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Design and Analysis of High-Speed FSO for Supporting Fifth Generation under various weather scenarios

Mays Kifah Faeq [1], Alaan Ghazi [1], Mohammed U.Zaenal [1], Lana Omar [1], Ranjdr M. Rafeeq [1], Ibrahim Jasim [1],
Mohammad Sarwar [1], Ahmed Ghazi [1], Mustafa Nadhim [1]
Computer Technical Engineering, Al-Qalam university College, Iraq
Emails: mays@alqalam.edu.iq

Abstract:
5G is expected to change the mobile communications environment by boosting data throughput, improving energy efficiency, expanding coverage, and lowering latency. FSO is a high-capacity, efficient, and scalable 5G architecture for transmitting radio signals via optical communication, taking use of the massive bandwidth available. In this research design MDM over FSO in various weather scenarios. This paper investigated the performance of BER and Q-Factor over different distances of over FSO in various weather scenarios based MDM. This study has transmitted 30 Gbit/s based on three channels. Furthermore, the results demonstrated that 3x 10 Gbit/s MDM-FSO system (various weather scenarios) in an optical wireless communication system, it is useful at improving data quality.

Keywords: MDM, FSO, different weather conditions

1. Introduction

With the rapid increasing technology, multimedia and devices, many organizations are facing a high demand for increasing data rate and number of users, hosts and addresses [1-3] caused by the rapid growing volume of data (Audio, video streaming, VoIP, GPS etc) all over the world. However, surfing web pages, downloading songs, sending and receiving photographs with the current bandwidth that is provided by today's cable modem and Digital Subscriber Line (DSL) is not probably good enough [4, 5].

Although, the user demands are moving toward high bandwidth application whereby, TVs are attaining HD and applications are becoming interactively, web gaming and entertainment applications are merging and more computing applications are moving into the cloud which requires a huge bandwidth to accommodate those demands. Free space optical (FSO) communication is a rapidly evolving technology that can handle enormous amounts of data at a high rate. FSO communication systems are touted as a viable alternative to fiber optics technology, which can transmit data, voice, and video in full duplex in some applications. Even though light can be properly put into fiber cables to route light information, there are some applications where the only accessible method of establishing a communication link is the vacant space between the transmitter and receiver. Only a clean line-of-sight (LOS) path between the transmitter and the remote receiver is required for this open space technique [6].

In recent years, a lot of work has gone into optical fiber research to realize mode-division multiplexing (MDM) to enable further scaling of the communication bandwidth [2, 7, 8]. MDM capitalized the characteristics of modes to carry information in parallel form to be multiplexed using multiplexer tools then propagate through the FSO then received in the receiver components [6]. The main advantages here is that MDM will transmit a huge data [1],[9] within countless number of modes to overcome the limitation of data rate and number of users.

In MDM, the wide core size for coupling the existing multiple modes in FSO been used to increase the optical capacity and to dangle and facilitate the connector tolerances and reduce the cost of attaching the components to the laser (VCSEL). As discussed in [9, 10]. In addition as discussed in [11], they used all-optical based mode filters to filter selected modes [12] that will reduce the attenuation of undesired high-order modes and also to decrease the differential mode attenuation between the modes in MMF[13, 14].

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Ultra-high carrier frequencies are required for 5G radio services to provide sufficient bandwidth and coverage. In contrast to the previous four generations of wireless radio networks, convergence of the 5G radio interface and spectrum with the optical interface and spectrum is required to provide high data rates and seamless coverage to customers. Spectrum, energy, and cost savings are all important factors to consider [15].

2. System Description

In this section, a simulation of MDM over the FSO link under various weather scenarios. The simulation aims to get the most medium-range and FSO channels possible. Opti-system software is used to run the simulations (as shown in Figure 1) [16]. The MDM system is used to build the physical layer components for the FSO. The transmitter, free space optics, and receiver are the three components of the model. There are three parts to the transmitter: a data generator, an electrical generator, and a laser. The data generator is the initial component, and it consists of three data generators, each of which can carry 10 Gbit/s. As a result, the overall data generating speed is 30 Gbit/s. The electric generator, which was set (non-return-to-zero (NRZ)) for each data created, is the second component. The last component of the transmitter part is lasers, which consist of three lasers with three modes Laguerre–Gaussian (LG) modes. LG 01, LG 02, and LG 03 are the LG modes, which operate on one wavelength; 1550.12 nm. the link is based on FSO with different weather conditions. Following the FSO, a de-multiplexer is used to extract the signals from the FSO and send them to three light detectors, a Low Pass Gaussian Filter, and a BER and Q-Factor analyser.

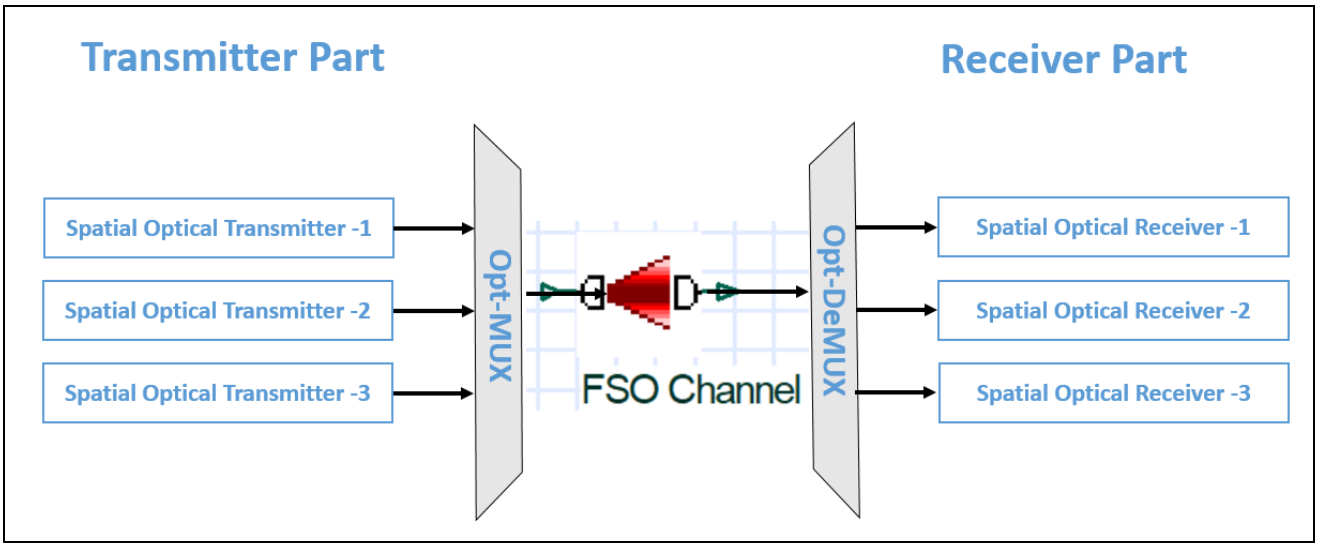

Figure 1 MDM over FSO under various weather scenarios

3. Results of MDM over FSO

The results of this study is based on Bit Error Ratio (BER), Q-Factor, and Eye diagram.

- Weather is very clear

This section shows the results of Q-factors as shown in Table 1, Table 2 in the case the weather is clear at a distance of 3 km, the results for channel 1, channel 2, and channel 3 are (28.0633), (31.4108), (31.086) for Q-Factor. At a distance of 6 km, the results for channel 1, channel 2, and channel 3 are Q-factors (9.94028), (11.5686), (11.4028). At a distance of 9 km, the results of channel 1, channel 2, and channel 3 are Q-factors (4.7192), (5.62183), (5.37334) At this distance the results were acceptable. At a distance of 12 km, the results of Q-Factor for channel 1, channel 2, and channel 3 are (2.62154), (3.18442) (2.9087). At this distance, the results were not acceptable. This section shows the results of BER as shown in table 4.1, table 4.2 in the case the weather is very clear. At a distance of 3 km, the results for channel 1, channel 2, and channel 3 are BER (1.29955e-173), (6.73153e-210), (1.72611e-212). At a distance of 6 km, the results for channel 1, channel 2, and channel 3 are BER (1.3738e-023), (2.91765e-031), (1.99131e-030). At a distance of 9 km, the results of channel 1, channel 2, and channel 3 are BER (1.1814e-006), (9.40311e-009), (3.85275e-006). At this distance the results were acceptable as shown the results of eye diagram for three channel in Figure 2. At a distance of

12 km, the results for channel 1, channel 2, and channel 3 are BER (0.00437641), (0.000724334) (0.00181309). At this distance, the results were not acceptable as shown the results of eye diagram for three channel in Figure 3.

Table 1 The results of Q-Factor for MDM over FOS under VERY CLEAR (0.15)

Channels	3km	6km	9km	12km
Ch1	28.0633	9.94028	4.7192	2.62154
Ch2	31.4108	11.5686	5.62183	3.18442
Ch3	31.086	11.4028	5.37334	2.9087

Table 2 The results of BER for MDM over FOS under VERY CLEAR (0.15)

Channels	3km	6km	9km	12km
Ch1	1.29955e-173	1.3738e-023	1.1814e-006	0.00437641
Ch2	6.73153e-217	2.91765e-031	9.40311e-009	0.000724334
Ch3	1.72611e-212	1.99131e-030	3.85275e-006	0.00181309

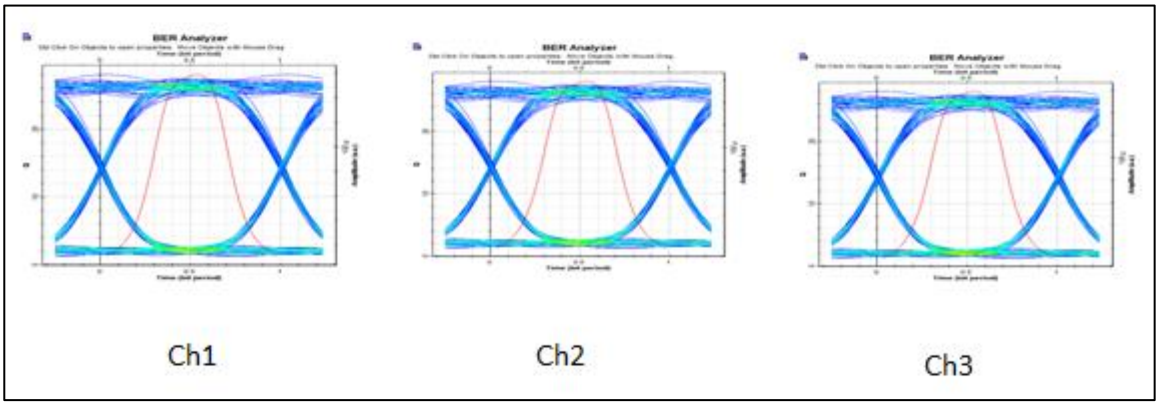

Figure 2 The results of Eye diagram for MDM over FOS under Very Clear (0.15) at distance 6 KM

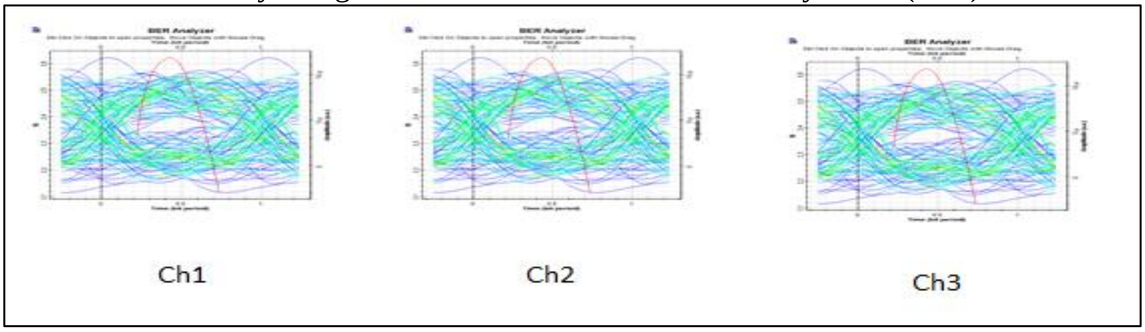

Figure 3 The results of Eye diagram for MDM over FOS under Very Clear (0.15) at distance 12 KM

- Weather is clear sky

This section shows the results of BER and Q-factors as shown in Table 3, Table 4 in the case the weather is clear sky at a distance of 2 km, the results for channel 1, channel 2, and channel 3 of Q-factor are (43.7552), (48.0552), (46.9537). At a distance of 4 km, the results for channel 1, channel 2, and channel 3 are BER and Q-factors (17.1202), (19.5235), (19.3999). At a distance of 6 km, the results of channel 1, channel 2, and channel3 are BER and Q-factors (8.41631), (9.84959), (9.66707). At this distance the results were acceptable as shown the results of eye diagram for three channel in Figure. At a distance of 8 km, the results for channel 1, channel 2, and channel 3 are BER and Q factors (4.67937), (5.57576) (5.32657). At this distance, the results were not acceptable as shown the results of eye diagram for three channel in Figure 5.

Table 3 The results of Q-Factor for MDM over FOS under CLEAR SKY (0.299)

Channels	2km	4km	6km	8km
Ch1	43.7552	17.1202	8.41631	4.67937
Ch2	48.0552	19.5235	9.84959	5.57576
Ch3	46.9537	19.3999	9.66707	5.32657

Table 4 The results of BER for MDM over FOS under CLEAR SKY (0.299)

Channels	2km	4km	6km	8km
Ch1	0	5.09779e-066	1.92694e-017	1.43586e-006
Ch2	0	3.32914e-085	3.39512e-023	1.22658e-008
Ch3	0	3.71305e-084	2.05602e-022	4.98935e-008

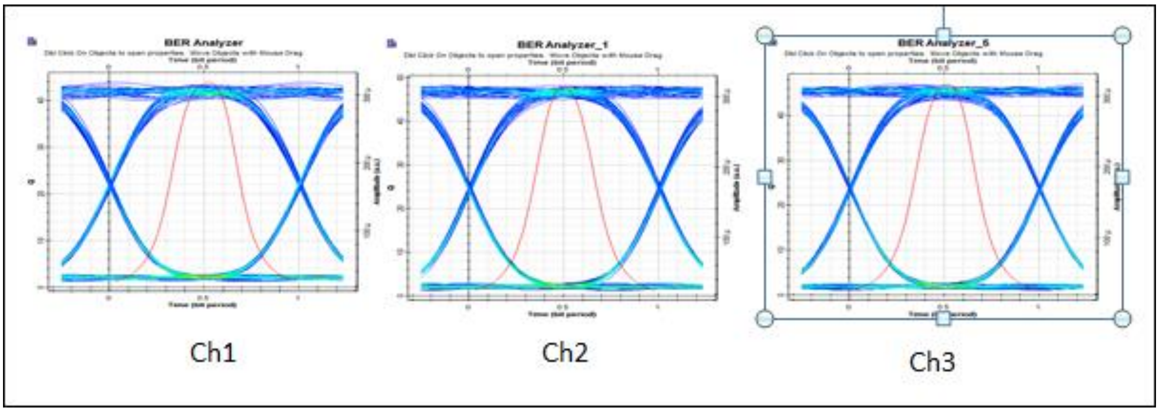

Figure 4 The results of Eye diagram for MDM over FOS under CLEAR SKY (0.299) at distance 6 KM

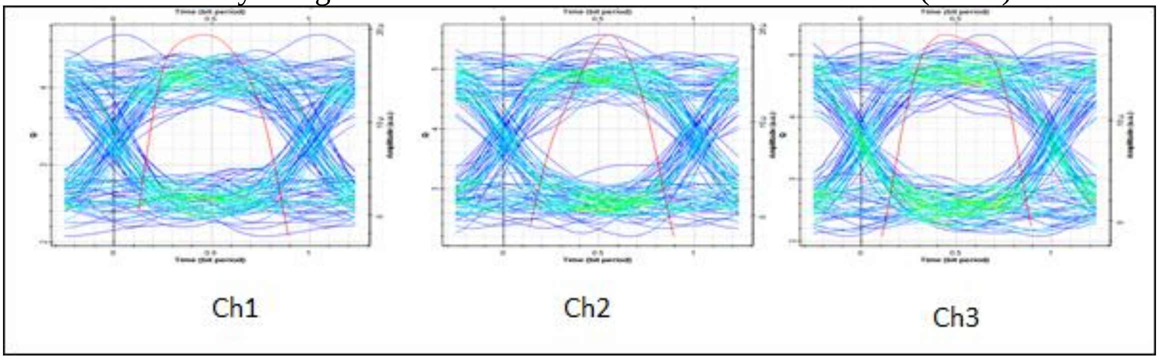

Figure 5 The results of Eye diagram for MDM over FOS under CLEAR SKY (0.299) at distance 8 KM

- Weather is light haze

This section shows the results of BER and Q-factors as shown in Table 5, Table 6 in the case the weather is light haze. At a distance of 5 km, the results for channel 1, channel 2, and channel 3 are Q-factor (13.836), (15.9045), (15.7748). At a distance of 6 km, the results for channel 1, channel 2, and channel 3 are Q-factors (5.88355), (6.96514), (6.73778). At a distance of 7 km, the results of channel 1, channel 2, and channel 3 are Q-factors (4.88355, 4.92314, 4.73438) at this distance the results were acceptable. At a distance of 5 km, the results for channel 1, channel 2, and channel 3 for BER (7.56622e-044, 2.86174e-057, 2.25169e-056), At a distance of 6 km, the results for channel 1, channel 2, and channel 3 are BER (1.9998e-9, 1.62865e-12, 7.99864e-12) the results is acceptable as shown the results of eye diagram for three channel in Figure.6. At a distance of 7 km, the results of channel 1, channel 2, and channel 3 are BER (1.2298e-5, 1.22865e-7, 7.94864e-7) at this distance the results were acceptable as shown the results of eye diagram for three channel in Figure.7

Table 5 The results of Q-Factor for MDM over FOS under light haze (0.61)

Channels	2km	3km	4km	5km	6KM	7Km
Ch1	84.1237	40.1832	22.686	13.836	5.88355	4.88355
Ch2	88.895	44.3076	25.5889	15.9045	6.96514	4.92314
Ch3	84.5911	43.4153	25.4135	15.7748	6.73778	4.73438

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Table 6 The results of BER for MDM over FOS under light haze (0.61)

Channels	2km	3km	4km	5km	6KM	7Km
Ch1	0	0	2.95061e-114	7.56622e-044	1.9998e-9	1.2298e-5
Ch2	0	0	9.59288e-145	2.86174e-057	1.62865e-`12	1.22865e-`7
Ch3	0	0	8.43839e-143	2.25169e-056	7.99864e-12	7.94864e-7

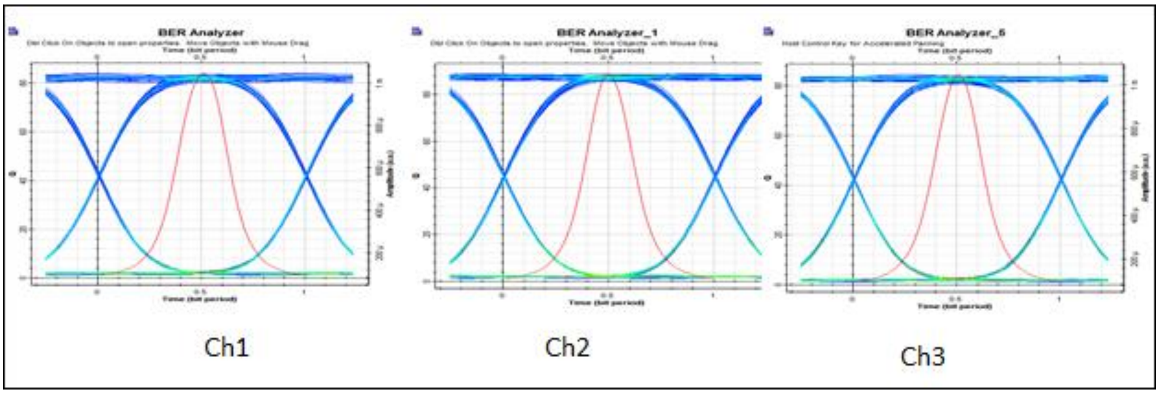

Figure 6 The results of Eye diagram for MDM over FOS under light haze (0.61) at distance 6KM

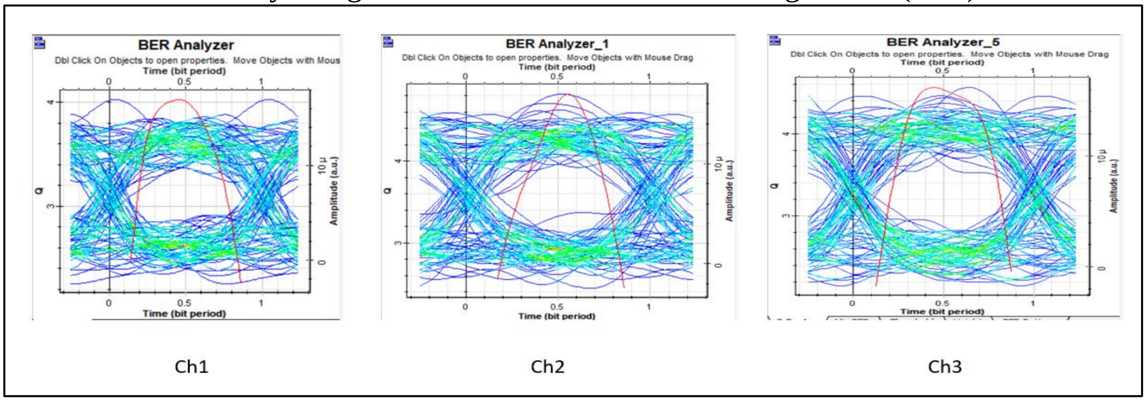

Figure 7 The results of Eye diagram for MDM over FOS under light haze (0.61) at distance 7 KM

- Weather under heavy haze

This section shows the results of BER and Q-factors as shown in Table 7, Table 8 in the case the weather is heavy haze At a distance of 1 km, the results for channel 1, channel 2, and channel 3 are Q-factor (66.4294), (71.2723), (66.4294). At a distance of 2 km, the results for channel 1, channel 2, and channel. At a distance of 3 km, the results of channel 1, channel 2, and channel 3 are Q-factors (7.92139), (9.28999), (9.09931). At this distance 3 km the results of Q-factors (22.1341), (24.9913), (24.8241) acceptable. At a distance of 4 km, the results for channel 1, channel 2, and channel 3 are Q factors (2.95393), (3.571580) (3.29681). At this distance, the results were not acceptable. Moreover, at a distance of 1 km, the results for channel 1, channel 2, and channel 3 are BER, (0), (0), (0). At a distance of 2 km, the results for channel 1, channel 2, and channel 3 are BER (7.12433e-109), (3.5998e-138), (2.32651e-136). At a distance of 3 km, the results of channel 1, channel 2, and channel 3 are (1.1652e-015), (7.62167e-021), (4.49839e-020), At this distance the results were acceptable as shown the results of eye diagram for three channel in Figure 8. At a distance of 4 km, the results for channel 1, channel 2, and channel 3 are BER (0.00156846), (0.000177134), (0.00048841). At this distance, the results were not acceptable as shown the results of eye diagram for three channel in Figure 9.

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Table 7 The results of Q-Factor for MDM over FOS under heavy haze (2.62)

Channels	1km	2km	3km	4km
Ch1	66.4294	22.1341	7.92139	2.95393
Ch2	71.2723	24.9913	9.28999	3.571580
Ch3	66.4294	24.8241	9.09931	3.29681

Table 8 The results of BER for MDM over FOS under heavy haze (2.62)

Channels	1km	2km	3km	4km
Ch1	0	7.12433e-109	1.652e-015	0.00156846
Ch2	0	3.5998e-138	7.62167e-021	0.000177134
Ch3	0	2.32651e-136	4.49839e-020	0.00048841

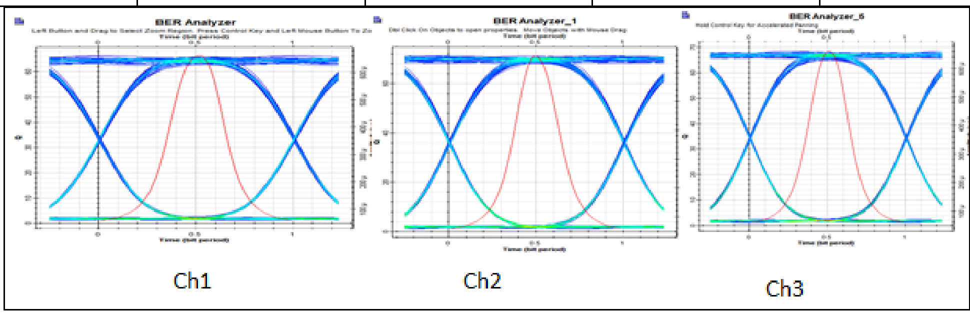

Figure 8 The results of Eye diagram for MDM over FOS under heavy haze (2.62) at distance 3 KM

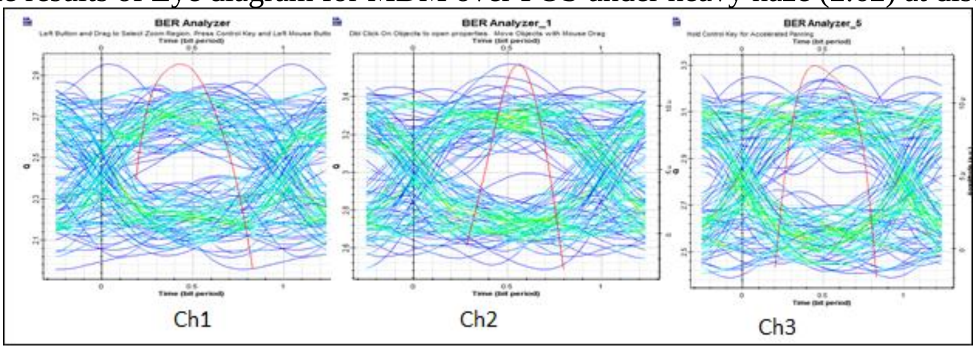

Figure 9 The results of Eye diagram for MDM over FOS under heavy haze (2.62) at distance 4 KM

4. Conclusion

This paper investigated the performance of BER and Q-Factor over different distances of FSO in different various weather scenarios based MDM. This study has transmitted 30 Gbit/s based on three channels. Furthermore, the results demonstrated that 3x 10 Gbit/s MDM-FSO system (various weather scenarios) in an optical wireless communication system, it is useful at improving data quality. Finally, the performance has been validated by measuring and analysing eye diagrams, Q-Factor and BER.

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