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INVESTIGATION OF 8 x 5 GB/S MODE DIVISION MULTIPLEXING -FSO SYSTEM UNDER DIFFERENT WEATHER CONDITION

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Abstract

This paper proposes Mode Division Multiplexing (MDM) of Laguerre-Gaussian (LG) mode over Free Space Optics (FSO) communication under different weather conditions to achieve the maximum possible medium range. FSO is a unique technique for the communication between the transmitted signal and the received signal. Moreover, MDM transmissions are significant interest because of the potentially high number of modes that can be used in a single optical. MDM multiplexing supporting several modes propagate through optical transmission, spatial modes in MDM are utilised as independent channels that will carry various data streams. In this study, an 8-channel MDM-FSO system has been designed and analysed in different weather conditions at 1550 nm wavelength. The simulated system has transmitted 40Gbps up for a distance of 3000-meter FSO in superbly under clear weather condition. It also transmitted 40 Gbps up for a distance of 650-meter FSO during heavy rain. The BER measure the performance of different scenario of FSO based on MDM.

Keywords: Bit error rates, Eye diagram, Free space optics, Laguerre Gaussian, Mode division multiplexing.

1. Introduction

Free Space Optics (FSO), a license-free technology, offers a broader and unlimited bandwidth. It can be installed quickly at a lower cost compares to laying down fiber optic cable [1]. Based on that advantageous, it has emerged as a promising solution for the last mile bottleneck problem. An FSO is an upgraded transmission medium from the fiber optics. For one transmission line, instead of sending the data in a closed glasses path, it is transmitted through the air. FSO uses similar optical transceiver like that in optical communication technology, and it operates through free space, in full-duplex mode. In FSO, each optical wireless unit acts as a transceiver. It uses an optical source, with a lens or telescope that transmits lights through the atmosphere to another lens that receives the information. The receiving lens has very high sensitivity due to atmospheric effects by using optical [2].

However, it is exposed to various effects of noise in different weather conditions[3-5]. At the same time, the amount of data to be transmitted keeps increasing. Wang et al. [6] explains that it could be possibly handled by considering some major challenges at the transmitter like minding the modulation techniques, suitable light source, estimation of transmitting power levels, and wavelength transmission [7]. Accordingly, the demand for bandwidth in supports for numerous applications keeps increasing too, for a couple of years [2]. When the bandwidth is expanded, the transmission capacity of the FSO has enhanced accordingly, which is necessary in current video-based information dissemination world. There are various multiplexing techniques in optical communication that used to increase the capacity and transmission distance. Most of these multiplexing schemes based on time division multiplexing (TDM) [8] and wavelength division multiplexing (WDM) [9] have been used. Besides, orthogonal frequency division multiplexing (OFDM) [10].

Based on studies by Tripathi et al. [11], amongst many of the multiplexing schemes, mode division multiplexing (MDM) is a swiftly emerging as a potential candidate for increasing the aggregate bandwidth of current optical fiber systems. MDM multiplexing supporting several modes propagate through optical fibers transmission. Ho et al. [12] reported that an MDM is an optical communication method where spatial modes are utilized as information channels carrying independent data streams. In the other hands, eight mode are used in MDM to drive the propagation of a number of channels on different modes generated by various mechanisms such as spatial light modulators [13, 14], optical signal processing [15, 16], photonic crystal fibers [17], modal decomposition methods [18, 19], and few-mode fiber [9, 20].

Moreover, the electronic and photonic equalization schemes [21, 22] could possibly be explored and integrated into the system. The other scheme of optimization bee algorithm [23-25] that can be used in optical communication to improve distortion nonlinearly in future work.

In this study, the MDM of LG modes is designed with different diameters from vertical cavity surface-emitting laser (VCSEL) arrays [26-28]. The remaining parts of this paper are organized as follows: Section 2 presents the MDM simulation for LG modes over FSO. The discussion of the results for MDM simulation presented in detail in Section 3. Section 4 concludes the entire paper and identifies some future directions.

2. Simulation of Optical Mode Division Multiplexer for LG modes over FSO

Figure 1 exhibits the MDM architecture over FSO based on LG modes. According to Kadhim et al. [29], it is designed using Opt-system 7.0 software. A special optical transmitter is used to generate the input signal. It is based on non-return-to-zero (NRZ) modulation. The proposed architecture comprises of eight special optical transmitters that subcarrier over one wavelength (1550nm). It sends eight LG modes (LG 0 1, LG 0 2, LG 0 3, LG 0 4, LG 1 1, LG 1 2, LG 1 3, LG 1 4) transmitted over 40 Gbps through a 3000 meters-long FSO under different weather conditions. In opt-system simulation, there is a specific parameter, which is attenuation that can produce the weather condition. Different weather condition has a different value that invokes as listed in Table 1.

Referring to Fig. 1, the optical carrier in Channel 1 is set to LG mode LG 0 1, Channel 2 goes to LG 0 2, Channel 3 goes to LG 0 3, Channel 4 goes to LG 0 4, Channel 5 goes to LG 1 1, Channel 6 goes to LG 1 2, Channel 7 goes to LG 1 3, and Channel 8 goes to LG 1 4. It is also seen that the output of the eight channels are combined and transmitted through a free space of distances ranging from 1000 m to 12000 m under clear weather condition. The FSO transmitter and receiver aperture are set to 20cm, beam divergence is set 1μrad, and special optical transmitter power is 0dBm [30-33] in clear weather condition. After FSO, the eight special optical receivers were used to retrieve the signals from FSO. Results of the test are discussed in the following section.

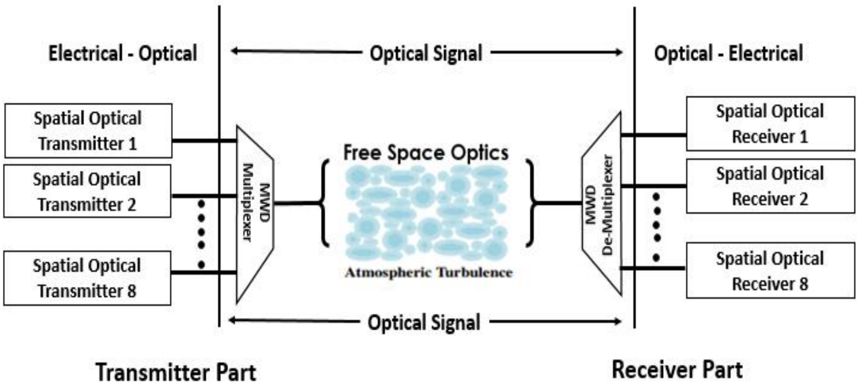


Fig. 1. Block diagram optical mode division multiplexer over FSO.

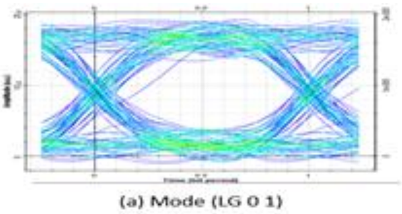
Table 1. BER for different weather condition with different FSO range.

Weather condition	Attenuation (dB/km)	Max-link-range (Meter)	BER
Very clear	0.15	3000 m	5.08986e-10
Clear sky	0.299	2700 m	4.55122e-12
Light rain	0.61	2500 m	1.23761e-11
Heavy rain	2.62	1700 m	3.44916e-12
Light haze	6.80	1150 m	1.68888e-10
Heavy haze	19.77	650 m	6.13106e-10

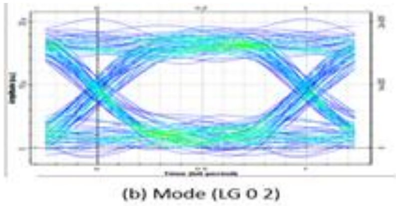
3. Results and Discussion

Clearly, the performance gets better along with the improvement of the bandwidth of the optical wireless communication system. Further, Fig. 2 and represent the Eye diagram with the eight LG modes in a clear weather condition, the eye diagrams exhibit good results.

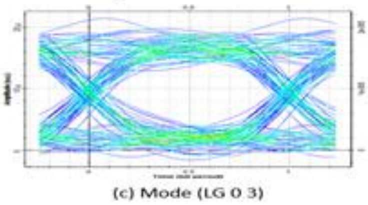
The value of t-he attenuation parameter that has been used in this study is based on the previous research in FSO, and the parameter has been changed in FSO properties in opti-system



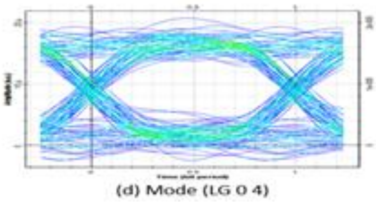
(a) Mode (LG 0 1).



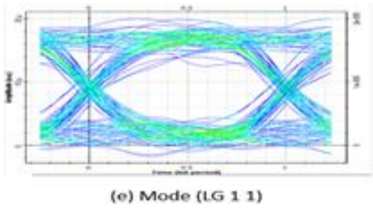
(b Mode (LG 0 2).



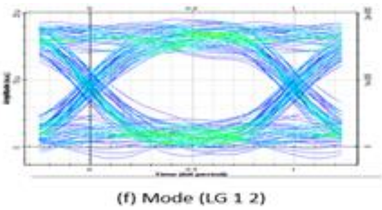
(c) Mode (LG 1 1).



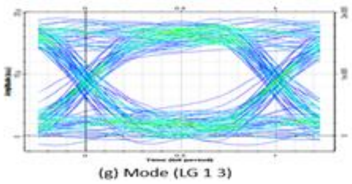
(d) Mode (LG 1 2).



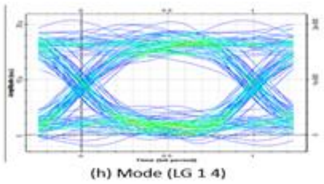
(e) Mode (LG 1 1).



(f) Mode (LG 1 2).



(e) Mode (LG 1 3).



(f) Mode (LG 1 4).

Fig. 2. Representing the eye diagrams of four channels.

Figure 3 represents the curves of the BER. It is seen that for BER 10-11, the transmission distance is up to 650 meters only when it is heavily raining and improves to 1150 meters when the rain is light. In a heavy haze, it is 1700 meters and improves to 2500 meters for light haze. When the weather is a clear sky, it goes up to 2700 meters. It then enhances to 3000 meters in very clear weather condition. These details are shown in Table 1. It can be seen that the increase in the distance of FSO make the BER curves decreases. Hence, it could be concluded that there is a coefficient in the BER and distance of data transmission. The different BER in the figure below is explaining the different result based on different condition. The best curve that is illustration very clear condition improves to 3000 meters and the second-best curve in clear (clear sky) weather condition is 2700 meters.

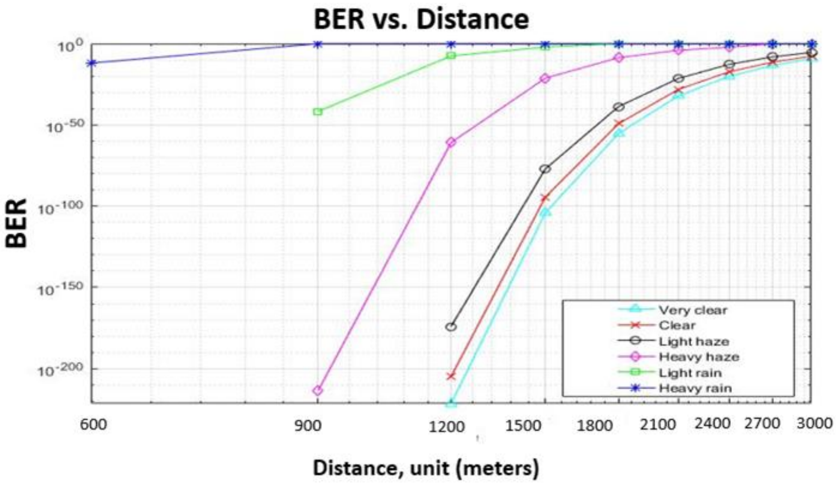


Fig. 3. BER result over a different range.

4. Conclusions

In this paper, the performance of BER over different distances of FSO in different weather conditions has been investigated. The results demonstrated that 8 x 5 Gbps MDM-FSO system is effective in improving the quality of data in an optical wireless communication system. Besides, the signals for all LG modes have been successfully simulated in the (Opt-system) simulation. This study has achieved 40Gbps data transmission over 3000 meters FSO very clear. Therefore, this improvement in performance has led to enhancement of the quality of the service.

- The performance of the optical communication system has been improved and validated based on BER and eye diagram over different weather condition.
- The capacity and distance after using MDM over FSO have been improved.

Nomenclatures

BER	Bit-Error Rates
FSO	Free Space Optics
LG	Laguerre Gaussian
MDM	Mode Division Multiplexing

NRZ	Non-Return-to-Zero
OFDM	Orthogonal Frequency Division Multiplexing
TDM	Time Division Multiplexing
VCSEL	Vertical Cavity Surface-Emitting
WDM	Wavelength Division Multiplexing

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