

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

Simulation and Comparative Analysis of (SISO over MIMO) FSO Communication Channel

Dr. Shehab A. Kadhim¹, Dr. Alaa H. Ali², Kanat M. Abdul Hussain³

Laser & Optoelectronics Research Center, Ministry of Science & Technology, Iraq¹

Dept. of Electrical Engineering, Al-Technologyia Univ., Iraq^{2,3}

ABSTRACT: Free Space Optical (FSO) Communication has developed to cover long distance with the growing needs of high speed. Its data transmission technology from one point to another by using laser carrying information in free space. Multiple of transmitters and receivers (MIMO) is used to improve the performance of (FSO) communication system and its quality at different weather conditions. In this paper, simulate and analyze the performance of (MIMO-FSO) configurations under clear, haze and fog weather conditions was implemented using (OptiSystem7.0) software, and compare the results with single input single output (SISO-FSO) technique. MIMO take benefit from the spatial diversity and receive multiple independent copies of the same signal at the receiver, hence the performance was analyzed by the received power, the bit error rate (BER) and Q- factor. From the measured data the visibility was calculated, which is the main factor for quality and estimation for the reliability and availability of FSO link.

KEYWORDS: FSO, SISO, MIMO, OptiSystem 7.0, Visibility, BER and Q-Factor.

I. INTRODUCTION

Free space optics (FSO) communication is a promising technology, that uses light sources and detectors to send and receive information through the atmosphere. The motivation for FSO is to eliminate the cost, time, benefit of high data rates (up to 1 GB/s and beyond) for transmission of data, voice, video and images. In addition, operating at unlicensed optical wavelengths, will provide broadband capacity and high security because of their directivity, their low cost and more compact equipment have emerged these systems as a complement to microwave and radio frequency (RF) counterparts[1].

Despite their important advantages, there are some detrimental effects, firstly, they need clear as well as alignment (LOS). Secondly, the link's performance sensitive to various weather conditions. In this case, the terrestrial (SISO-FSO) channel provide a considerable complicated environment, with attenuators like scintillation, fog, ambient light, snow, and rain, which all of them are contributing to reduce the practical capacities, however the main challenge is the high vulnerability to the variations of optical intensity [2]. For the system performance to be improved by employing MIMO technology can be significantly improve the data capacity through spatial multiplexing by increasing the numbers of points at the transmitter and/or receiver [3]. The MIMO technology cannot only increase the data rate but also improve the system reliability through spatial diversity [4].

II. THE ORETICAL CONCEPT

One of the challenges of the FSO channel which can lead to link failure and signal loss is the atmospheric attenuation. In addition, scattering and turbulence phenomena have a high affection on the transmitted signal's power. Atmospheric attenuation due to scattering is modeled for various weather and particle's size conditions. Kim, Kruse

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

[5] and Al-Naboulsi [6] are some of the famous models that treated the effect of scattering on the transmitted beam of the FSO channel .

$$P_R = P_T \exp(-\alpha Z) \quad \dots\dots (1)$$

The coefficient of atmospheric attenuation " α " depends on the sort of scattering, signal wavelength, the size of the particles of the atmosphere and the link visibility as represented by Kim's Model given by [5]:

$$\alpha = \frac{3.912}{V} \left(\frac{\lambda}{550nm} \right)^{-q} \quad \dots\dots (2)$$

That V is the visibility (in km) and "q" is the size distribution of the scattering particle. We must know the particle size "q", and by Kim's model, the parameter "q" takes the given values that are varied in accordance with the various weather conditions [5].

$$q = \begin{cases} 1.6 & \text{if } V > 50km \\ 1.3 & \text{if } 6 km < V < 50 km \\ 0.16V + 0.34 & \text{if } 1km < V < 6km \\ \dots & \dots \\ V - 0.5 & \text{if } 0.5 km < V < 1km \\ 0 & \text{if } V < 0.5 km \end{cases} \quad (3)$$

III. MIMO WIRELESS CHANNEL

MIMO technology is the most generally used in wireless communication systems as shown in Figure (1), because it gives a large increase in link range and data throughput without additional bandwidth or transmitted power. It transmits the required power over antennas to achieve the array gain, which improves the efficiency. It enhances link reliability also and decreases the fading effect. Because of these merits of MIMO technique, it becomes a very important part of modern wireless systems [7].

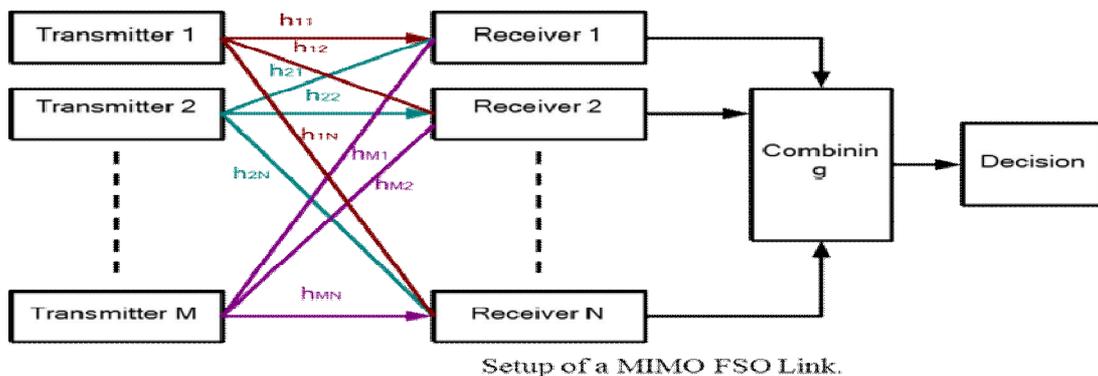


Figure (1): MIMO system with M transmitters and N receivers.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

It's well-known that the using of MIMO channel provides the performance gain, in comparing with the SISO communication scheme, that the transmitted power is unchanged. An FSO as SISO channel was integrated into (OptiSystem 7.0), and a MIMO system of 4 units is modeled to enhancing the performance of FSO link. The SISO and MIMO constructions are modeled with the basic components of the FSO as shown in Figure (2).

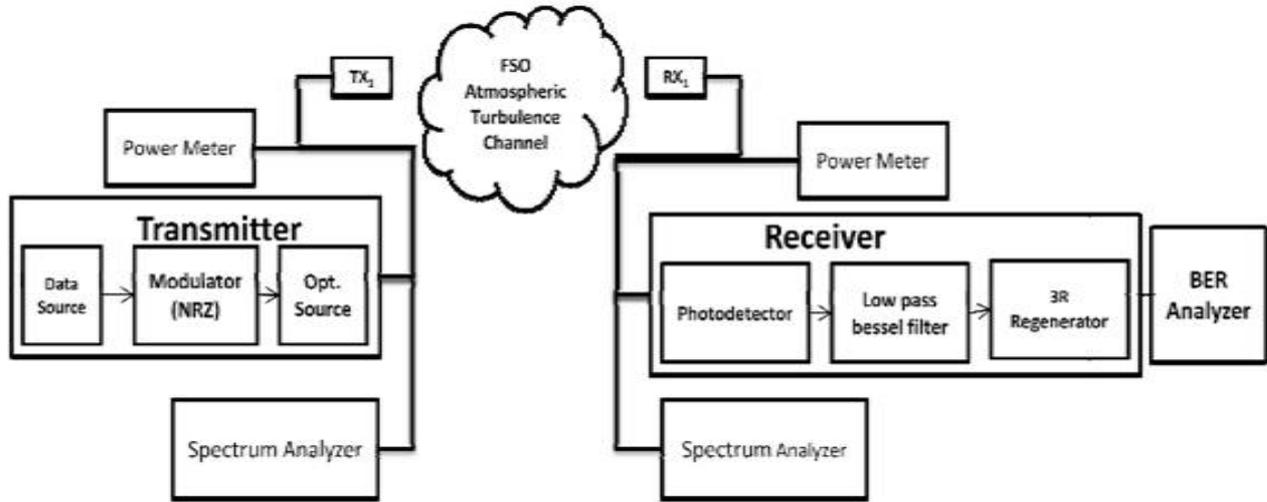


Figure (2): Design model of Single-Input Single-Output free space optical system

The widely used measure of performance is (Q-factor) that represents the signal-to-noise ratio (SNR) at receiver decision circuit, BER that gives the upper limit to signal before some degradation introducing to it at the receiver, and the eye opening that considers only samples at optimum sampling instants. The last parameter is the difference between the minimum value of those samples decided as logical "1" and the maximum value of those decided as logical "0". On the other hand, the value of BER can be calculated mathematically as:

$$BER = \frac{1}{2} \operatorname{erfc}\left(\frac{Q}{\sqrt{2}}\right) = \frac{1}{Q\sqrt{2\pi}} \exp\left(-\frac{Q^2}{2}\right) \dots (4)$$

IV. SIMULATION RESULTS AND DISCUSSION

Based on the above system model, the FSO link behavior, for multiple MIMO technique sizes at strong turbulence in non-homogeneous version of the operating environments was evaluated. Performance simulation of the link at 1550 nm wavelength and a distance "L" of 1.5 km with NRZ code and APD receiver at different weather conditions is carried out. Optical power meter and BER analyzer are used to determine the received and transmitted signal power levels and the system BER. The visibility under different weather conditions are as presented in Table (1) [8], while table (2) shows the values of attenuation based on the Kim model for various visibility values and according to the mathematical model previously discussed. Weather conditions of the atmospheric have a noticeable effect on the FSO links, and that affect is related to "q" the size distribution of the scattering particles and to "V" the visibility. In addition, they affect the power levels of the signal due to the FSO dependence on the operating wavelength.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

Table 1. Visibility range values under different weather conditions.

Weather Condition	visibility (km)
Thick fog	= < 200
Moderate fog	300-700
Light fog	0.8 – 1000
Thin fog/heavy rain(25mm/hr)	1000 – 1800
Haze/medium rain(12.5mm/hr)	2000 – 4000
Clear/drizzle (0.25mm/hr)	18000– 20000
Very clear	23000 – 50000

Table 2. Atmospheric attenuation at wavelength 1550 nm for different weather conditions.

Weather Condition	Attenuation (dB/km)	
Clear air high visibility ($v=23$)	0.1	4.2872
Haze ($v=2$km)	15.5633	25.5
Light fog (0.8)	43	
fog (0.6)		
Moderate fog (0.2)		
Heavy fog (0.2)		

Table (3) presents the system parameters which used in simulating the FSO link with the aid of (Optisystem 7.0).

Table (3):ParametersusedinFSOsimulation

Parameter (Symbol)	Value
Operating signal wavelength (λ)	1550 nm
Transmission Rate	1.25 Gbps
Link Distance (z)	2.5, 25 cm
Optical Transmitted Power (P_T)	0 dB
Transmitter and Receiver Apertures (D_T, D_R)	3 dB
Transmitter and Receiver Gain	1
APD Photodetector Gain	
APD Responsivity	$0.75 \times$ Bit rate
APD Dark Current	
Low Pass Filter Cutoff Frequency (at receiver)	

Figure (3) presented SISO link simulation design, while Figure (4) presented MIMO link simulation design using Optisystem 7.0 software.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

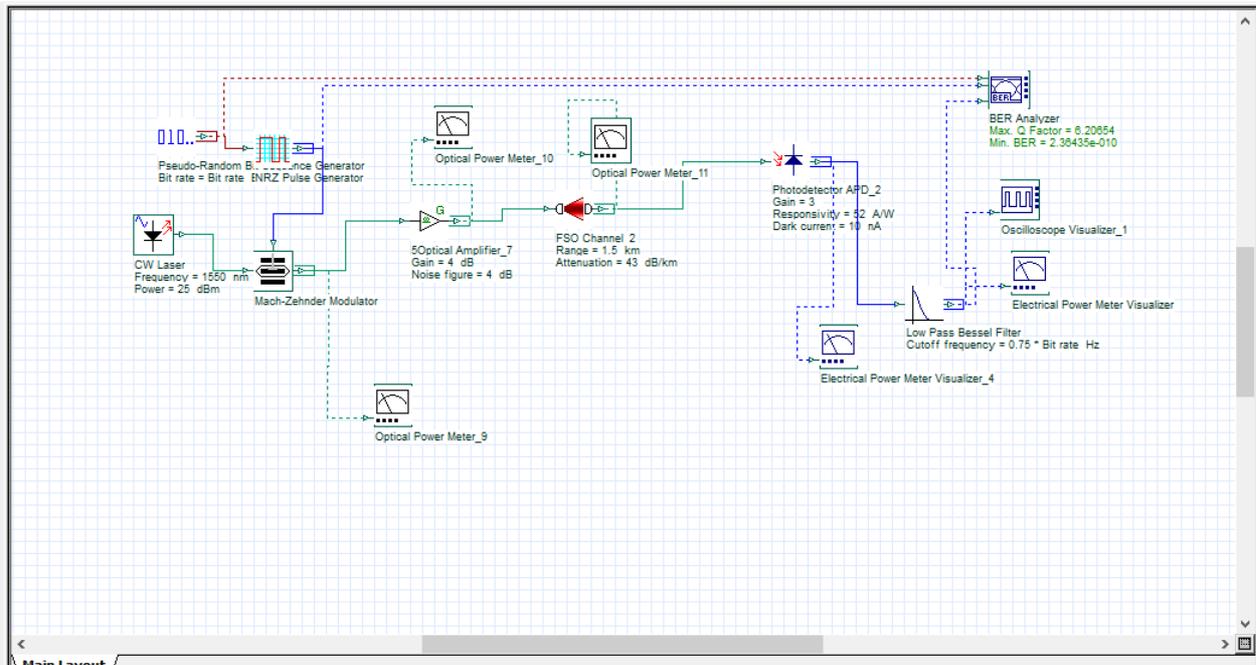


Figure (4): MIMO link simulation design using (Optisystem 7.0) software.

Figure (5) shows the relationship between the number of units of the MIMO systems and the received power for various weather conditions. It is seen that, in all cases the power of the received signal enhances as the size of the MIMO system increases. In other words, using MIMO technique will improve the level of the received power. On the other hand, the improvement in the behavior of FSO starts at a two elements (2x2) MIMO.

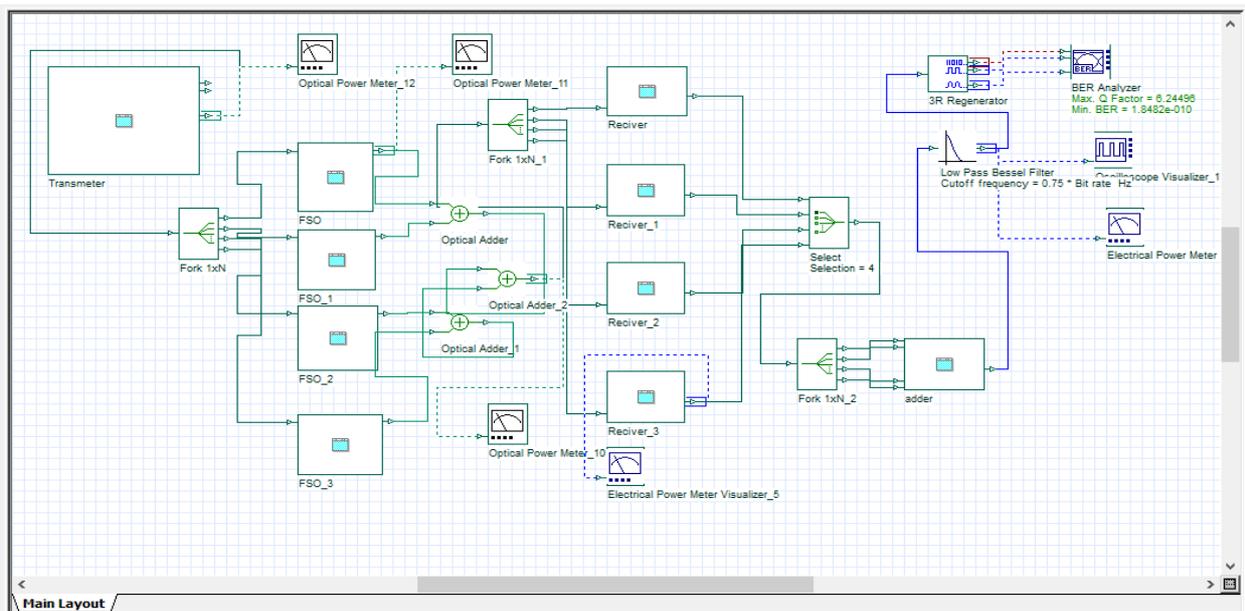


Fig.5-Received power vs. size of MIMO system in different weather condition

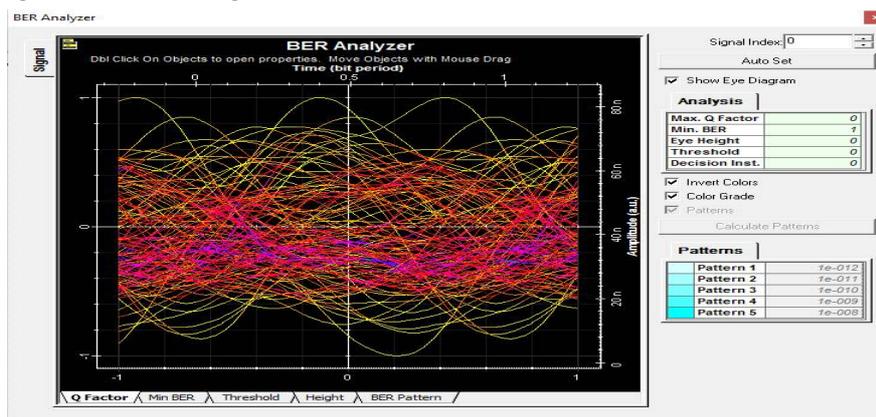
International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

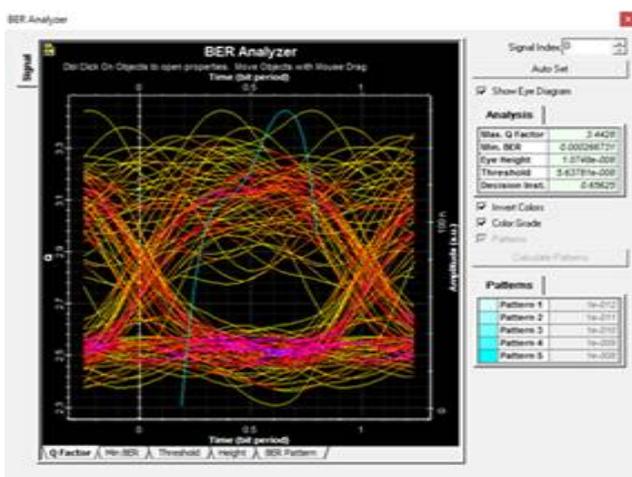
Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

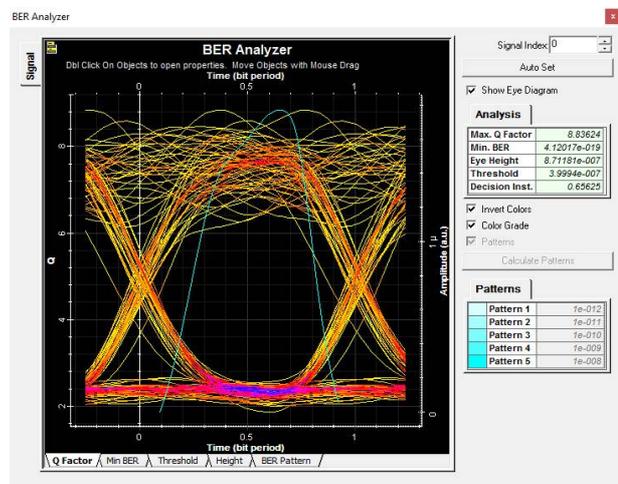
Now, to show how the size of the MIMO can affect the behavior of the FSO system, figure (6) for the SISO and 4x4 MIMO combinations in a heavy weather condition at a distance of 1.7 km apparent that increasing the number of MIMO units will increase the eye opening owing to the reduction in the signal jitters. A wider eye opening means that the occurrence of the errors in data is reduced. Generally, the wider the eye opening is, the better the system performance becomes. In addition, it is noticed that as the number of transmitters and receivers increases, the size of eye opening increases and the resulting jitter decreases, and for SISO system, there is no splitting of power and the size of the eye opening is very small. In this situation, the established link is bad. On the contrary, the MIMO technique enhances the performance of FSO network and as the size of the MIMO system increases, the improvement in the quality of the FSO link becomes better. Performance evaluation of a link at 1550 nm, with NRZ line codes (NRZ line code achieves a better performance than RZ by providing a higher receiving a signal and better BER) and APD receivers under different weather conditions is numerically computed. Figure (6.a) shows the output received power versus the wavelength for SISO and Figure (6.b & c) MIMO scheme with two (2x2) and four units (4x4), respectively.



(a)



(b)



(c)

Figure (6): Eyediagram for heavy Fog weather condition at (950 m) (a) SISO, (b) 2x2 MIMO, (c) 4x4 MIMO

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

At the worst weather conditions, the loss factor of atmospheric attenuation increases and this affects the received power. A graph is plotted to demonstrate the variation of the element number of a MIMO system (at 1.5 km and 43 dbm) with the Q-factor and it is illustrated in Figure (7).

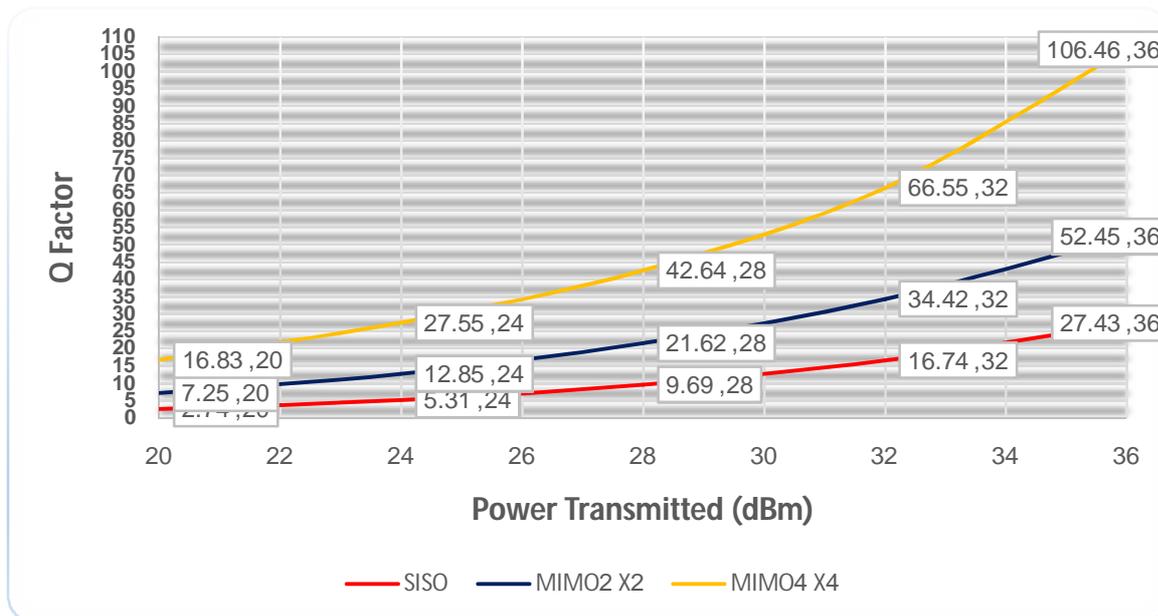


Figure (7):Q-factorvs.transmittedpowerfor 1.5 km with heavy fog weather condition.

It is clear that the element number of a MIMO system plays an important role in its performance, where 4x4 MIMO system gives Q-factor higher than for 2x2 MIMO and SISO procedures, respectively. The minimum values of transmitting power required to establish a communication channel for 1.5 km and different weather conditions and several sizes of MIMO system are listed in Table (4).

Table (4):Minimum power required for operation in different weather conditions at (1.5Km)

NO.OF MIMO	Minimum required value of transmitted power (dbm)		
	Haze : 4.3 dbm	Light fog: 25.5 dbm	Heavy fog: 43 dbm
1x1 MIMO	-31dbm	4.5dbm	34.5dbm (2.818 w)
2X2 MIMO	-28.5dbm	-7.5dbm	19 dbm (79.43 mw)
4X4 MIMO	-44dbm	-13.2dbm	12.8dbm (19.05 mw)

By performing simulation, and as listed in the table above, the minimum value of transmitted power required in establishing different successful communication channels is calculated. It seems that in strong turbulence situations, the transmitted powers required for establishing a communication channels are 34.5dbm (2.818 w) to SISO system and 12.8 dbm (19.05 mw) to MIMO system, and one can get a Q-factor of 89.38 by MIMO system with the same level of the transmitted power (34.5dbm) of the SISO system at the strong turbulence situation.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

Demonstrates the effect of the scattering particles (in the case of different weather conditions) in the maximum distance required to establish the communication channel of different systems is listed in Table (5).

Table 5. Calculated max. distance of varies systems at wavelength 1550 nm for (25 dbm transmitted power and attenuation of different weather conditions)

Weather Condition	Attenuation (dB/km)	Visibility at 1x1 MIMO (km)	Visibility at 2X2 MIMO (km)	Visibility at 4X4 MIMO (km)
Clear air high visibility	0.1	215	260	305
	4.3		12.3	13.8
Haze	25.5	11	2.59	2.78
	43		1.62	1.75
Moderate fog		2.38		
Heavy fog		1.5		

An attesting to the designed system (by Optisystem 7) at a very turbulent weather to find the maximumattenuation that every system will establish its communication (1Km) channel length is 1km as shown in Table (6).

Table 6 : Q-Factor vs BER at 1Km & 25 db for diffirent systems atturbulent weather

NO.OF MIMO	(58 db)		(73 db)		(80 db)	
	Q	BER	Q	BER	Q	BER
1x1 MIMO	6.193	2.57 e-10	2.734	0.002	0	1
2X2 MIMO	47.231	0	7.231	2.04 e-013	2.299	0.01
4X4 MIMO	94.588	0	24.439	2.43 e-132		2.01 e-0106.231

V. CONCLUSIONS

The link of MIMO wireless optical is a multi-element link that exploits spatial diversity to achieve gains in reliability and spectral efficiency. So, this paper is devoted to analyze the design of the MIMO FSO link. Different weather conditions, including the difficult ones are treated in the operation of such a link which employs NRZ and APD in its receiver. For this link, the power loss due to various weather conditions is evaluated by Optisystem program and results are displayed graphically and by tables. The results demonstrate that MIMO enhances the performance of FSO system and the enhancement increases as the size of its elements augments where the received power is ameliorated. The displayed results would provide a useful approach for the optimization of diversity configurations to maximize channel capacity of MIMO FSO links over a different atmospheric turbulence conditions.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

REFERENCES

- 1-Xu F, Khalighi MA, Bourennane S. (Pulse Position Modulation for FSO Systems: Capacity and Channel Coding) International Conference on Telecommunication. 2009;31–38.
- 2-Strohbehn J. (Laser beam propagation in the atmosphere) New York: Springer; 1978.
- 3- Navidpour SM, Uysal M, Kavehrad M. (BER Performance of Free-Space Optical Transmission with Spatial Diversity) IEEE Transactions on Wireless Communications. 2007; 6(8): 2813-2819.
- 4- Peng Deng, Mohsen Kavehrad, Zhiwen Liu, Zhou Zhou, XiuHua Yuan. Capacity of MIMO free space optical communications using multiple partially coherent beams propagation through non-Kolmogorov strong turbulence. Optics Express. 2013; 21(13):15213-15229.
- 5- Kim II, McArthur B, Korevaar E. (Comparison of Laser Beam Propagation at 785 nm and 1550 nm in Fog and Haze for Optical Wireless Communications) In: Proc. SPIE. 2001; 4214:26-37.
- 6- Awan MS, Marzuki E, Leitgeb F, Nadeem Khan MS, Capsoni C.(Fog attenuation dependence on atmospheric visibility at two wavelengths for FSO link planning. Loughborough Antennas & Propagation Conference) UK. 2010;193-196.
- 7- Abolfazl Chaman-Motlagh, Mehdi Mofidi.(Error and channel capacity analysis of SIMO and MISO free-space optical communications) Conference on Electrical Engg. Tehran, Iran. 2012; 20: 1414-1418.
- 8 -Zhu X, Kahn J. (Free space optical communication through atmospheric turbulence channels) IEEE Trans. Communication. 2002; 50(8): 1293–1300.