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Analytical performance evaluation of MIMO-FSO under meteorological turbulence using link range, bit rate and transmitted power

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Abstract

In order to fulfill our modern world demand, Free Space Optics (FSO) is developed. And (multiple input multiple output) MIMO-FSO systems have been put in place to analysis and implement the exhaustive achievement for transfers the data in wider bandwidth and in the form of light waves to achieves higher data rate transmission using different encoding schemes executed with four various communication channels. The various meteorological turbulence such as wind, snow, fog, rain, etc significantly affected MIMO-FSO transmission medium performance as means of reception and transmission FSO system employ direct detection and intensity modulation. MIMO-FSO systems simulation has been analyzed as a function of link range, bit rate and transmitted power, however, FSO widespread growth has been restrain by reliability issues and availability. With consideration to the value of Q. Factor, Eye Diagram and BER. The Simulation results characterize that MIMO-FSO system play a good solution with meteorological turbulence. Compare to the low power and minimum distortion for long distance While maintaining reliability. The result displayed that RZ is the preferable type of modulation accommodate a large value of Q-factor. while NRZ allocate on top of Q-factor values in case in MIMO-FSO. It is precious noticing that improving the achievement of MIMO-FSO system is highly dependent on the Meteorological turbulence, specially by link range, bit rate and transmitted power. However, noting this performance increasing led to cost and complexity also increases.

Keywords: *BER (Bit Error Rate), Q-Factor, Free Space Optics (FSO), Meteorological Turbulence, Eye Diagram, MIMO (Multiple Input Multiple Output)*

1. Introduction

The semaphore system used in the year 1792 to transmit a message among two separated towers was poor and limit. Not so long at the end of 18th century the innovation of optical telegraph assists in communication over long distances and served a lot of purposeless starting from transforming bank money [1]. Over the last few decades, the established technologies like Radio Frequency (RF) systems that used for data and voice communication is not enough, especially with the needs of the users are also growing and the advancement in the technology, therefore, higher bandwidth is the main demand of these requirements [2]. Due to a relatively increase population in the last forty years, a wide range of technology, such as radio systems (RF) have been appear Since cost and capacity limit the electro-magnetic RF spectrum band, with the demand of heavy data and ever-increasing popularity, the provider of RF bands has fallen short, compared to the needs of the users that has growing and required higher bandwidth as a main demand specially with the invention of intranet between compose and university that required a big network capacity the RF cannot obey[3]. Until the innovation of laser as a viable substitutional trustworthy source of light. In 1905 Albert Einstein describe stimulated emission to be known the first working laser and then in 1960 used by Theodore Maiman to introduce the laser technology as a milestone for optical era in which take the science to the invention of optical communication depending on fibers optic cable, but with large attenuation of 100 dB/Km [4]. Later in 1970 by using pure silica of fiber the loss was decreased to 20 dB/Km. And the

decrement continues as the fiber manufactory industry developed generation by generation and become in 1990, the loss of reach 0.2 dB/Km only [5]. Figure 1 shows the fiber-wireless integration [6].

Therefore, communication using Fiber optic has obtained huge space for various telecommunications technology [7,8]. Starting from telegraph systems passing through DSL and PSTN until now days. The transmission capability of wired systems for long communication is always rapidly increasing because about 600% to 700% of user are added to the internet that generate extra load and demand as shown in figure 2. That needs the state-of-the-art technology Dense Wavelength Division Multiplexing (DWDM) as a cable connection. Therefore, communication using Fiber optic has obtained huge space for various telecommunications technology [9,10]. Starting from telegraph systems passing through DSL and PSTN until now days. The transmission capability of wired systems for long communication is always rapidly increasing because about 600% to 700% of user are added to the internet that generate extra load and demand as shown in figure 2. That needs the state-of-the-art technology Dense Wavelength Division Multiplexing (DWDM) as a cable connection.

The FSO technology that developed by the NASA and military.is comparatively unprecedented and supply almost comparable transmission capabilities and bandwidth as fiber optics [12]. FSO was originally from the last decade FSO communication in all over the world has been widely investigated and uses unregulated frequency 300 GHz and above, which is worldwide unlicensed and therefore, do not need license fees. With other several advantages, such as low cost, immunity to electromagnetic interference, high capacity and secure data transmission and finally high bandwidth. FSO uses line of sight (LOS) communication system as shown in figures 1,2 [13]. So, it works over short distances due to atmospheric turbulences. and commercially unpopular, against usual fiber optic techniques are done by transmitting the pulses of light over glass fiber for long distance, but a lot of money and time wastage to loss in digging the roads to lay fiber cable. The world record bandwidth stands for FSO communications system is or 1200 Gbps [14]. Higher speeds can be obtained by correct setup and use multiple channels acting like separate wavelengths [15]. The FSO provide connection technology between satellite which is almost ideal and can connect ground to satellite links along with the terrestrial link and this is when it gets more terrible it is substantial to pick a few numbers of FSO parameters while examining FSO performance, these consideration parameters can be split in to two main parts, external parameters and internal parameters [16,17].

External parameters are related to operate system environment. Internal parameters include receiver field of view (FOV), receiver sensitivity and BER on receiver side and optical loss, Divergence angle, bandwidth, wavelength and optical power on transmitter side [18]. To eliminate the geometrical fading, highly precise tracking system is introducing to track the optical beam narrow in FSO links to obtain the link interval [19]. A lot of techniques are still under development by several investigators to cut the tracking trouble the FSO system endure from phenomenon known as random fluctuations that happened because of space layers in inhomogeneous shape called atmospheric turbulence [20,21]. However, accomplishment of FSO system is restricted by different reason, like stringent orientation requirements, scintillations, haze, fog and atmospheric turbulence. Thus, led to determination in transmission distance to cover and eventually reduce signal-to noise ratio (SNR). Between them, when come to atmospheric turbulence's is severally affected fog compared with rain and snow. FSO main utilized in satellite telecommunication significance is in terrestrial transaction as a wireless communication [22,23]. FSO is connect short and long range line of sight (LOS) links, and performed when it is impossible to make physical connection as shown in figure 3. However, FSO still required a few improvements to work perfectly in the bad meteorological turbulence [24,25]. FSO network contained both of GEO and LEO scenarios the atmospheric attenuation conditions change from 0.066 dB/km in the situation of extremely clear weather to 127 dB/km in the situation of dry big snow.Presence of H2O and CO2 molecules in the diffusion way of the signal led to absorption of the information signal. similarly, because of differential heating led to fluctuations in the strength of the signal in the receiving side and therefore, Random divergence in the refractive index of the atmospheric [26]. To spatial confinement of the light rays FSO use a very narrow beam to inherent security and a high reuse factor not forget to mention the benefit of robustness to electromagnetic interference generated by laser source. at an altitude of 25 km a remarkable increase turbulence has been found [27]. Thus, led to fade signals in size of several milliseconds even. unlike clouds and Fog, their affect shorts in altitude below 12 km which affect the long-haul optical links by different in index-of-refraction turbulence (IRT) caused by fading and not forget link blockage caused by obscuration.

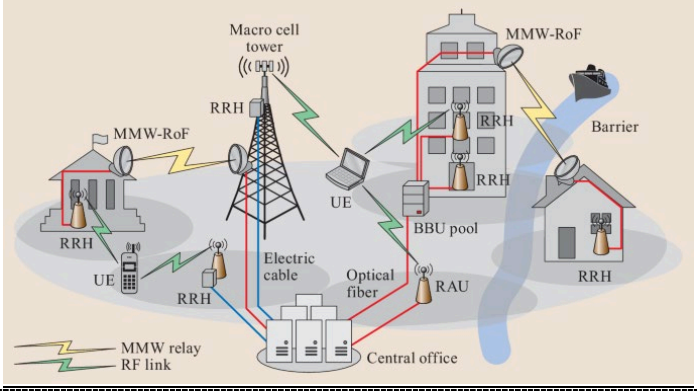

Fig. 1: Fiber-wireless integration [6].

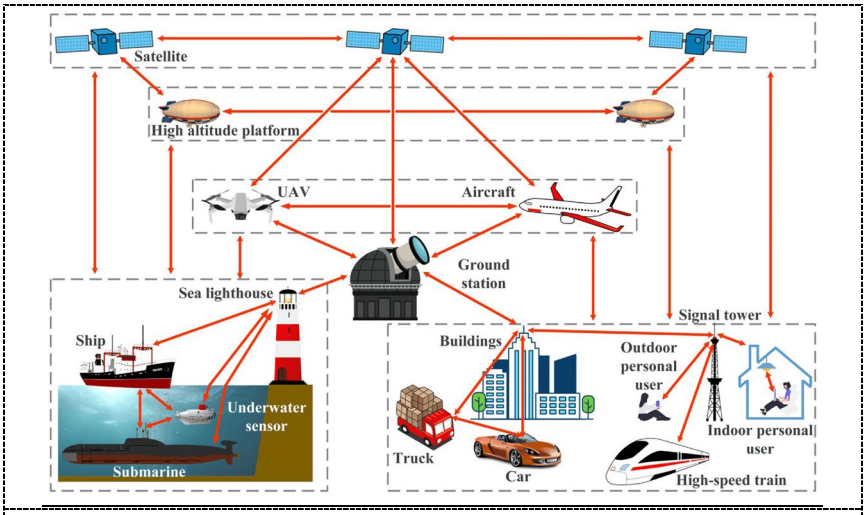

Fig. 2: The wide communication scenario implicates in next generation [11].

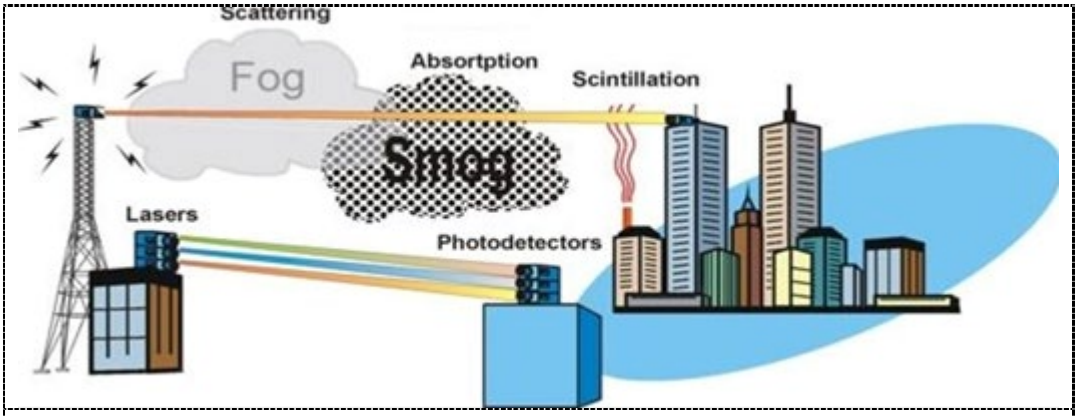

Fig. 3: Terrestrials' connection in FSO system [28].

2. Material and method

MIMO-FSO Block Diagram System is Simplified and shown in figure 4. Which have been simulated using OptiSystem program. The FSO system consists of three main parts first the transmitter includes data source, modulator, driver, laser diode and optics lens. Second the channel part which either a fiber optic or in our case air (FSO) with all trouble in it as we will see. And third the receiver which consist of receiving optics, photo detector, amplifier, demodulator and data sink as shown in the figure 5 below the sequence of data is generated from a generator named pseudo random bit sequence (PRBS) in the transition side. Then a various modulation type like (DRZ,CSRZ and NRZ,MDRZ, RZ) are work as a light source modulator .Which have been analysis in terms of Q-Factor, eye diagram and BER for various meteorological turbulence like rain, fog, haze and clear weather After passing the FSO conditions the receiver side consisted of the usual component for receiving any signal and demodulator it and to appear the Q-factor , BER and eye diagram(a low-pass Bessel filter, a BER analyzer and PIN photodetector). While distance is change from 0.25 Km to 5 Km Q-Factors and BER decreases as distance increases for all type of modulation. still CSRZ get the best result in Q-Factor it ranges from 11.9 to 14 a like the MDRZ that get the minimum Q-Factor passing through the same distance the result shows to as many facts like for example for hazy weather condition for the same distance the Q-Factor for DRZ and CSRZ at every distance point is equal to each other but in hazy condition FSO system for all different modulation formats performs well till distance range 3.75 km the BER become 1.

For light rain the systems work effectively for all type of modulation till 2.75 Km and after 3.25Km, Q-Factor become lower than 6 and near to 0. Medium and heavy rain has huge negative influence on the FSO systems accomplishment, specially the heavy in the contrast to light rain. the system is efficiently work until range of 2 Km in medium and 0.25 in heavy rain and after that Q-Factor is 0 and BER is 1. Fog turbulence has the second worst influence on the effectiveness of the FSO system after the heavy rain for all type of modulation used above the foggy system performs effectively only till 1Km range and after that, the BER of the system become 1. Continue the DRZ and CSRZ modulation formats has nearly the same number for BER with almost the same change in all kind of rain and fog.

Then the CSRZ-FSO, which accomplish a very good Q-factor but RZ give a better accomplishment compared to NRZ and CSRZ up to 3.75 km and then low power that NRZ and RZ have nearly the same outcome, meaning RZ and NRZ as the attenuation increases, their effectiveness turns into equal.

Therefore, the schematic of the pulse shaping for CSRZ NRZ and RZ show increase in attenuation value until heavy rain, dense fog and dense rain which None of the results are obtained due to distortion.in our multi-channel system The implementation of, NRZ, RZ and CSRZ is done with four channels that analyzed and absorbed the change in the link range, bit rate and transmitted power in this system. The Data rate analysis to obtained a bigger data transition with few costs diversified from 1.5 Gbps to 6 Gbps.

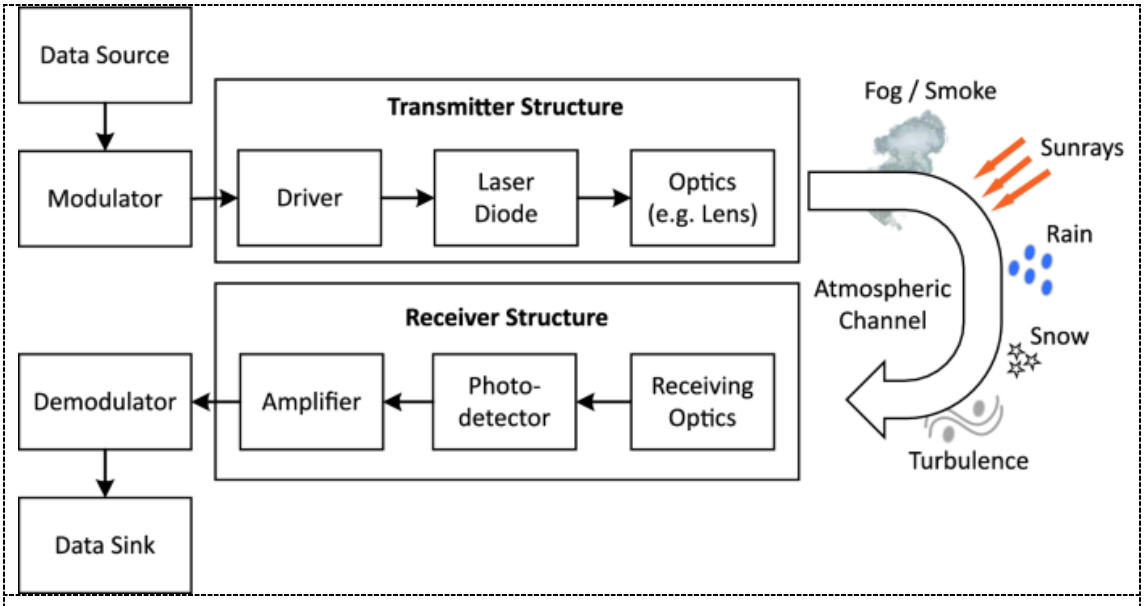

Fig. 4: Block diagram of FSO system.

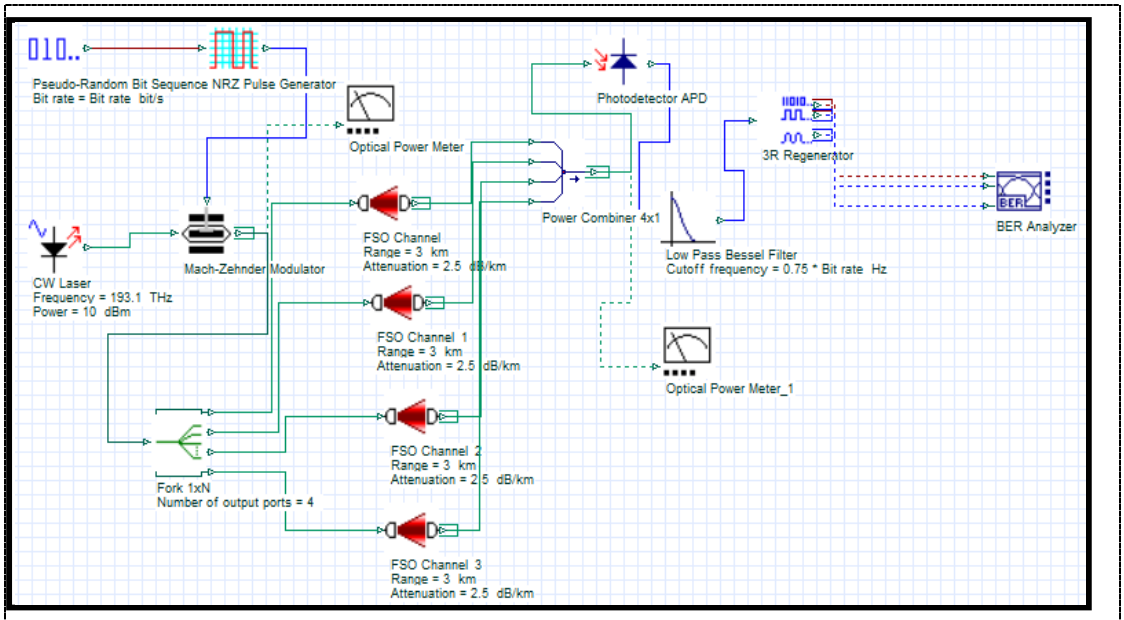

Fig. 5: Block diagram of FSO system in optisystem.

3. Result and discussion

This work introduces a full dissection of effectiveness of FSO system by changing transmitted power, bit rate and link distance for various type of modulation (like NRZ, MDRZ, CSRZ, DRZ, RZ). It is concluded that in situation of dense snow heavy rain and dense fog, establishing a communication is not possibility close. Unlike other situation like haze, little fog and light rain.

As we all know the system achievement is good when signal to optical noise ratio is high and this come from decrease of maximum BER or increase in Q-factor. In our design we analysis the data receiving capacity of a specific system we chose it for a purpose and we use eye opening method to determine the minimize of data error. The eye opening method produces less jitters of the signal It output less jitters from the signal. in addition, the time variant detected the signal is measured by the length of eye opening when observing reduction in data distortion in the amplitude an Increase of eye opening will

appear, moreover to indicate the system sensitivity in the time error we examine the rate of eye sampling time. The transmitter of optical spectrum at 8 Gbps is shown in figure 6 equal to -8dBm. with a wireless channel wavelength 1390 m. This signal power at the receiver part after spread through the entire system it reduces to about - 32dBm. as shown in figure 7.

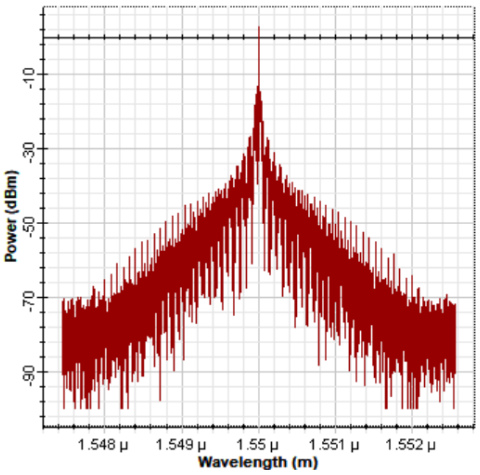

Fig. 6: Input spectrum of optical transmitter.

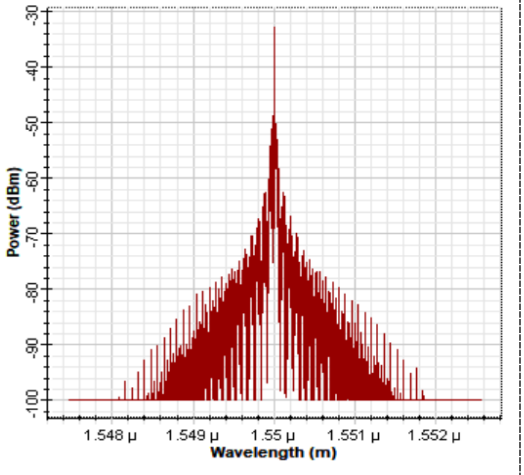

Fig. 7: Optical spectrum of receiver.

Figure 8 display the eye diagram shape of the link range from 0 m to 6600 m with Q-factor respectively. (a) display a clear eye diagram opening for clear whether, (b) for haze, (c) for little rain and (d) for little fog. However, the eye diagram for Fog shows little drastically disturb or clumsy.

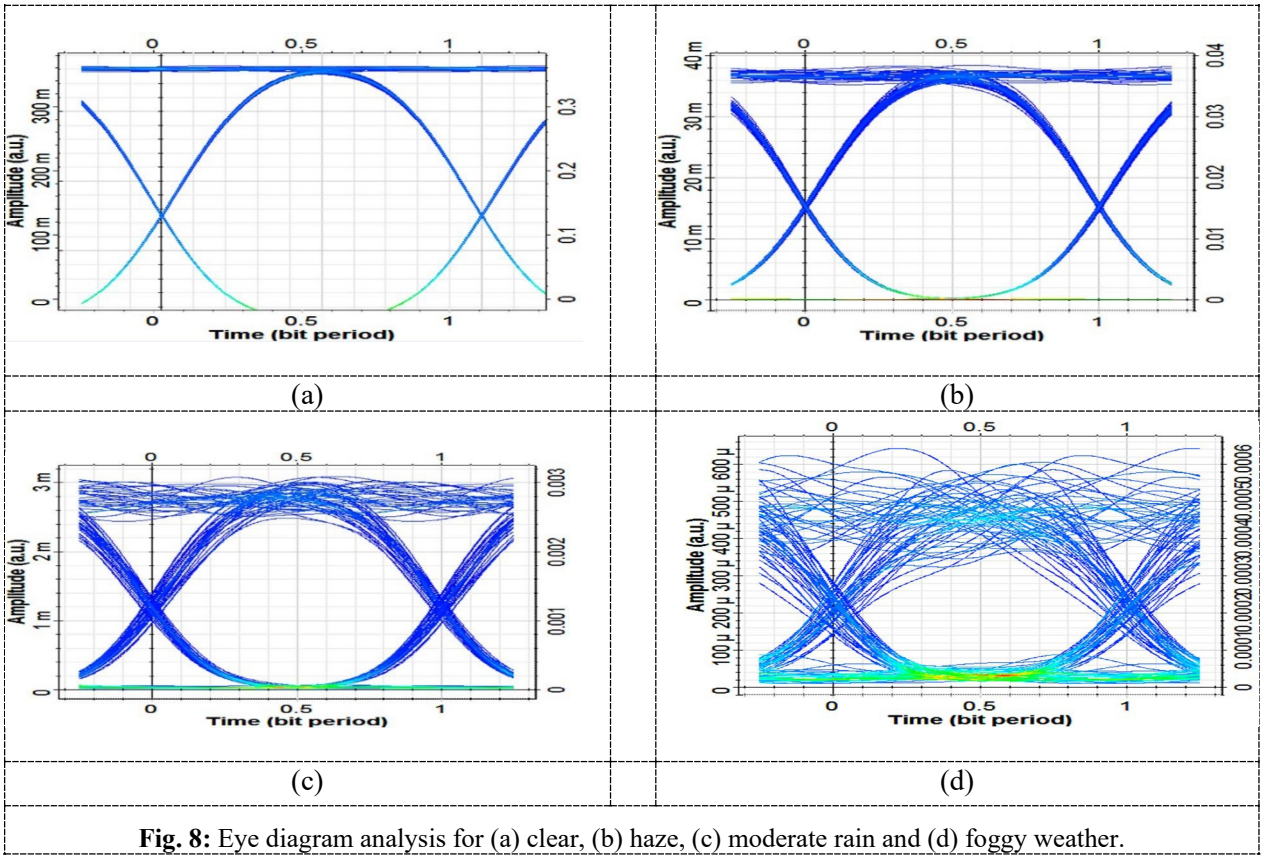

Fig. 8: Eye diagram analysis for (a) clear, (b) haze, (c) moderate rain and (d) foggy weather.

Figure 9 shows the bad weather condition for five conditions that were previously explained. Their results were measured on all types of modulation and the results were shown for the q- factor and according to the best modulation RZ for multichannel system

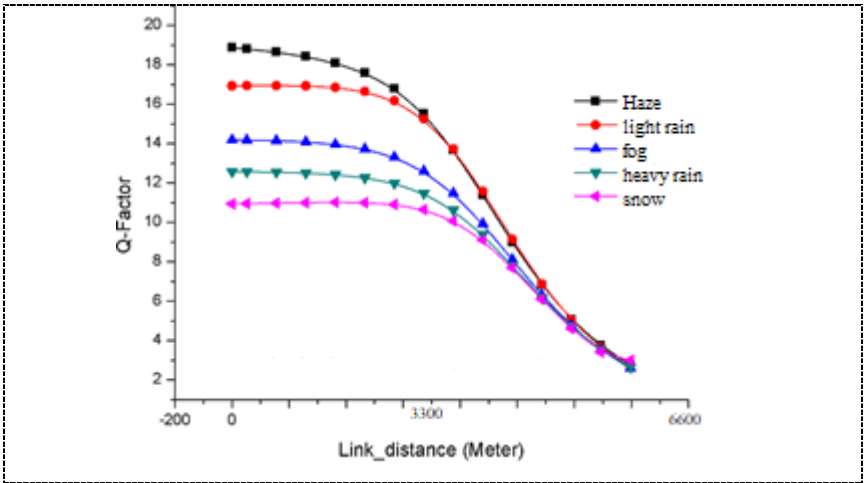

Fig. 9: The behavior for each whether condition in case RZ modulation.

In the figure 10, the results end to insure the CSRZ modulation keep up it is preferable as compared to MDRZ and even to DRZ in the short distance only than it critically decrease compared to MDRZ and DRZ. In the same time CSRZ continuing to maintain its superiority in quality factor and at all distances over the RZ and NRZ.

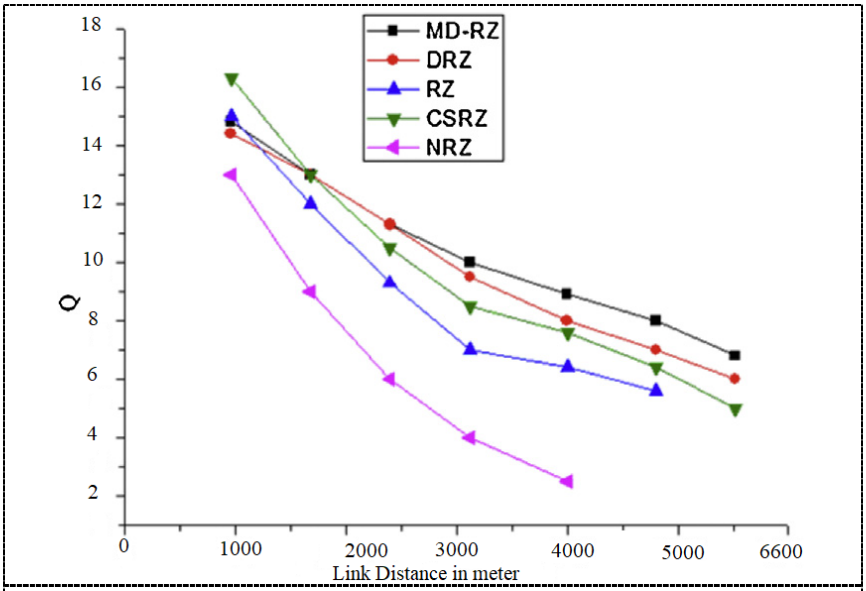

Fig. 10: The behavior for whether condition in various modulation.

4. Conclusion

This paper evaluates different modulations like MDRZ, DRZ, and CSRZ used in FSO system to measure the effect of rain, haze, clear weather and fog, etc on the effectiveness of FSO communication system by analyzing the change in the link range, bit rate and transmitted power. It has been noticed that, the CSRZ performs excellent result in case of clear weather. While NRZ is the most vulnerable between the other type of modulation under the same parameters and conditions. But still fog affects the FSO very much compared to other weather condition rain, mild rain, haze and medium rain etc. The analysis starts on single channel system without mention any kind of nonlinearity or distortion. The result display that RZ is the excellent type of modulation accommodate a large value of Q-factor. While NRZ allocate on top of Q-factor values in case in MIMO-FSO. It is precious noticing that improving the achievement of MIMO-FSO system is highly dependent on the Meteorological turbulence, specially by link range, bit rate and transmitted power.

finally, Simulation results under turbulence conditions shows that the order in MIMO diversity increase when link reliability increases and BER decreases. Relatively mean with a particular Q-Factor, BER value more distance can be covered. moreover, we noted that distortion decreases as diversity order increase, in addition the Eye Diagrams shows decreasing in the synchronization errors / sensitivity to timing. However, noting this performance increasing led to cost and complexity also increases.

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