DWDM over FSO under the Effect of Different Atmospheric Attenuations

by Heyam Maraha

DWDM over FSO under the Effect of Different Atmospheric Attenuations

Heyam Maraha[1], Kameran Ali Ameen[2] Aras Al-dawoodi[2],
[1]Network Department, College of Computer Science and Information Technology, Kirkuk University, Kirkuk, Iraq
[2]Computer Science Department, College of Computer Science and Information Technology, Kirkuk University, Kirkuk, Iraq

Article Info

Article history:

Received …………..
Revised ……………
Accepted …………..

Keywords:

A DWDM
B FSO
C Steganography
D Different weather condition
E Atmospheric attenuations
F Low pass raised cosine electrical filter

ABSTRACT

This study aims to study the compensation of different atmospheric attenuations of eleven-channel dense-wavelength division multiplexing (DWDM) over free-space optics (FSO). The channels operate over (1561.42 nm, 1559.79 nm, 1558.17 nm, 1558.55 nm, 1554.94 nm, 1553.33 nm, 1551.72 nm, 1550.12 nm, 1548.51 nm, 1546.92 and 1545.32 nm) wavelengths that have separated based on the traditional International Telecommunication Union (ITU) grid. The performance of an eleven-channel DWDM system is evaluated in FSO link under the clear air, haze and rain atmospheric attenuation based on low pass raised cosine electrical filter at the receiver. In the experiments, the system transmits 110 Gbit/s for FSO distances 9500 m, 3000 m and 2500 m in superbly clear air, haze and heavy haze atmospheric attenuations, respectively. Over different atmospheric attenuations, we evaluated our system performance using BER, eye diagram and the quality factor (Q-Factor).

Corresponding Author:

Aras Al-dawoodi,
Computer Science Department,
College of Computer Science and Information Technology, Kirkuk, Iraq.
Email: aras.ghazi86@uokirkuk.edu.iq

1. INTRODUCTION

In the last decade, a rapid increase has been seen on traffic demand due to the invention of different needs to large data downloads, such as gaming systems (Play station, Xbox, etc.). These systems require onboard storage to enable players to download software and games rather than buying in DVDs. It is expected that by 2022, the large files of graphically intense games are expected to take 4 percent of all IPs [1]. Additionally, during peak usage periods, these downloads tend to occur with gaming downloads getting up to 8 percent of heavy hour traffic. Besides, by 2022 also, the rapid growth of gaming traffic is anticipated to increase, and the gaming will be crucial in limiting the likelihood that video traffic will exceed the projected 82 percent [2]. However, different multiplexing has been developed to overcome this demand such as: 1) Orthogonal Frequency-Division Multiple Access (OFDMA); 2) Optical Code Division Multiple Access (OCDMA); 3) Wavelength Division Multiplexing (WDM); and 4) Space Division Multiplexing (SDM) [3-9]. These multiplexing methods can be worked on a different medium like optical wireless and fiber optics. FSO plays an important medium to transfer data over different atmospheric attenuations [3, 4, 6, 8].

It is well known that the FSO communication system is a growing technology, and implement as an alternate technology where internet service fails to fulfill the demands. In FSO systems, as a transmission medium, the light signal is sent from the transmitter to the receiver using the air. FSO systems have several pros, such as easy and fast deployment, license-free operation, bandwidth scalability, high transmission security, high bit rates, and full-duplex transmission, etc [10, 11]. The wireless telecommunication system of FSO utilizes a transmission medium of free space to transmit optical data at high bit rates. This study applies

DWDM for FSO that operate over (1561.42 nm, 1559.79 nm, 1558.17 nm, 1558.55 nm, 1554.94 nm, 1553.33 nm, 1551.72 nm, 1550.12 nm, 1548.51 nm, 1546.92, and 1545.32 nm) wavelength to improve the capacity. In the optical networks, DWDM technology became the main choice for fulfilling the rapidly increasing of bandwidth demands [12]. Furthermore, it has been implemented to increase the capacity of long-haul optical transport systems [13]. Researches have paid more attention to move this promising technology into the broadband access networks that serve business and residential clients [14]. Moreover, on a single optical, DWDM enables multiple signals to be transmitted simultaneously at several wavelengths and implement to increase bandwidth over the optical communication networks [15]. In this study, compensation for clear air atmospheric attenuation, haze atmospheric attenuation and rain atmospheric attenuation of eleven-channel DWDM over FSO.

The remainder of the paper is structured as follows. Section 2 presents the methodology of our systems. Section 3 evaluates the findings. Finally, Section 4 concludes this article.

2. SYSTEM MODEL

As illustrated in Figure 1, different components of we used components and the parameter of the DWDM system. The eleven-channel DWDM over FSO have separated based on the ITU grid. Briefly, the basic blocks of DWDM-FSO consist of a transmission, medium (FSO-channel), and reception. FSO requires line of sight configuration between transmitter and receiver. The transmitter side consists of eleven-channel, each channel includes data in (pseudorandom bit sequence generator at 10 Gbps (total capacity is 110 Gbps)), NRZ pulse generator, the laser and multiplexer which will multiplex eleven wavelengths. The wavelengths are as follows: (1561.42 nm, 1559.79 nm, 1558.17 nm, 1558.55 nm, 1554.94 nm, 1553.33 nm, 1551.72 nm, 1550.12 nm, 1548.51 nm, 1546.92, and 1545.32 nm). The power of the Laser power is 1 dBm. The performance of an eleven-channel DWDM system is evaluated in FSO link under the following atmospheric attenuations: 1) Haze; and 2) rain [16]. The evaluation was performed based on low pass raised cosine electrical filter at the receiver.

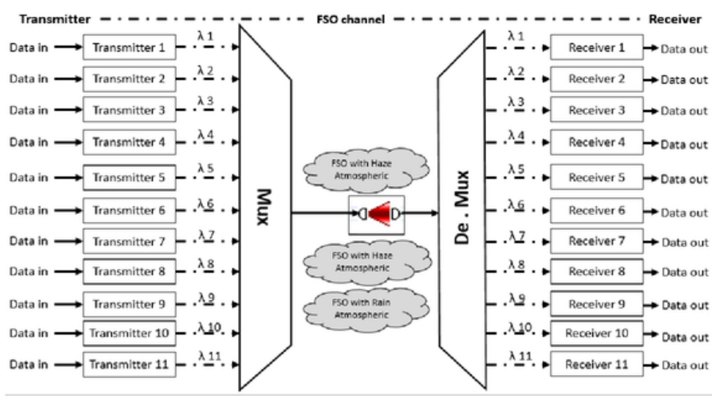

Figure 1. Optical DWDM over FSO under the effect of clear air atmospheric attenuation, haze atmospheric attenuation, and atmospheric rain attenuation

3. PERFORMANCE EVALUATION

To achieve a maximum possible medium range of 11-channels, opti-system simulator software has been conducted of DWDM over FSO link under several weather conditions [17]. Table 1 summarizes the medium is based on FSO-channel that transmitted data over atmospheric attenuations. Additionally, based on atmospheric attenuation, the laser power is set to 1 dBm, and beam divergence is assigned as 1 μrad [18]. As shown in Figure 1, after FSO, the de-multiplexer is made to retrieve the signals from the FSO. The receiver sides are comprised of eleven receivers, and the electrical filter is based on low pass raised cosine.

Table 1. Transmitted data over atmospheric attenuations

Atmospheric	Attenuation (dB-Km)
Clear air	0.43
Haze	4.2
Rain	5.8

In the experiments, the performance results of eleven channels DWDM are measured with BER, Q-Factor and eye diagram over FSO under the effect of clear air atmospheric attenuation, haze atmospheric attenuation, and rain atmospheric attenuation. In the first experiment, Figures 2 and 3 illustrate the BER, Q-Factor results of FSO under the effect of clear air atmospheric attenuation over the distances: 7500 meters, 8000 meters, 8500 meters, 9000 meters, 9500 meters and 1000 meters. Additionally, the eye diagrams of the channels are shown in Figure 4. From the findings of Figures 2-4, it is clear that FSO under the effect of clear air atmospheric attenuation based on DWDM has successfully transmitted data until the distance 9500 meters with acceptable performance for both BER and Q-Factor.

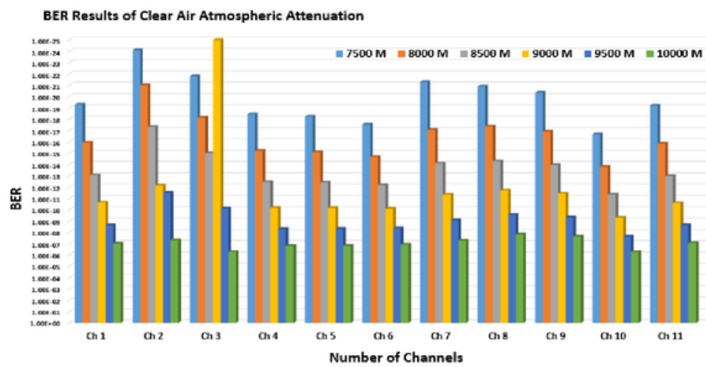

Figure 2. BER results of eleven channels DWDM-FSO under the effect of clear air atmospheric attenuation

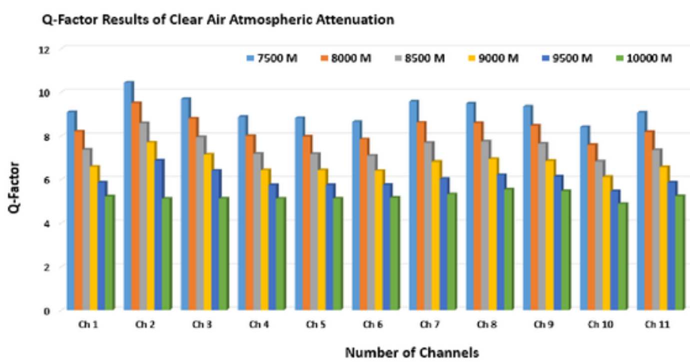

Figure 3. Q-Factor results of eleven channels DWDM-FSO under the effect of clear air atmospheric attenuation

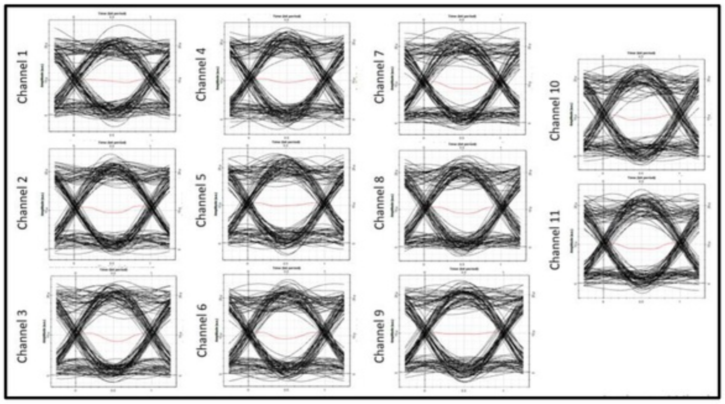

Figure 4. eye diagram results of eleven channels DWDM-FSO under the effect of clear air atmospheric attenuation

In the second experiment, Figures 5 and 6 show the BER, Q-Factor results of FSO under the effect of haze atmospheric attenuation over the distances: 1000 meters, 1500 meters, 2000 meters, 2500 meters, 3000 meters and 3500 meters. Similar to the first simulation, we evaluated the eye diagrams of the channels (see Figure 7). According to the outcomes, FSO under the effect of haze atmospheric attenuation based on DWDM has successfully transmitted data until the distance 3000 meters with acceptable performance for both BER and Q-Factor.

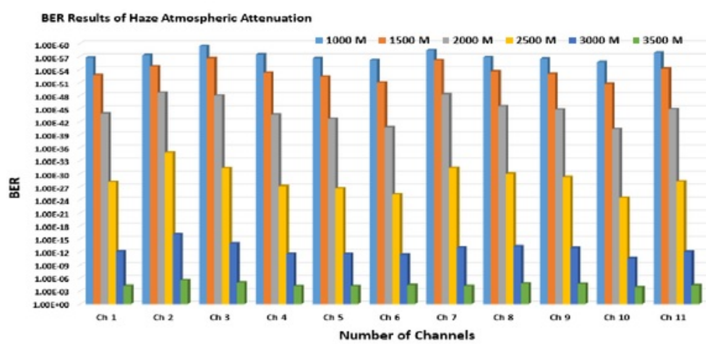

Figure 5. BER results of eleven channels DWDM-FSO under the effect of haze atmospheric attenuation

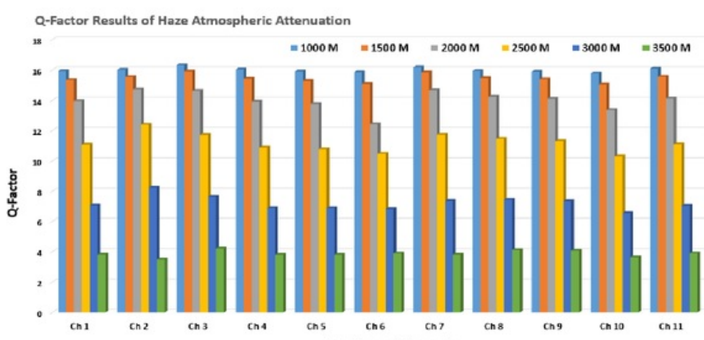

Figure 6. Q-Factor results of eleven channels DWDM-FSO under the effect of haze atmospheric attenuation

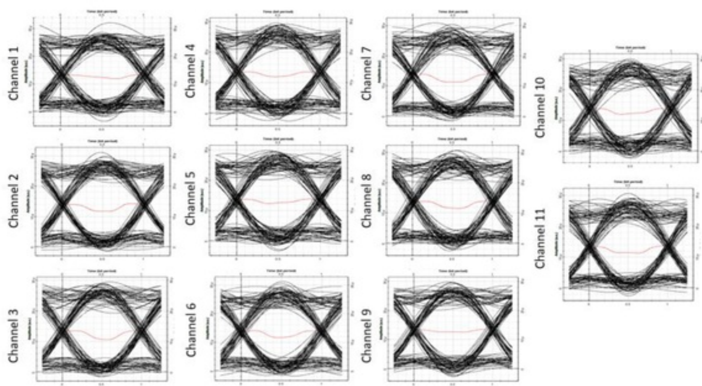

Figure 7. Eye diagram results of eleven channels DWDM-FSO the effect of haze atmospheric attenuation

In the last experiment, Figures 8 and 9 show the BER, Q-Factor results of FSO under the effect of rain atmospheric attenuation over the distances: 500 meters, 1000 meters, 1500 meters, 2500 meters and 300 meters. Additionally, Figure 10 presents the eye diagrams of the channels. The results confirm that FSO under the effect of rain atmospheric attenuation based on DWDM has successfully transmitted data until the distance 2500 meters with a suitable performance for both BER and Q-Factor.

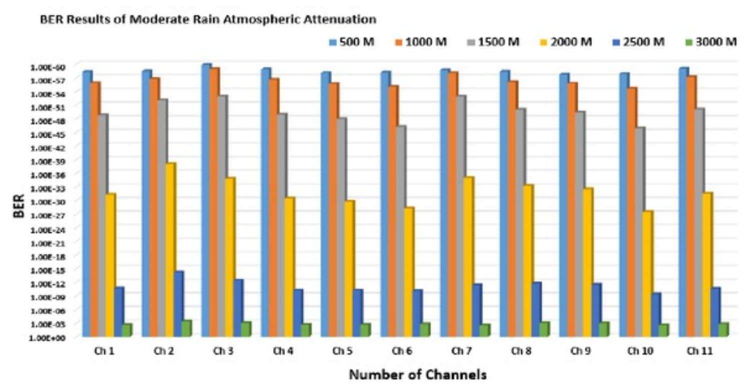

Figure 8. BER results of eleven channels DWDM-FSO under the effect of rain atmospheric attenuation

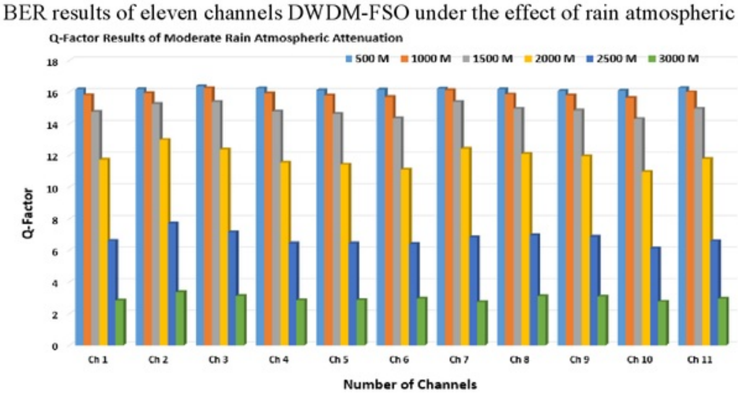

Figure 9. Q-Factor results of eleven channels DWDM-FSO under the effect of rain atmospheric attenuation

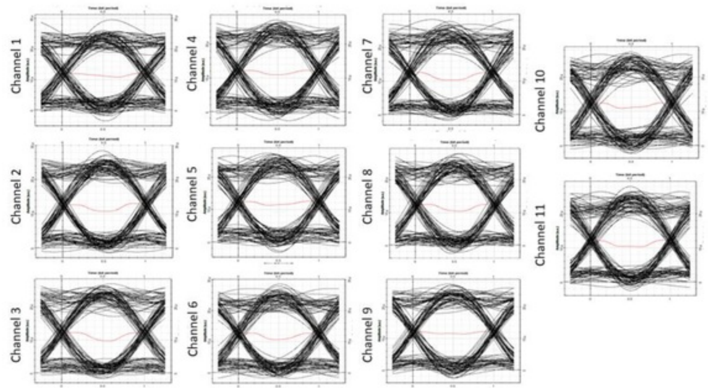

Figure 10. Eye diagram results of eleven channels DWDM-FSO under the effect of rain atmospheric attenuation

4. CONCLUSION

To overcome the capacity in optical wireless communication, we evaluated eleven-channel DWDM-FSO operated over the wavelengths 1561.42 nm, 1559.79 nm, 1558.17 nm, 1558.55 nm, 1554.94 nm, 1553.33 nm, 1551.72 nm, 1550.12 nm, 1548.51 nm, 1546.92 and 1545.32 nm. In the simulation, 110 Gbps has been transmitted over eleven channels under the effect of clear air, haze and rain atmospheric attenuations reached the distances 9500 meters, 300 meters and 2500 meters, respectively. The evaluation was based according to BER, Q-Factor, and eye-diagram.

References

[1] C. V. N. Index, "Forecast and Trends 2017–2022 White Paper," *Cisco: San Jose, CA, USA,* 2019.

[2] C. V. N. Index, "forecast and trends, 2017–2022 White Paper. 2018," ed, 2019.

[3] A. M. F. S. A. Aljunid and Syed Zulkarnain Syed Idrus Sara Alshwani, Mohammed Nasih Ismael, Aras Al-Dawoodi, Alaan Ghazi, "HERMITE-GAUSSIAN MODE IN SPATIAL DIVISION MULTIPLEXING OVER FSO SYSTEM UNDER DIFFERENT WEATHER CONDITION BASED ON LINEAR GAUSSIAN FILTER," *International Journal of Mechanical Engineering and Technology (IJMET),* vol. 10, pp. 1095-1105, 2019/2/2.

[4] A. A.-D. Alaan Ghazi Ahmed M. Fakhrudeen Mohammed Nasih Ismael, Sara Alshwani, "SDM OVER HYBRID FSO LINK UNDER DIFFERENT WEATHER CONDITIONS AND FTTH BASED ON ELECTRICAL EQUALIZATION" *International Journal of Civil Engineering and Technology,* vol. 10, pp. 1396-1406, 2019/2/2.

[5] A. Noori, A. Amphawan, A. Ghazi, and S. A. Ghazi, "Dynamic evolving neural fuzzy inference system equalization scheme in mode division multiplexer for optical fiber transmission," *Bulletin of Electrical Engineering and Informatics,* vol. 8, pp. 127-135, 2019.

[6] A. Ghazi, S. Aljunid, A. Noori, S. Z. S. Idrus, C. R. B. Rashidi, and A. Al-Dawoodi, "Design & investigation of 10x10 gbit/s MDM over hybrid FSO link under different weather conditions and fiber to the home," *Bulletin of Electrical Engineering and Informatics,* vol. 8, pp. 121-126, 2019.

[7] A. Al-Dawoodi, A. Fareed, T. Masuda, A. Ghazi, A. Fakhrudeen, S. Aljunid, *et al.*, "Comparison of Different Wavelength Propagations over Few-Mode Fiber based on Space Division Multiplexing in

Conjunction with Electrical Equalization," *International Journal of Electronics and Telecommunications,* 2019.

[8] A. Amphawan, A. Ghazi, and A. Al-dawoodi, "Free-space optics mode-wavelength division multiplexing system using LG modes based on decision feedback equalization," in *European Physical Journal Web of Conferences*, 2017.

[9] M. Anuar, S. Aljunid, A. Arief, and N. Saad, "LED spectrum slicing for ZCC SAC-OCDMA coding system," in *7th International Symposium on High-capacity Optical Networks and Enabling Technologies*, 2010, pp. 128-132.

[10] M. A. Khalighi and M. Uysal, "Survey on free space optical communication: A communication theory perspective," *IEEE communications surveys & tutorials,* vol. 16, pp. 2231-2258, 2014.

[11] K. Prabu, S. Charanya, M. Jain, and D. Guha, "BER analysis of SS-WDM based FSO system for Vellore weather conditions," *Optics Communications,* vol. 403, pp. 73-80, 2017.

[12] M. H. Ali, A. M. Almufti, and H. A. Abu-Alsaad, "Simulative Analyzing of Covering Suburban Areas with 32× 10 Gbps DWDM-PON FTTH Using Different Dispersion and Power," *Journal of Communications,* vol. 14, 2019.

[13] P. Krishnan, "Performance Analysis of Hybrid RF/FSO System Using BPSK-SIM and DPSK-SIM Over Gamma-Gamma Turbulence Channel With Pointing Errors for Smart City Applications," *IEEE Access,* vol. 6, pp. 75025-75032, 2018.

[14] G. Grammel and K. P. Jones, "Wavelength provisioning for customer premise equipment (CPE) in dense wavelength-division multiplex (DWDM) networks," ed: Google Patents, 2019.

[15] S. A. Al-Gailani, M. R. B. Arshad, O. M. Kharraz, and R. Q. Shaddad, "Performance Evaluation of 6-Gbps Hybrid DWDM/Multibeam Free-Space Optical Network in an Unusual Haze," in *10th International Conference on Robotics, Vision, Signal Processing and Power Applications*, 2019, pp. 373-380.

[16] A. Mansour, R. Mesleh, and M. Abaza, "New challenges in wireless and free space optical communications," *Optics and lasers in engineering,* vol. 89, pp. 95-108, 2017.

[17] O. U. Guide, "RSOFT Design Group," ed: Inc, 2010.

[18] A. Amphawan, S. Chaudhary, R. Din, and M. N. Omar, "5Gbps HG 0, 1 and HG 0, 3 optical mode division multiplexing for RoFSO," in Signal Processing & Its Applications (CSPA), 2015 IEEE 11th International Colloquium on, 2015, pp. 145-149.

DWDM over FSO under the Effect of Different Atmospheric Attenuations

ORIGINALITY REPORT

8%	6%	6%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

3%

★ S. Diaz, M. Lopez-Amo. "[INVITED] Multiwavelength operation of erbium-doped fiber-ring laser for temperature measurements", Optics & Laser Technology, 2016

Publication

Exclude quotes	Off	Exclude matches	< 1%
Exclude bibliography	On		