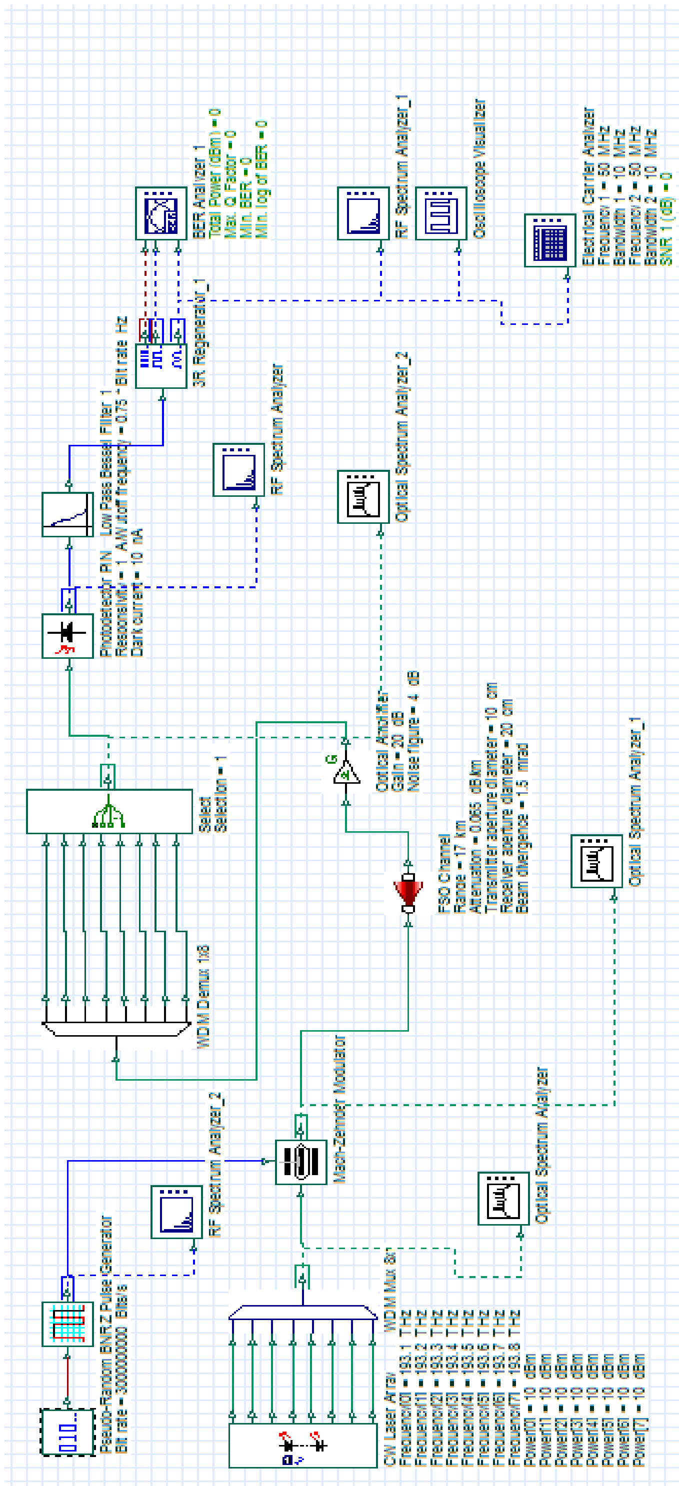


Figure 1. Optical link design

This part presents simulated results for analyzing the performance of (FSO) communication under weather channel. A comparative study has been carried out for (FSO) communication at different attenuation coefficient. The signal optimization is achieved successfully to handle the condition on weather conditions, with certain parameters change. Table (1) shows the parameter's optimization, this system is running at maximum link. The performance analysis of the system under heavy rain, medium rain, light rain, heavy haze, light haze, clear sky and very clear conditions are shown in Table (2). It can be noticed that under optimized conditions of laser power and data rate, the increase in the attenuation causes reduce in the maximum transmission link with acceptable BER and Q. factor values. It can be seen that for very clear weather condition the maximum link can be carried out up to 17 km while it get reduced to 1.2 km for heavy rain condition. The eye opening and BER for the very clear, heavy haze, light rain and heavy rain are seen in Fig. (2).

It is meaningful to study achievable distance of optical beam under different weather conditions. It is observed in Fig (3,4) the received signal power reached to 13.4 km and 2.37 km for clear and heavy haze respectively. The transmission distance is limited to 1.2 km and 2.6 km for heavy rain and light rain respectively.

Fig. (5, 6) shows The SNR for different weather climate. The SNR decreasing with increasing distance link. It is achieved that for very clear sky has presented the highest SNR compared with the other weather conditions under the same operating conditions. SNR was carried out at the maximum link distance, when the heavy rain is applied, SNR reached to 31.375 dB at link 1.2 km, but for light haze SNR limited to 30.352 dB at link 10.1 km.

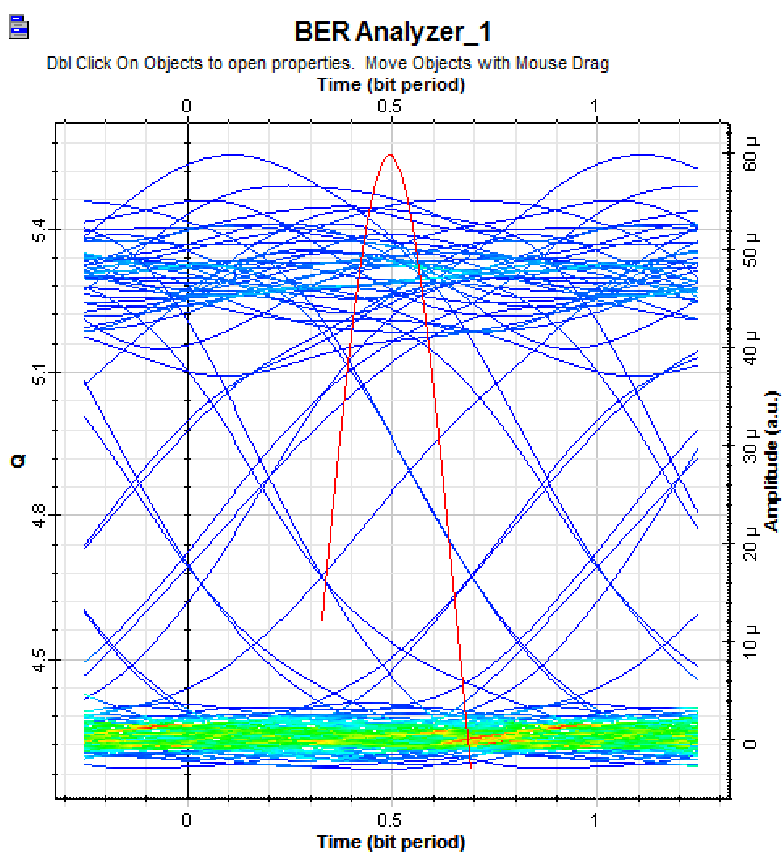
Table 1. Data parameters

parameter	value
Bit rate	3 Gbps
power	10 dBm
Cw array laser frequency	193.1-193.8 THz
Transmitter aperture diameter	10 cm
Receive aperture diameter	20 cm
Beam divergence	1.5 mrad
Amplifier gain	20 dB
Noise figure	4 dB
Photodiode gain	3
Responsivity	1 A/W
Dark current	10 nA

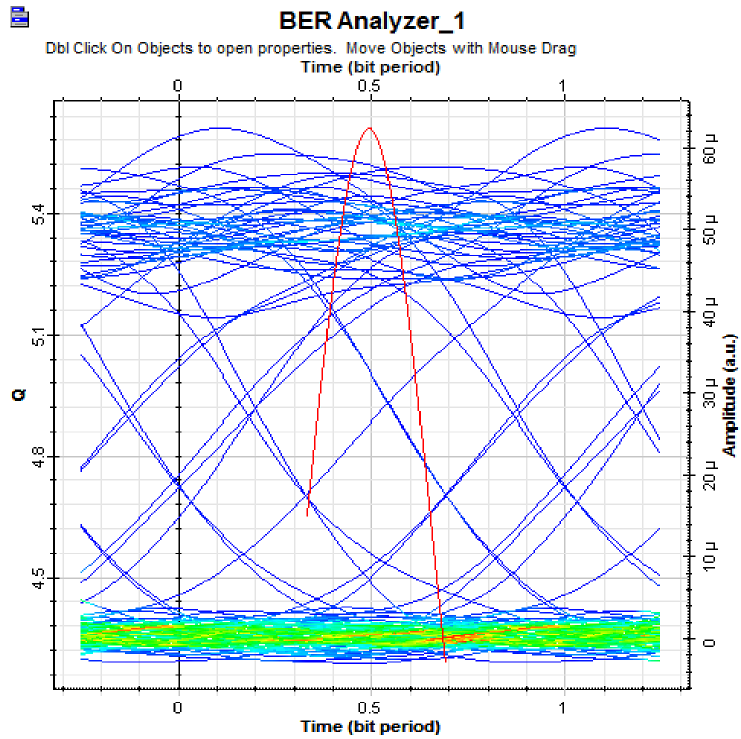
Table 2. Performance analysis of FSO with various turbulence.

Atten (dB/km)	Max. Link (km)	SNR (dB)	Pr (dBm)	BER	Q. factor
19.28	1.2	31.375	-60.4107	4.406e-9	5.6933
9.64	2	30.579	-61.1992	7.735e-9	5.5973
6.27	2.6	32.107	-59.678	2.716e-9	5.7745
2.37	4.9	30.681	-61.097	7.176e-9	5.6102
0.55	10.1	30.352	-61.424	9.157e-9	5.5683
0.233	13.4	30.335	-61.441	-9.28e-9	5.56602
0.065	17	30.254	-61.522	9.868e-9	5.5554

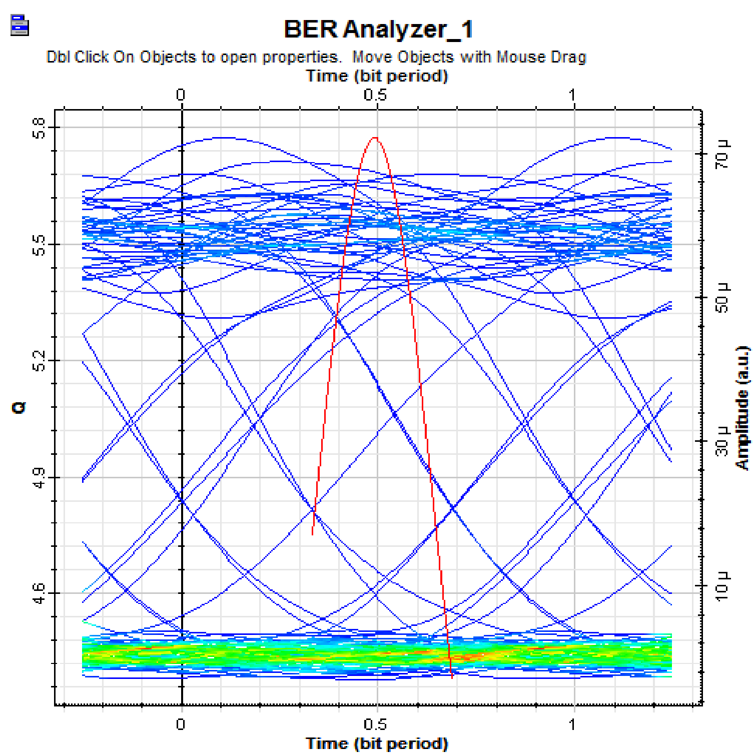
It can be seen that in Fig. (7, 8) the depicted of Max. Q. factor under different weather conditions. The increase in the attenuation leads to decreasing in the distance link. the acceptable Q. factor was about 5.693 and 5.555 for heavy rain and very clear weather at the maximum link distance.



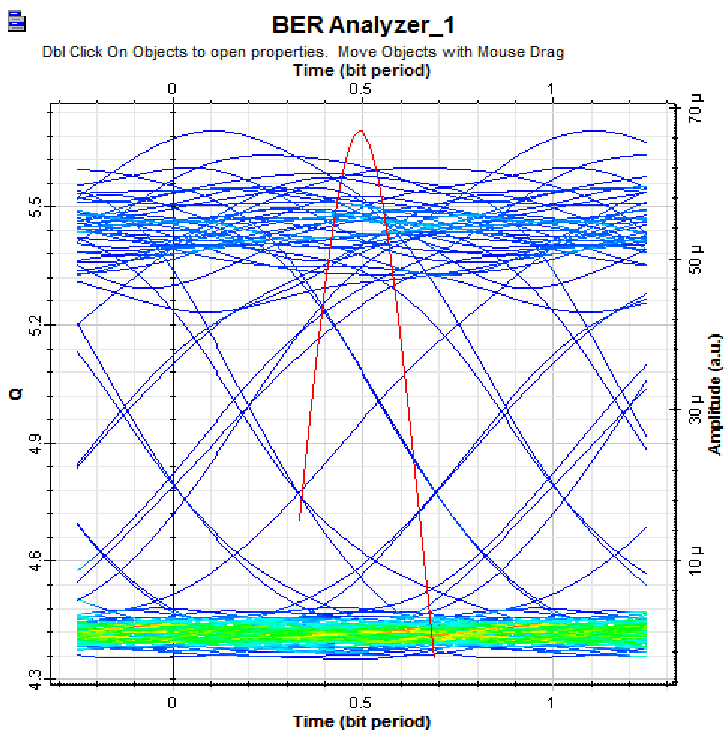
(a)


BER Analyzer_1
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Time (bit period)
Q
Amplitude (a.u.)
Time (bit period)

(b)


BER Analyzer_1
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Time (bit period)
Q
Amplitude (a.u.)
Time (bit period)

(c)



(d)

Fig. 2. Eye opening diagram for different conditions, a: very clear sky, b: heavy haze, c: light rain, d: heavy rain.

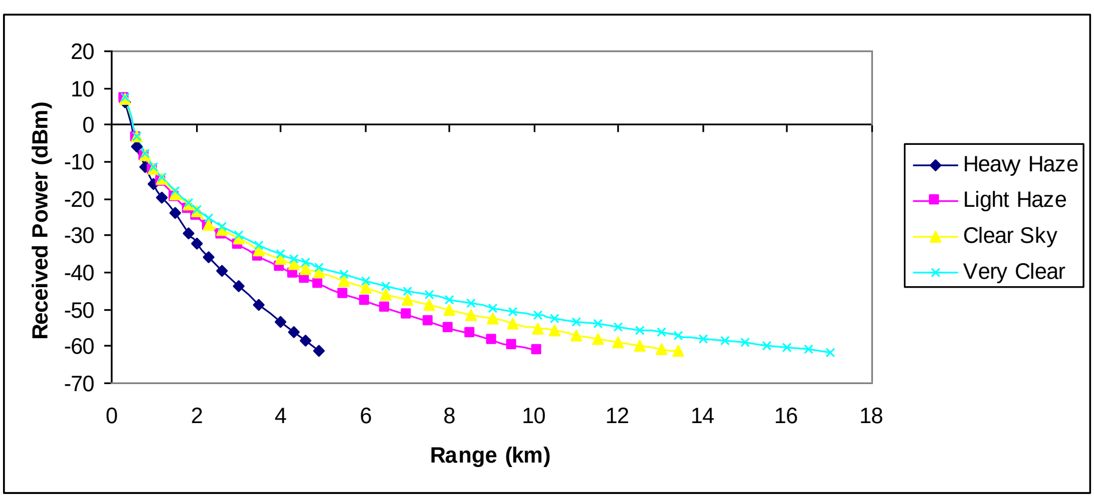


Fig. 3. Received signal power for light and medium attenuation

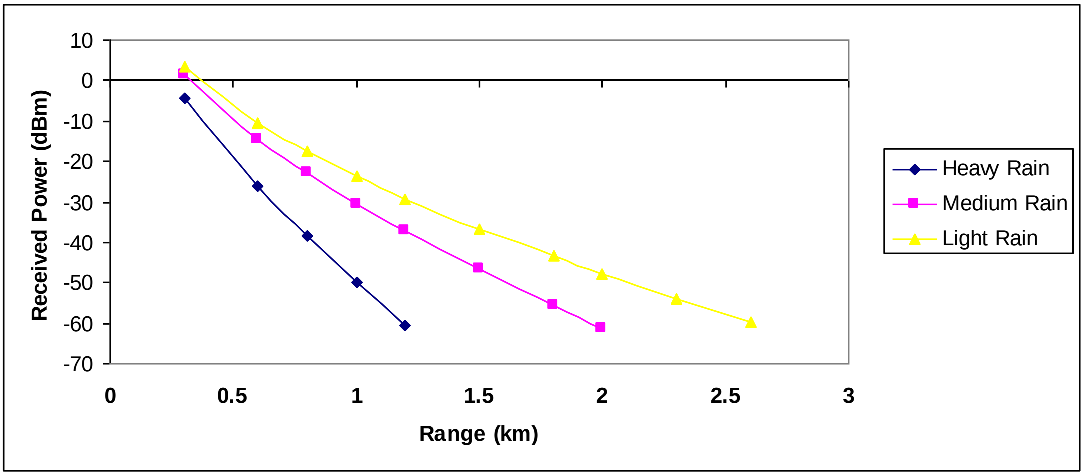


Fig. 4. Received signal power for strong attenuation (rain)

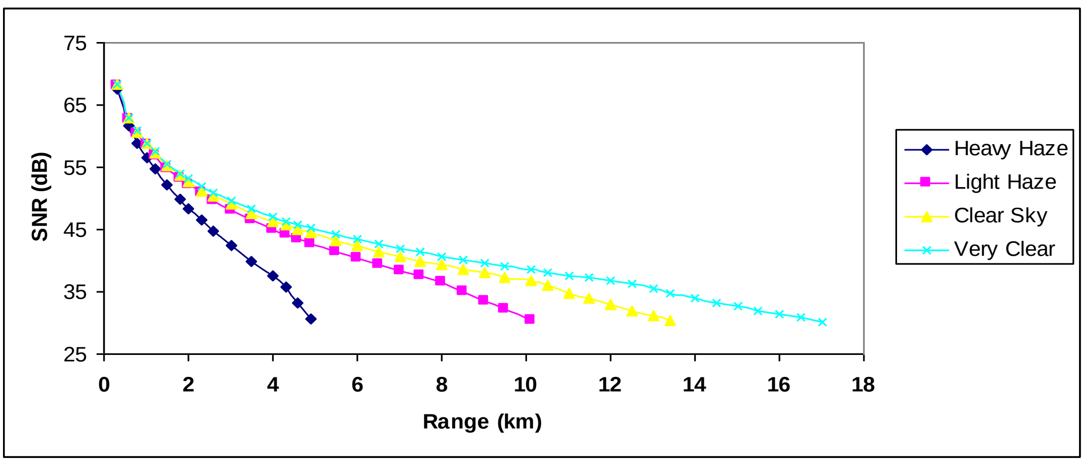


Fig. 5. SNR for light and medium attenuation

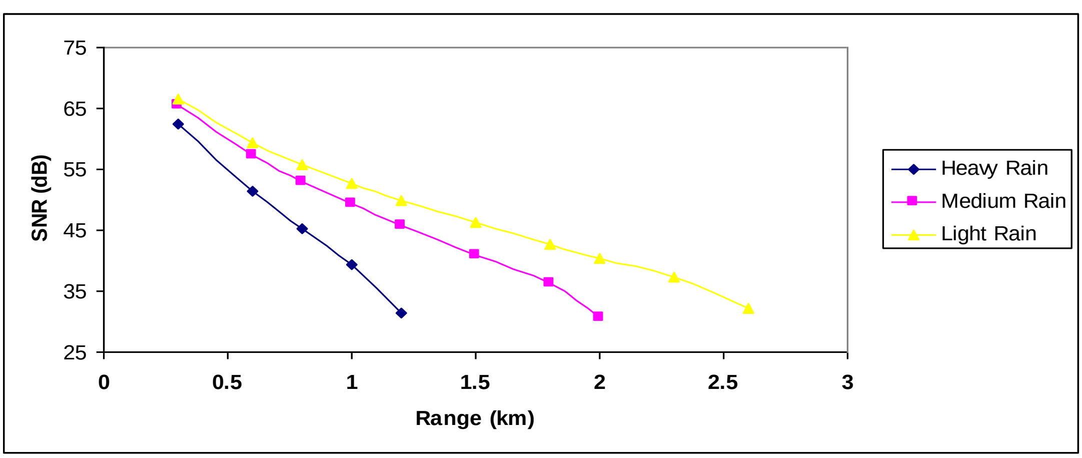


Fig. 6. SNR for strong attenuation (rain)

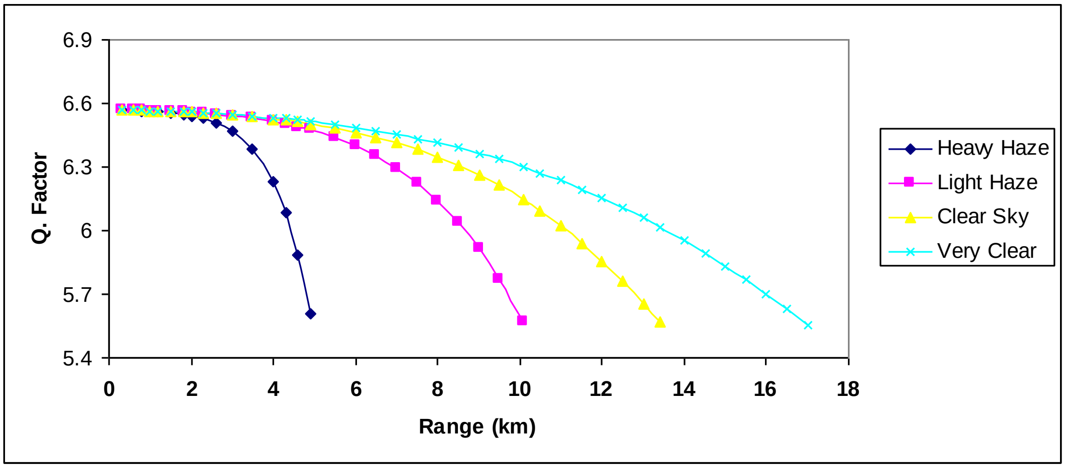


Fig. 7. Max. Q. factor for light and medium attenuation

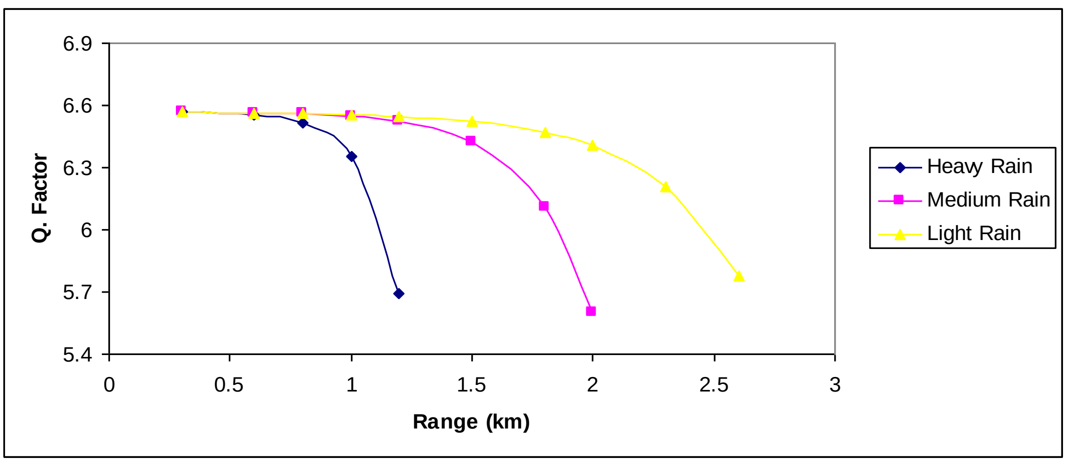


Fig. 8. Max. Q. factor for strong attenuation (rain)

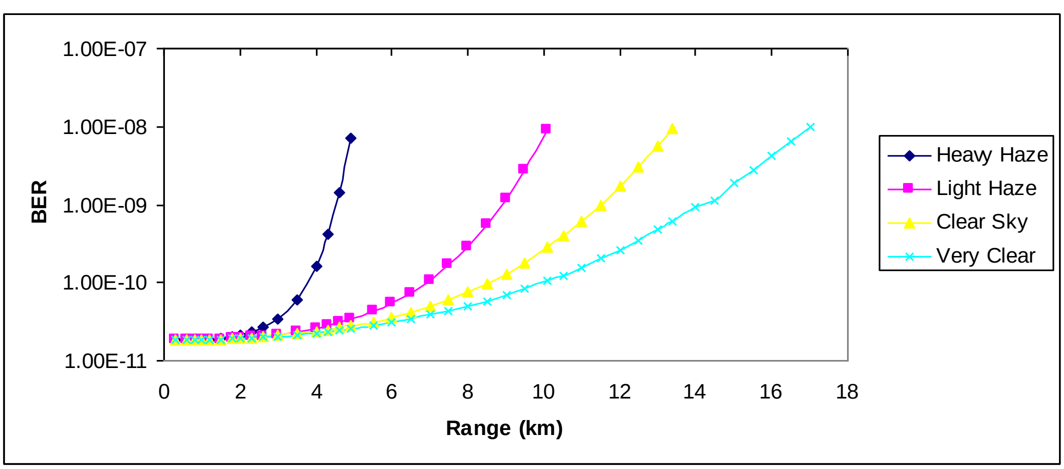


Fig. 9. BER for light and medium attenuation

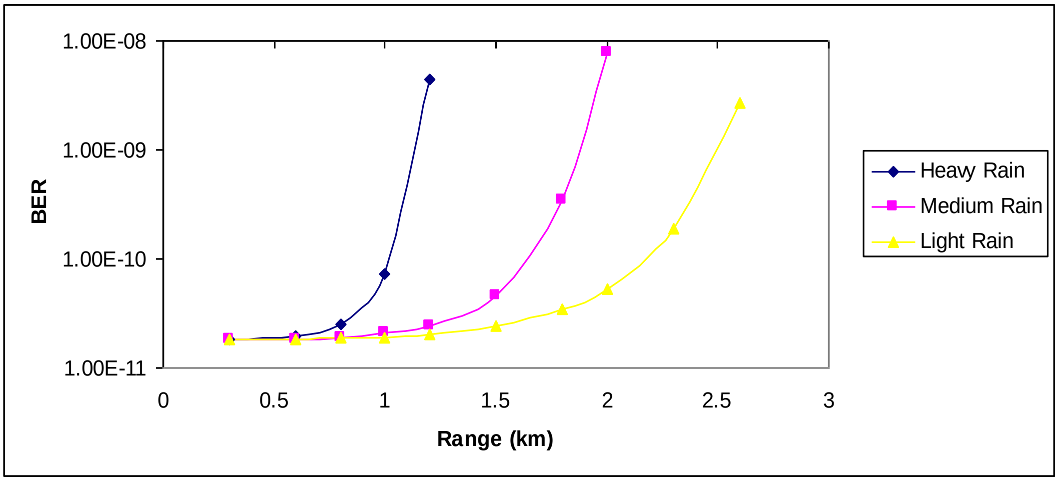


Fig. 10. BER for strong attenuation (rain)

Let us consider the BER performance as a function of the distance of transmission. Fig. (9, 10) shows the curves of the BER for different weather conditions. In this case, it is noticed that for BER 10^{-9}, the distance transmission is limited to 17 km, 13.4 km, 10.1 km and 4.9 km for very clear, clear, light haze and heavy haze, respectively as shown in Table (2) . It is clear that the BER curves decreases with increase in the distance of transmission. In this case, For strong attenuation the data of the transmission does not exceed 2.6 km, 2 km and 1.2 km for light rain, medium rain and heavy rain respectively. This decrease in distance of data transmission comes from increase in attenuation coefficient.

4. CONCLUSION

This paper provides a simulation analysis of a WDM-FSO communication link using NRZ modulation technique and performance is investigated under similar optimized parameters. WDM over FSO communication system is very suitable and effective in providing high data rate transmission with very low bit error rate (BER). Therefore, WDM – FSO system has achieved very good results, it has many problems, such as heavy attenuation coefficient. For the heavy rain condition the maximum link range about 1.2 km at BER 10^{-9}.

References

[1] N. Kumar, A. K. Rana, Impact of various parameters on the performance of free space optics communication system, Optik, 124, 2003, 5774-5776.

[2] S. Chaudhary, A. Amphawan, realization of free space optics with OFDM under atmospheric turbulence, optik, , 125, 2014, 5196-5198.

[3] M. A. Esmail, H. Fathallah, M. S. Alouni, channel modeling and performance evaluation of FSO communication systems in Fog, 23rd International Conference on Telecommunications (ICT), Thessaloniki, 2016

[4] Z. Ghassemlooy, W. Popoola, and S. Rajbhandari, optical wireless communications: system and channel modeling with Matlab. United kingdom: CRC Press Taylor and Francis group, 2013.

[5] D. A. Luong, C. T. Truong, and Anh T. Pham, effect of APD and thermal noises on the performance of SC-BPSK/FSO systems over turbulence channels, 18th Asia-Pacific Conference on Communications (APCC), pp. 344-349, 2012.

[6] M. S. Khan, S. S. Muhammad, M. S. Awan, V. Kvicera, M. Grabner,and E. Leitgeb, Further results on fog modeling for terrestrial free space optical links, *Optical Engineering*, vol. 51, pp. 031207-1 -031207-9, 2012.

[7] D. Kedar and S. Arnon, Urban optical wireless communication networks: the main challenges and possible solutions, *IEEE Communications Magazine*, vol. 42, pp. S2-S7, 2004.

[8] I. I. Kim, B. McArthur, and E. J. Korevaar, Comparison of laser beam propagation at 785 nm and 1550 nm in fog and haze for optical wireless communications, in *Proc. SPIE 4214, Optical Wireless Communications III*, 2001, pp. 26-37.

[9] F. Demers, H. Yanikomeroglu, and M. St-Hilaire, A survey of opportunities for free space optics in next generation cellular networks, in *Ninth Annual Communication Networks and Services Research Conference* (CNSR), Ottawa, 2011.

[10] P. W. Kruse, L. D. McGlauchlin, and R. B. McQuistan, Elements of Infrared Technology: Generation, Transmission and Detection, *New York: Wiley*, vol. 1, 1962.

[11] M. Al Naboulsi, Fog attenuation prediction for optical and infrared waves, *Optical Engineering*, vol. 43, pp. 319-329, 2004.

[12] M. Ijaz, Z. Ghassemlooy, J. Pesek, O. Fiser, H. Le Minh, and E. Bentley, Modeling of fog and smoke attenuation in free space optical communications link under controlled laboratory conditions, *IEEE/OSA Journal of Light Wave Tech.*, vol. 31, pp. 1720-1726, 2013.

[13] Mazin Ali A. Ali, Performance Analysis of Fog Effect on Free Space Optical Communication System, IOSR Journal of Applied Physics 7(2), pp. 16-24, 2015.

[14] Mazin Ali A. Ali, Comparison of NRZ, RZ-OOK Modulation Formats for FSO Communications under Fog Weather Condition, International Journal of Computer Applications, vol.108, no. 2, 2014.

[15] M. A. Esmail, H. Fathallah, M. S. Alouni, Outdoor FSO Communications Under Fog: Attenuation Modeling and Performance Evaluation, IEEE Photonics Journal, vol. 8, no. 4, 2016

[16] M. A. Esmail, H. Fathallah, M. S. Alouni, analysis of fog effects on terrestrial free space optical communication links, IEEE International Conference on Communications Workshops (ICC), Kuala Lumpur, Malaysia, 2016

[17] S. Bloom, E. Korevaar, J. Schuster, H. Willebrand, 'Understanding the performance of free-space optics', Journal of Optical Networking. Vol. 2, No. 6, pp. 178-200, June 2003.

[18] N. A. Mohammed, A.S. El-Wakeel, and M. H. Aly, pointing error in FSO link under different weather conditions, international journal of video& image processing and network security IJVIPNS-IJENS, vol. 12, pp. 6-9, 2012.

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