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HYBRID COARSE AND DENSE WDM OVER FSO LINK UNDER THE EFFECT OF MODERATE AND HEAVY RAIN WEATHER ATTENUATIONS

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Abstract

Free-space optics (FSO) has emerged as an essential technique to overcome attenuations of atmospheric weather (e.g., rain) and to fulfil the growing demand in communication capacity and scalability. Moderate and heavy rain atmospheric weather cause attenuations and reduce the coverage (i.e., distance) of the communication system. To mitigate this concern, this paper investigates implementing hybrid coarse wavelength division multiplexing (CWDM) and dense wavelength division multiplexing (DWDM) over the FSO link network. The network has fourteen wavelengths with standard downlink channel spacing (ITU grid specification) of 20 nm and 0.8 nm for CWDM and DWDM, respectively. The results of the proposed system improve the performance of an FSO link in terms scalability, data rate, link distance and the received power. Furthermore, our system provides access data to fourteen end-users, where each one has a data rate of 140 Gb/s along an FSO link distance of 2.6 km and 1.6 km for moderate and heavy rain atmospheric weather attenuations, respectively.

Keywords: Atmospheric weather attenuations, CWDM, DWDM, FSO link,.

1. Introduction

Recently, there has been a demand for large internet access and high-definition television broadcasting services. Therefore, optical wireless communication offers a potentially high data rate and wide bandwidth; in consequence, an attractive system to meet the increasing demand for broadband traffic [1-3]. Free Space Optical communication (FSO) is a leading topic in wireless and optical communication, and it is the line of sight technology [4, 5]. To transmit data between two or more points, a highly narrow beam in free space is used despite the high data rate. In optical communication, the FSO technology is as same as the fiber optics communication [6, 7]. However, FSO has a number of pros such as low cost, security not necessary, license-free, attractive solution for voice and high data rate transmission [8]. Furthermore, the quality and data rate of FSO depends on weather conditions and atmospheric attenuations [9].

In the literature, Wavelength Division Multiplexing (WDM) has been employed in FSO to transmit various wireless service signals independently and simultaneously [10-12]. There are two types of WDM: 1) Dense Wavelength Division Multiplexing (DWDM), and 2) Coarse Wavelength Division Multiplexing (CWDM). Specifically, the channel spacings in the DWDM channels are 1.6nm/0.8nm/0.4 nm. Whereas, the channel spacing of CWDM channels is 20 nm [13]. Besides, the wavelength range in the CWDM system is 1260 nm-1625 nm and for DWDM is 1470 nm-1625 nm [14].

There are different studies applied hybrid CWDM-DWDM system but based on limited distance and capacity. For example, the authors in [15] proposed a hybrid WDM-FSO system for DWDM and CWDM system at 810 km and 780 km in a very clear condition. The system was designed to evaluate the quality of a data rate of 2.5 Gbps for 12 users with 20 dBm power. In another work in [14], a Hybrid WDM-FSO system was designed and to achieve better performance than the conventional WDM-FSO. The system showed an acceptable BER over FSO for the transmission of 2.5 Gbps data rate. The authors considered 12 beams in the free space channel and attained link distance at a very clear condition with 20 dBm launch power.

Similarly, the work on [16] applied 8 channel hybrid CWDM/DWDM-FSO link for 2.5 Gbps data rate at a clear-sky condition based on launch power 20 dBm. In 2018, the authors in [17] proposed a hybrid WDM system over the FSO 1.9km with 2.5 Gbps data rate and input power 25 dBm. The system assigned 1550 nm wavelength with rain attenuation 20.5 dBm. However, in this study, we investigate 14×10 Gbit/s hybrid coarse CWDM and DWDM over the FSO link network having fourteen wavelengths with standard downlink channel spacing (ITU grid specification) of 20 nm and 0.8 nm for CWDM and DWDM, respectively. In our system, we adopt 1 dBm launch power.

The rest of this paper is structured as follows. Section 2 describes the hybrid System over Optical Link. Section 3 evaluates our system and discusses the obtained results. Finally, Section 4 concludes the paper.

2. Hybrid System over Optical Link

The block diagram of the hybrid CWDM and DWDM over the FSO link is depicted in Fig. 1. The system comprises of three parts: 1) optical transmitter; 2) optical atmospheric link; and 3) optical receiver. We designed and simulated the system using opti-system [18] and MATLAB [19]. The optical transmitter side consists of fourteen- optical channels, where each optical channel includes:

- Data generator at 10 Gbps (total capacity is 140 Gbps).
- NRZ electrical pulse generator.
- Laser and multiplexer, which will multiplex fourteen wavelengths.

The hybrid system consists of six CWDM channels with channel spacing is 20 nm and eight DWDM channels with 0.8 nm channel spacing. The wavelengths of CWDM and DWDM channels are (1590 nm, 1570 nm, 1550 nm, 1530 nm, 1510 nm and 1490 nm) and (1543 nm, 1542.2 nm, 1541.4 nm, 1540.6 nm, 1539.8 nm, 1539 nm, 1538.2 nm, and 1547.4 nm), respectively. On the other hand, the optical receiver side consists of:

- Fourteen- optical receiver: used to converts light into an electrical current.
- Electrical filter: passes signals with an incidence lesser than a definite cut-off frequency and mitigates signals with frequencies greater than the cut-off frequency. Furthermore, it is used to eliminating all the undesirable frequencies.

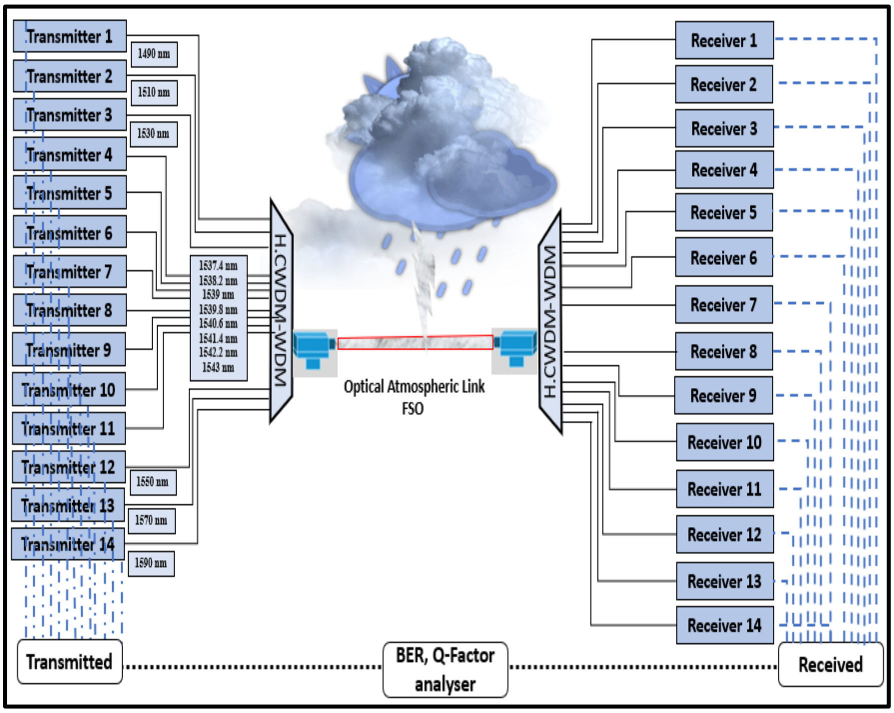

Fig. 1. The architecture of Hybrid CWDM and DWDM over the FSO system.

Lastly, the FSO channel is evaluated under moderate rain and heavy rain atmospheric attenuations weather. Tables 1 and 2 summarize the attenuation coefficients and the used parameters in the hybrid CWDM and DWDM over the FSO system.

Table 1. Simulation parameters of hybrid-CWDM and DWDM over FSO communication system.

Parameters	Values
Beam divergence	1 mrad
Channel spacing: CWDM/DWDM	20 nm/0.8 nm
Transmitter's & Receiver's Apertures	30 cm
Launch Power	1 dBm
Data Rate	140 Gbps

Table 2. The weather attenuation coefficients of the adopted FSO.

Weather conditions	Rainfall amount (mm/h)	α[dB/km]
Moderate rain	12.5	5.8
Heavy rain	25	9.2

3. Results and Discussion

The performance of an eleven-channel DWDM system has evaluated in the FSO link under the two different atmospheric attenuations and measured based on Bit Error Rate (BER) and Quality Factor (Q-Factor). Figures 2 and 3 illustrate the BER and Q-Factor of the system in the case of moderate rain weather attenuation over the different distances (1 km, 1.5 km, 2 km, 2.5 km, and 3 km). According to standard BER and Q-Factor, the results from the distance 1 km to the distance 2.5 km are acceptable. However, at distance 3 km, the results of BER and Q-Factor not acceptable. Consequently, this study demonstrates that we can transmit data of 140 Gbps until distance 2.5 km with perfect performance results under the effect of moderate rain weather attenuation.

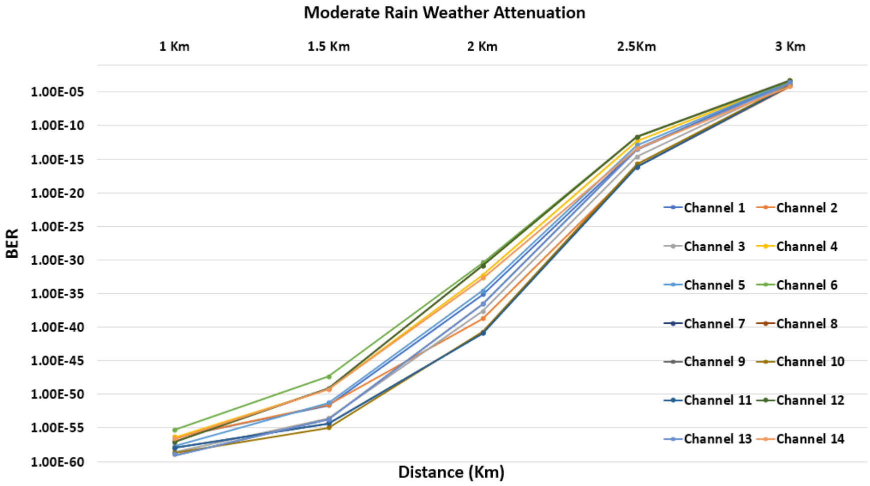

Fig. 2. BER results under the effect of moderate rain weather attenuation.

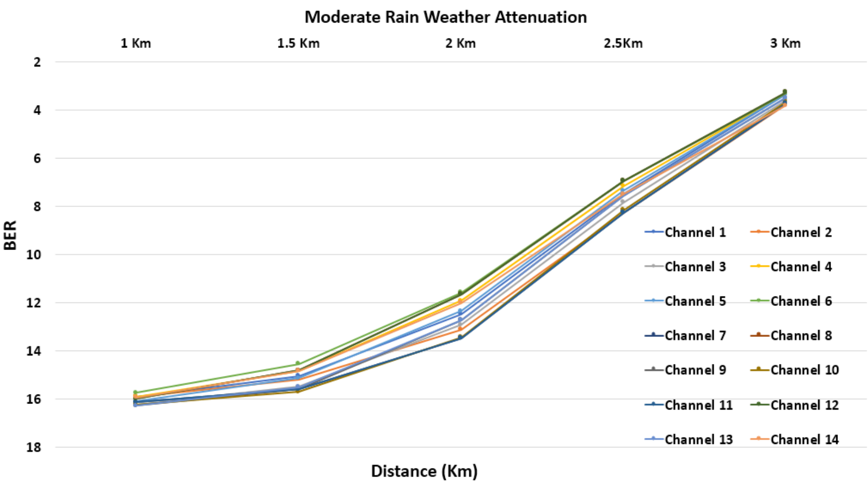

Fig. 3. Q-Factor results under the effect of moderate rain weather attenuation.

In the second experiment, we evaluated the hybrid CWDM and DWDM system over the FSO link under the effect of heavy rain weather attenuation. As shown in Figs 4 and 5, the evaluations were based on BER and Q-Factor over the distances (0.4 km, 0.8 km, 1.2 km, 1.6 km and 2 km). The findings at the distances 0.4 km-1.6 km) are acceptable in terms of the standard BER and Q-Factor value. However, at the distance 2 km, the results of BER and Q-Factor are not acceptable. Therefore, this study shows that we can transmit data of 140 Gbps until distance 1.6 km with perfect performance results under the effect of moderate rain weather attenuation.

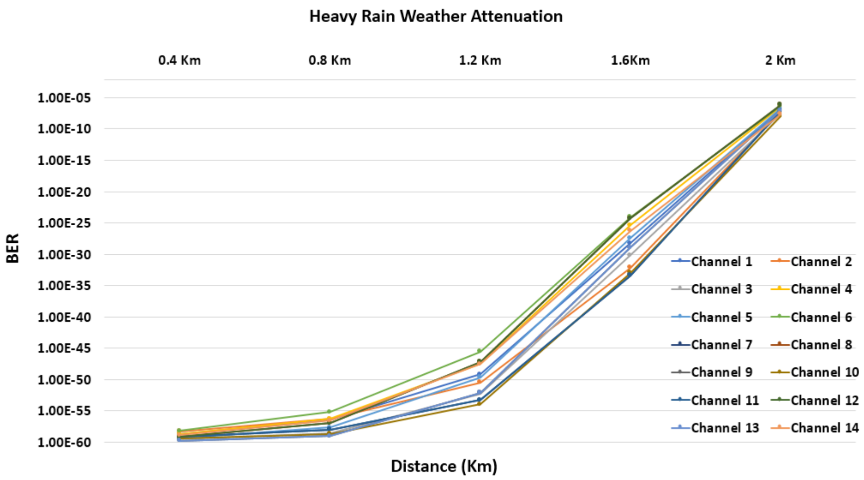

Fig. 4. BER results under the effect of heavy rain weather attenuation.

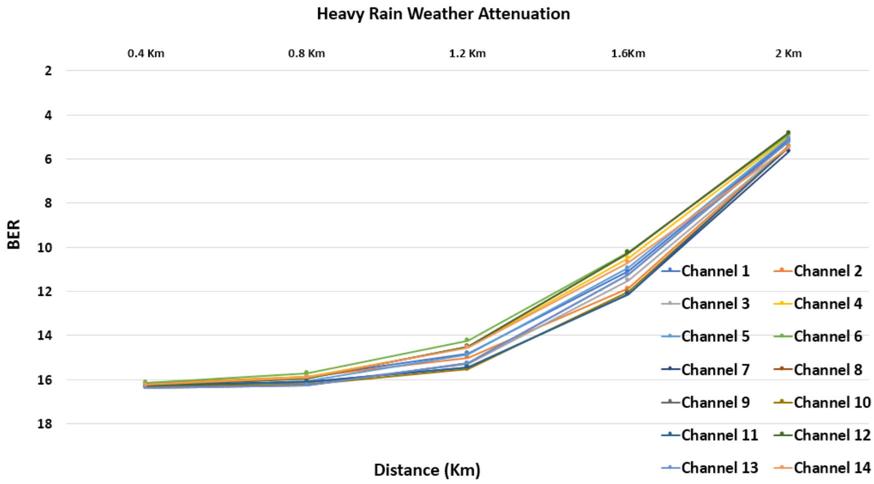

Fig. 5. Q-Factor results under the effect of heavy rain weather attenuation.

4. Conclusions

In this study, we successfully demonstrated 140 GB/s hybrid CWDM and DWDM over the FSO communication system at the distances of 2.6 km and 1.6 km for moderate and heavy rain atmospheric weather attenuations. Performance investigation on this designed hybrid CWDM and DWDM over FSO was carried out using NRZ modulation with different parameters, such as attenuation, and distance. In this study, Opti-system simulation has been applied to evaluate and present the performance results of hybrid CWDM and DWDM system over FSO link based on BER, and Q-Factor. Finally, as future work, the authors, this work will be extended by considering more atmospheric weather attenuations at different distances.

Abbreviations

BER	Bit Error Rate
CWDM	Coarse Wavelength Division Multiplexing
DWDM	Dense Wavelength Division Multiplexing
FSO	Free Space Optics
NRZ	Non-Return-to-Zero
Q-Factor	Quality Factor
WDM	Wavelength Division Multiplexing

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