DISTURBANCE ANALYSIS AND COMPARISON OF FSO ITERATIVE ADAPTIVE CHANNEL USING MIMO IN WDM MODULATION UNDER DIFFERENT ATMOSPHERIC CONDITIONS

K.J.Darshin Daniel[1], C.Meena[2]

[1]Student, Dept of ECE, GCE- Tirunelveli, TamilNadu ,India
[2]Professor,Dept of ECE, GCE- Tirunelveli, TamilNadu, India

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Abstract - *Free space optics (FSO) is a Optical communication technique that starts to evolve the world into a modernized society by securing and fast transmissible of data through air medium without much contamination of the environment by transmitting a high power laser beam through free space. Wavelength Division Multiplexing (WDM) combines the data from different carrier signals into a single signal using non-ideal wavelengths with larger bandwidth. FSO communication is implemented by using 4 different Multiple Input Multiple Output (MIMO) channels i.e.,(2x2,4x4,8x8 &16x16) and a amplifier series using adaptive optimization, a technique that grands an advantage over an varying environment such as rain, mist, fog, etc., that causes the attenuation of the signal and analyse the result by various factor such as BER and Quality factor vs Distance, data rate and attenuation using Optisystem16.0*.

Key Words: **Free Space Optics (FSO), Wavelength Division Multiplexing (WDM), MIMO Channel, Bit Error Rate(BER), Quality Factor.**

1. INTRODUCTION

Optical Communication has been a major contributor in the development of modern 21st century. With improvement in the modern technology the usage of spectrum bandwidth creates a major issue. Data Privacy and Encoding are beginning to be major problem in cybernetic world developments. FSO technology brings a solution to this problem by transmitting the data through the air medium with help of the Laser or any other optical signal for transmission.

1.1 Free Space Optics Communication

Currently, Free Space Optics is capable of several Giga bits of data, voice and video communications through the air, which allows optical connectivity without requiring fiber-optic cable or securing spectrum licenses. Communication links typically operate between the 780 – 1600 nm wavelengths bands and use Optical to Electric and Electric to Optic converters. FSO requires light, which can be focused by using either light emitting diodes (LEDs) or lasers (light amplification by stimulated emission of radiation.

FSO communication is consider as an alternative to radio relay link line-of sight (LOS) communication systems. FSO communications can provide high data rates in Gbps range through the atmosphere for range from a few hundreds of meters to a few kilometers. FSO channel is considered to be air medium where atmospheric attenuation factors plays a major role.

1.2 Challenges in FSO Channel

Loss in the FSO system happens due to attenuation caused by different weather conditions and the Line of sight of the signal transceived. Attenuation is a telecommunications term that refers to a reduction in signal strength commonly occurring while transmitting analog or digital signals over long distances, Signal attenuation within the optical fibers is usually expressed in the logarithmic unit of the decibel. Decibel is defined by the input and output power ratio of the signal for a specific operating wavelength. The overall signal attenuation is defined by the number of dB, which is expressed as given below

$$dB = 10 \log_{10} (Pin/Pout)$$

The atmospheric attenuation in FSO communication system is mainly caused by the Mie scattering and local weather condition. The atmospheric attenuation is time-varying and will depend on the current local conditions and weather.

In general, the atmospheric attenuation is given by the following Beer's law,

$$\tau = e\ \beta L$$

where β is the total atmospheric co-efficient, contributed by absorption and scattering and L is the distance between the transmitter and receiver.

2. Proposed System

The four models of FSO links are four different number of channels (2x2,4x4,8x8,16x16) operating at a wavelength of 1550nm by using different modulation formats i.e. NRZ and RZ. The FSO system consists of transmitter, propagation medium and receiver which is shown in fig. 3. The free space channel between the transceiver is the propagation medium that is use to transmit the light signal. Optical wireless communications uses light at near infrared frequency to communication.

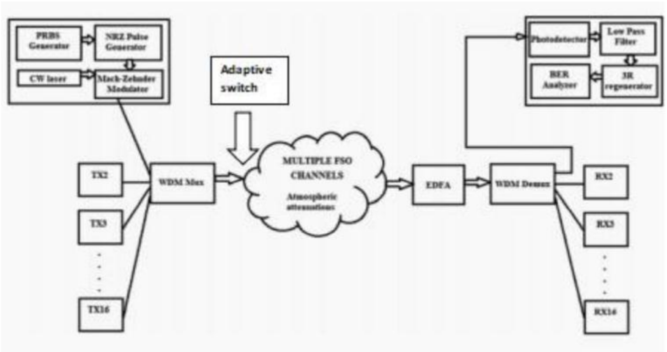

Fig – 1: FSO Block Diagram

The FSO system is not much different from fiber optic communication where the difference relies in the propagation medium. In the Optisystem 16 software, the FSO channel is model between an optical transmitter and optical receiver where the attenuation takes place. The adaptive channel optimization is achieved with the help of a switch circuit that chooses the path which has inline amplifier that activates the amplifier circuit based on the visibility of the channel, thus optimizing the channels performance by adaptive optimization. Attenuation occurs due to presence of different atmospheric disturbances in the channel that is analyzed by considering standard attenuation values for different atmospheric condition.

Table -1: Standard Attenuation Values

For Different Atmospheric Codition(in dB/km)			
Rain	15	Dust	7
Haze	7	scintillation	1.5
Fog	25	Snow	20
Clear Weather	2		

FSO communication (FSO) channel which used for propagation of signal in the channel, which attenuates the signal in presence of the environment. FSO channel has a attenuation value that varies based on different atmospheric conditions they are standardized using different laws and practical stimulation that produce the following table:

S.No	Atmospheric Condition	Attenuation(dB/km)
1.	Rain	15
2.	Haze	4.5
3.	Snow	20
4.	Fog	25
5.	Clear Weather	1
6.	Turbulence	1.5
7.	Dust	7

3. Result and Discussion

A FSO Adaptive channel is designed with help of Optisystem simulator that compares different Bit Error Rate(BER) and Q factor for different atmospheric conditions across different MIMO Channels at a data rate of 2Gps operating at a modulating frequency of 1550nm ± for 16 different message signals.

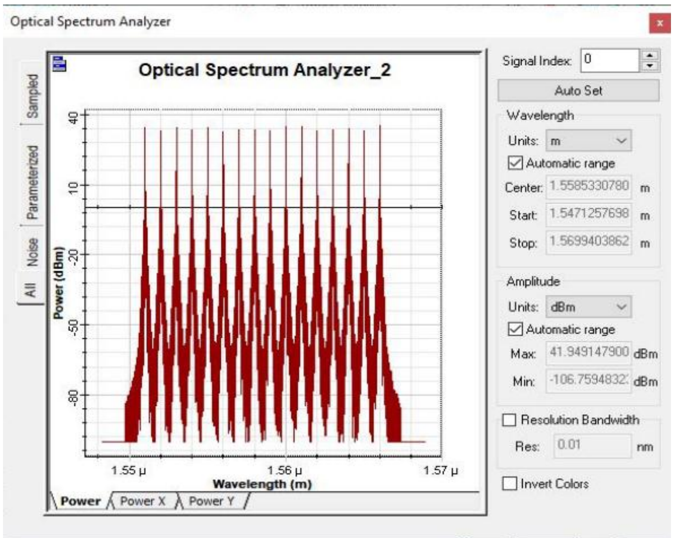

Fig – 2: Transmitted Signal

3.1 FSO Channel Layouts

The 2 x 2 Free Space Optical channel consisting of 2 copies of the modulated signal transmitted through 2 different FSO channels at a varying range and attenuation values are shown in figure 3.

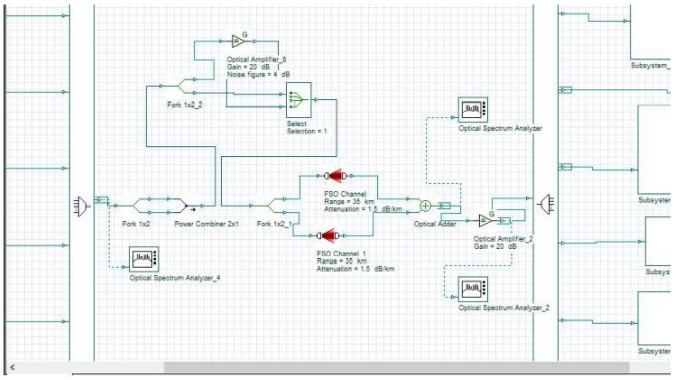

Fig – 3: Layout diagram of 2x2 FSO Channel

The 4 x 4 Free Space Optical channel consisting of 4 copies of the modulated signal transmitted through 4 different FSO channels at a varying range and attenuation values are shown in figure 4.

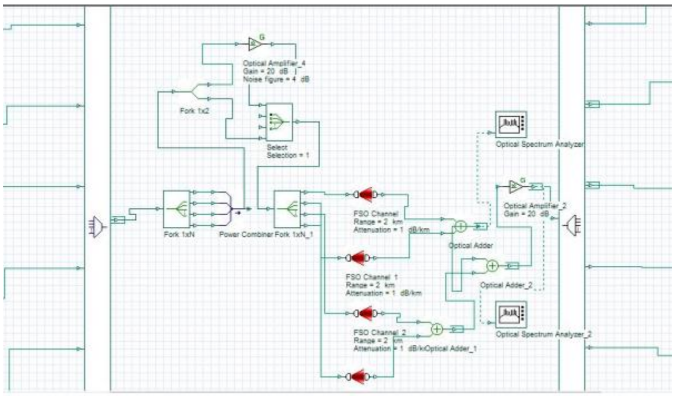

Fig – 4 : Layout diagram of 4x4 FSO Channel

The 8x8 Free Space Optical channel consisting of 8 copies of the modulated signal transmitted through 8 different FSO channels at a varying range and attenuation values are shown in figure 5.

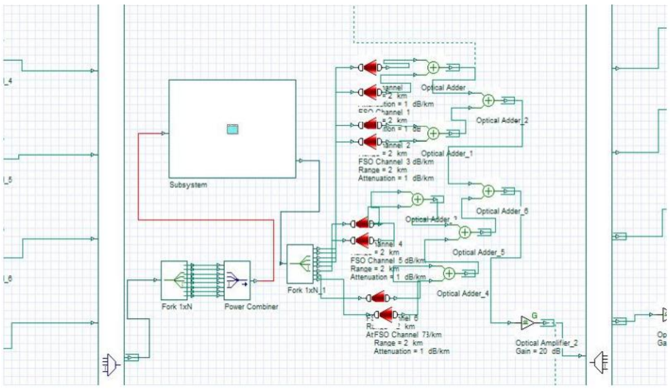

Fig – 5: Layout diagram of 8x8 FSO Channel

The 16 x 16 Free Space Optical channel consisting of 16 copies of the modulated signal transmitted through 16 different FSO channels at a varying range and attenuation values are shown in figure 6.

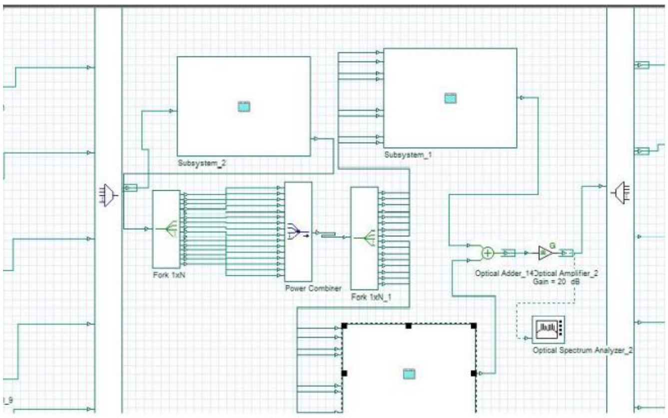

Fig – 6: Layout Diagram of 16x16Channel

3.2. BER & Q factor across various weather conditions

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors.

The Bit Error Rate (BER) is the number of bit error per unit time. The bit error ratio is the number of bit errors divided by the total number of transferred bits during a studied time interval. Bit error ratio is a unit less performance measure, often expressed as a percentage. This visualize allows the user to calculate and display the bit error rate of an electrical signal automatically.

It can estimate the BER using different algorithms such as Gaussian and Chi-Squared and derive different metrics from the eye diagram, such as Q factor, eye opening, eye closure, extinction ratio, eye height, jitter, etc. It can also take in account Forward Error Correction, plot BER patterns and estimate system penalties and margins.

Clear Weather conditions:

In clear weather conditions with a attenuation standardized to a value of about 1db/km the various Q factor and BER factors across 4 different FSO channel models for a link range of about 1-35 km are given as follows

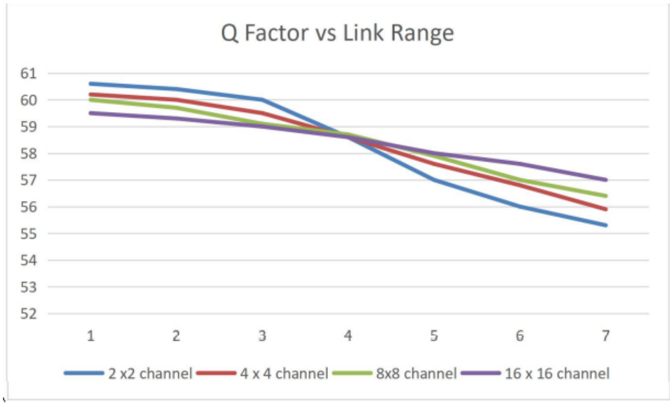

Fig – 7: Quality Factor under Clear weather

It shows that, the use of adaptive optimized channel increases the Q factor value of about 60.6 in 2x2 channel and with the increase in link range,16 x16 channels shows best transmission rate in comparison to other MIMO channels .

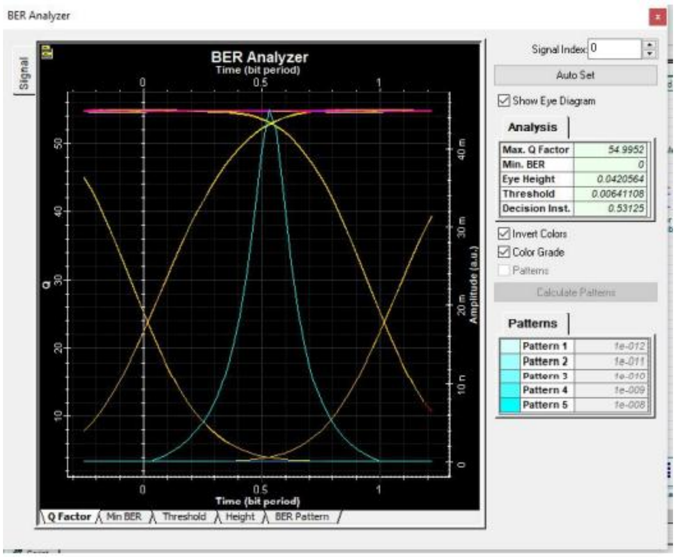

Fig – 8: Eye Diagram of 2x2 channel at clear weather (35km)

Range in km	2 x2 channel		4 x 4 channel		8x8 channel		16 x 16 channel	
	BER	Q Factor	BER	Q Factor	BER	Q Factor	BER	Q Factor
5	0	60.6	0	60.2	0	60	0	59.5
10	0	60.4	0	60	0	59.7	0	59.3
15	0	60	0	59.5	0	59.1	0	59
20	0	58.6	0	58.6	0	58.7	0	58.6
25	0	57	0	57.6	0	57.9	0	58
30	0	56	0	56.8	0	57	0	57.6
35	0	55.3	0	55.9	0	56.4	0	57

Fig – 9: BER & Q-Factor across MIMO channels

It shows that at clear weather conditions the link range of the signal can last above 35kms as a result of the adaptive optimized channel and the BER & Q factor values gets increased with increase in MIMO channels for longer distances.

Turbulence Weather conditions:

In Turbulence weather conditions with a attenuation standardized to a value of about 1.5db/km the various Q factor and BER factors across 4 different FSO channel models for a link range of about 1-35 km are given as follows .

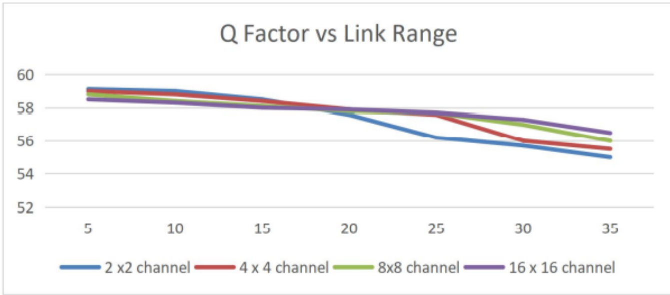

Fig- 10: Quality Factor under Turbulence weather

It shows that, the use of adaptive optimized channel increases the Q factor value of about 59.12 in 2x2 channel and with the increase in link range,16 x16 channels shows best transmission rate in comparison to other MIMO channels.

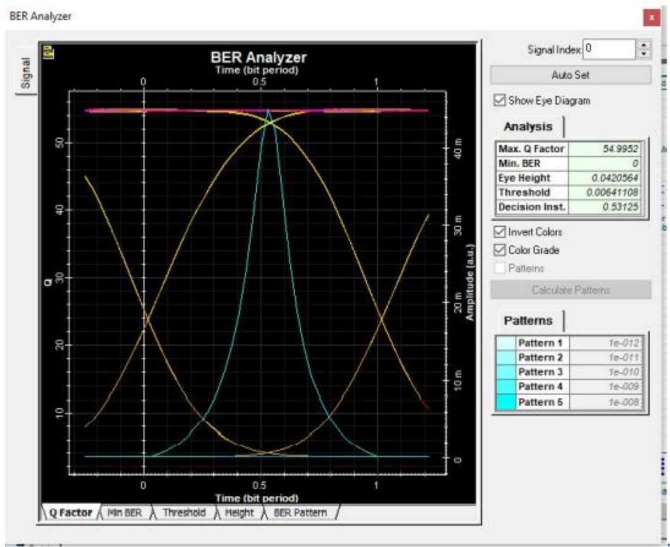

Fig11:EyeDiagram of 2x2channel at Turbulence35km

Range in km	2 x2 channel		4 x 4 channel		8x8 channel		16 x 16 channel	
	BER	Q Factor	BER	Q Factor	BER	Q Factor	BER	Q Factor
5	0	59.12	0	59	0	58.8	0	58.5
10	0	59	0	58.8	0	58.4	0	58.3
15	0	58.5	0	58.4	0	58.1	0	58
20	0	57.6	0	57.9	0	57.8	0	57.9
25	0	56.2	0	57.6	0	57.7	0	57.7
30	0	55.7	0	56	0	57	0	57.3
35	0	54.99	0	55.5	0	56	0	56.5

Fig – 12: BER & Q-Factor across MIMO channels

It shows that at turbulence weather conditions the link range of the signal can last above 35kms as a result of the adaptive optimized channel and the BER & Q factor values gets increased with increase in MIMO channels for longer distances.

Haze Weather conditions:

In Haze weather conditions with a attenuation standardized to a value of about 4.5db/km the various Q factor and BER factors across 4 different FSO channel models for a link range of about 1-35 km are given as follows

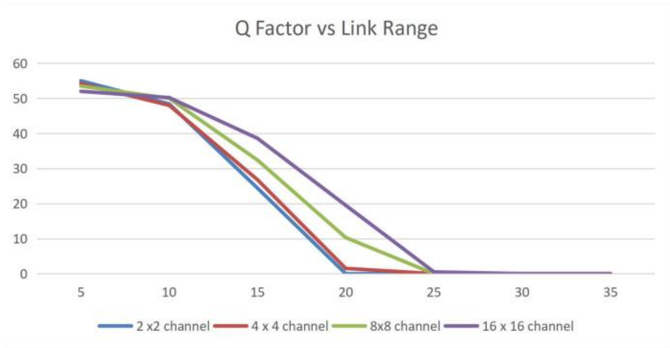

Fig – 13: Quality Factor under Haze weather

It shows that, the use of adaptive optimized channel increases the Q factor value of about 55 in 2x2 channel and with the increase in link range,16 x16 channels shows best transmission rate in comparison to other MIMO channels .

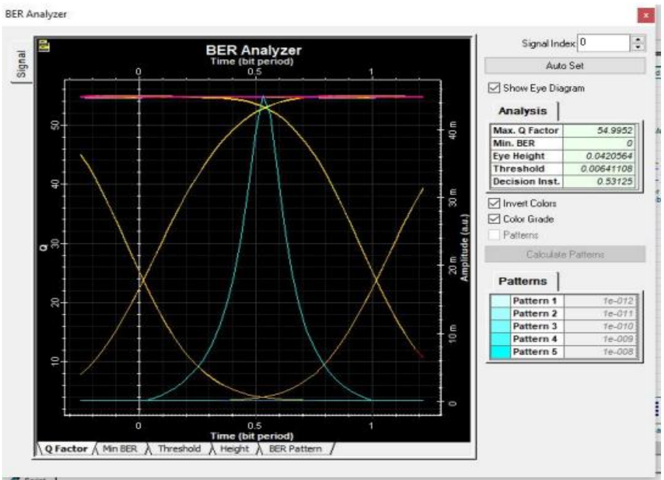

Fig -14: Eye Diagram of 2x2channel at Haze (5km)

Range in km	2 x2 channel		4 x 4 channel		8x8 channel		16 x 16 channel	
	BER	Q Factor	BER	Q Factor	BER	Q Factor	BER	Q Factor
5	0	55	0	54.2	0	53.5	0	52
10	0	48.4	0	48	0	50	0	50.2
15	3.4e-125	24.4	1.5e-151	26.8	0	32.4	0	38.6
20	1	0	0.3e-002	1.5	3.5e-030	10.3	15e-090	19.5
25	1	0	1	0	1	0	0.003e-001	0.5
30	1	0	1	0	1	0	1	0
35	1	0	1	0	1	0	1	0

Fig – 15: BER & Q-Factor across MIMO channels

It shows that at haze weather conditions the link range of the signal can last above 15kms as a result of the adaptive optimized channel and the BER & Q factor values gets increased with increase in MIMO channels for longer distances.

Dust Weather conditions:

In Dust weather conditions with a attenuation standardized to a value of about 7 db/km the various Q factor and BER factors across 4 different FSO channel models for a link range of about 1-21 km are

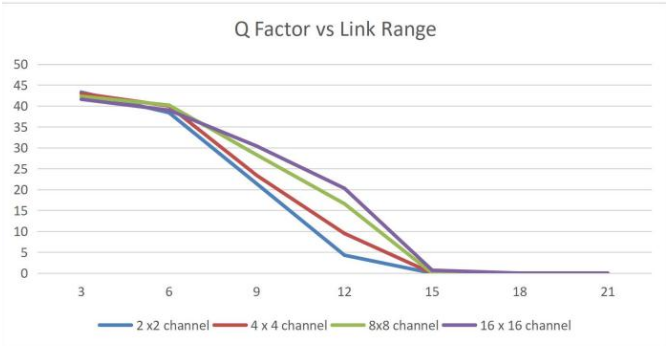

Fig – 16: Quality Factor under Dust weather

It shows that, the use of adaptive optimized channel increases the Q factor value of about 43.3 in 2x2 channel and with the increase in link range,16 x16 channels shows best transmission rate in comparison to other MIMO channels .

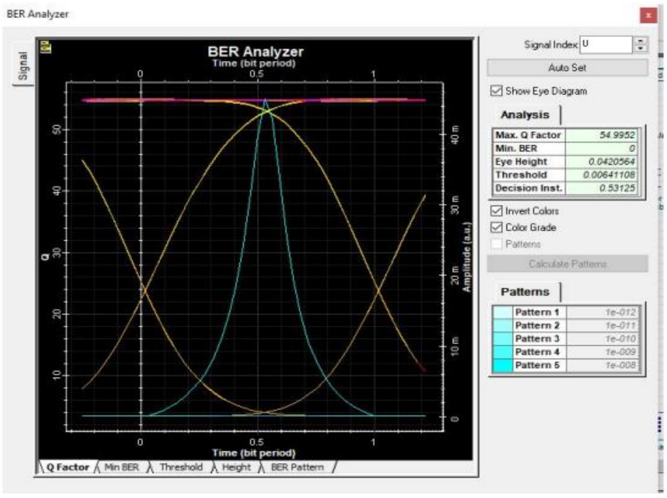

Fig- 17: Eye Diagram of 2x2 channel at Dust

Range in km	2 x2 channel		4 x 4 channel		8x8 channel		16 x 16 channel	
	BER	Q Factor	BER	Q Factor	BER	Q Factor	BER	Q Factor
3	0	43.3	0	43	0	42.3	0	41.6
6	0	38.4	0	40	0	40.2	0	39
9	$1.7e^{-102}$	21.4	$4.3e^{-110}$	23.4	$3e^{-186}$	28.3	0	30.4
12	$54e^{-007}$	4.3	$12e^{-029}$	9.5	$13e^{-065}$	16.6	$4e^{-095}$	20.3
15	1	0	1	0	1	0	$0.7e^{-0015}$	0.7
18	1	0	1	0	1	0	1	0
21	1	0	1	0	1	0	1	0

Fig- 17: BER & Q-Factor across MIMO channels

It shows that at dust weather conditions the link range of the signal can last above 12kms as a result of the adaptive optimized channel and the BER & Q factor values gets increased with increase in MIMO channels for longer distances.

Rain Weather conditions:

In Rain weather conditions with a attenuation standardized to a value of about 15db/km the various Q factor and BER factors across 4 different FSO channel models for a link range of about 1-7km are given as follows .

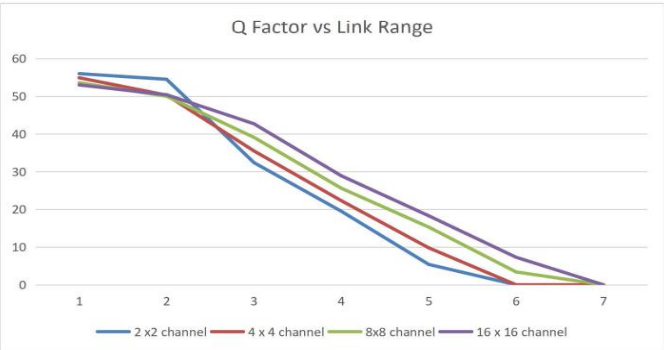

Fig – 18: Quality Factor under Rain weather

It shows that, the use of adaptive optimized channel increases the Q factor value of about 56 in 2x2 channel and with the increase in link range,16 x16 channels shows best transmission rate in comparison to other MIMO channels .

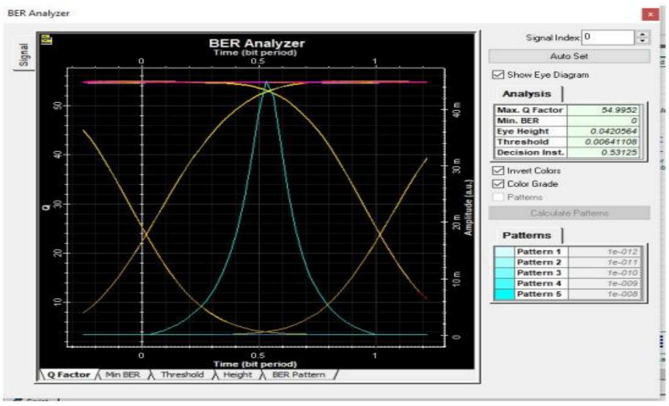

Fig -19 : Eye Diagram of 2x2 channel at Rain

Range in km	2 x2 channel		4 x 4 channel		8x8 channel		16 x 16 channel	
	BER	Q Factor	BER	Q Factor	BER	Q Factor	BER	Q Factor
1	0	56	0	54.9	0	53.6	0	53
2	0	54.5	0	50.3	0	50	0	50.4
3	0	32.4	0	35.5	0	39.1	0	42.7
4	$15e^{-090}$	19.5	$18e^{-110}$	22.3	$2.2e^{-137}$	25.6	$5e^{-191}$	28.9
5	$6.3e^{-015}$	5.4	$8e^{-029}$	9.8	$7.8e^{-050}$	15.3	$1e^{-072}$	18.3
6	1	0	1	0	$3.5e^{-005}$	3.4	$5.2e^{-51}$	7.3
7	1	0	1	0	1	0	1	0

Fig – 20: BER & Q-Factor across MIMO Channel

It shows that at rain weather conditions the link range of the signal can last above 6kms as a result of the adaptive optimized channel and the BER & Q factor values gets increased with increase in MIMO channels for longer distances.

Snow Weather conditions:

In Haze weather conditions with a attenuation standardized to a value of about 20db/km the various Q factor and BER factors across 4 different FSO channel models for a link range of about 1-7 kms are given as follows .

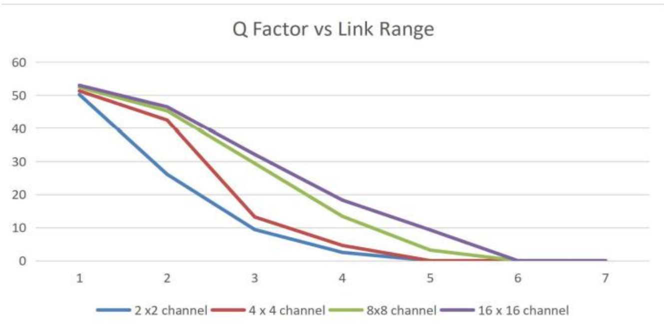

Fig – 21: Quality Factor under Snow weather

It shows that, the use of adaptive optimized channel increases the Q factor value of about 30 in 2x2 channel and with the increase in link range,16 x16 channels shows best transmission rate in comparison to other MIMO channels .

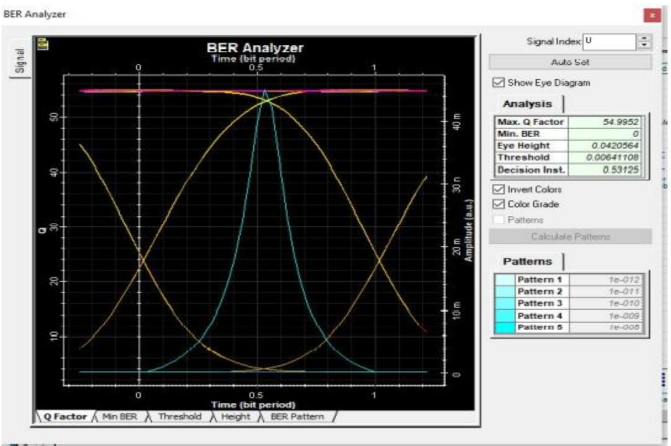

Fig -22: Eye Diagram of 2x2 channel at Snow

Range in km	2 x2 channel		4 x 4 channel		8x8 channel		16 x 16 channel	
	BER	Q Factor	BER	Q Factor	BER	Q Factor	BER	Q Factor
1	0	50.2	0	51.3	0	52.4	0	53
2	$5e^{-140}$	26.1	0	42.5	0	45.3	0	46.5
3	$4.5e^{-025}$	9.4	$13e^{-090}$	19.4	$1e^{-199}$	29.4	0	32.1
4	$5e^{-003}$	2.5	$15e^{-008}$	4.6	$5e^{-047}$	13.4	$17e^{-072}$	18.3
5	1	0	1	0	$4e^{-006}$	3.2	$3e^{-029}$	9.3
6	1	0	1	0	1	0	1	0
7	1	0	1	0	1	0	1	0

Fig-23: BER & Q-Factor across MIMO channels

It shows that at snow weather conditions the link range of the signal can last above 4kms as a result of the adaptive optimized channel and the BER & Q factor values gets increased with increase in MIMO channels for longer distances.

Fog Weather conditions:

In Haze weather conditions with a attenuation standardized to a value of about 25db/km the various Q factor and BER factors across 4 different FSO channel models for a link range of about 1-4 km are given as follows

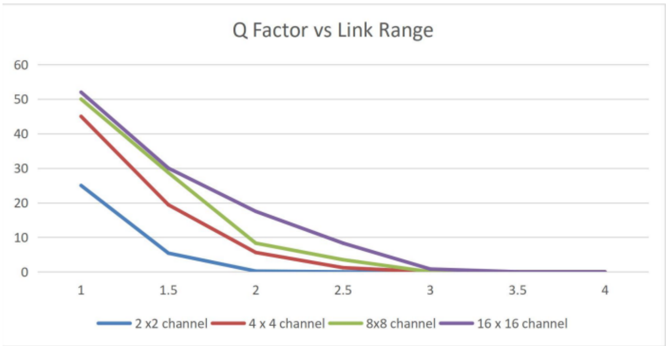

Fig – 24: Quality Factor under Fog weather

It shows that, the use of adaptive optimized channel increases the Q factor value of about 25 in 2x2 channel and with the increase in link range,16 x16 channels shows best transmission rate in comparison to other MIMO channels .

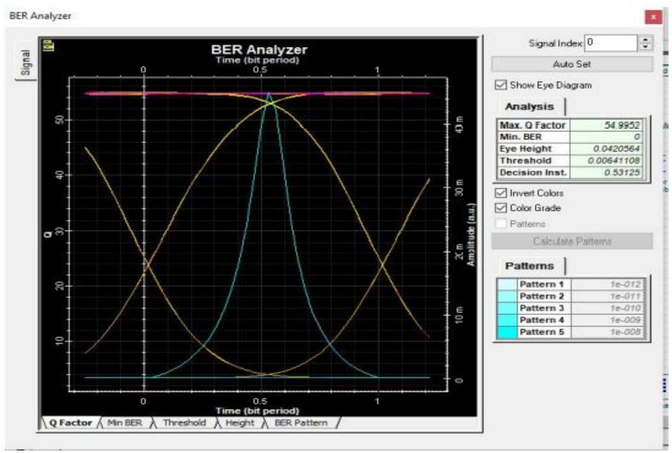

Fig – 25: Eye Diagram of 2x2 channel at Fog

Range in km	2 x2 channel		4 x 4 channel		8x8 channel		16 x 16 channel	
	BER	Q Factor	BER	Q Factor	BER	Q Factor	BER	Q Factor
1	$5e^{-173}$	27.4	0	45	0	50	0	52
1.5	$4.5e^{-025}$	9.4	$13e^{-090}$	19.4	$3.5e^{-189}$	28.7	0	30
2	$0.002e^{-001}$	0.2	$6.3e^{-014}$	5.6	$2e^{-25}$	8.3	$4.2e^{-068}$	17.5
2.5	1	0	$12e^{-002}$	1.2	$15e^{-005}$	3.5	$2e^{-25}$	8.3
3	1	0	1	0	1	0	$15e^{-001}$	0.8
3.5	1	0	1	0	1	0	1	0
4	1	0	1	0	1	0	1	0

Fig -26: BER & Q-Factor across MIMO channels

It shows that at fog weather conditions the link range of the signal can last above 2kms as a result of the adaptive optimized channel and the BER & Q factor values gets increased with increase in MIMO channels for longer distances.

3. CONCLUSIONS

The model system encompasses an n- channel WDM multiplexed adaptive FSO system operating at 2 Gbps using different MIMO formats for 20dbm input power at various weather conditions. Afterwards, adaptive optimization technique enables FSO signals to be improved and travelled long distances by optimizing post amplification system between the transmitter and receiver. In Free Space Optical system , the 16 x 16 MIMO channel performs better than other MIMO channels at all weather conditions as it performs a link range of more than 35kms in clear and turbulence and 3kms in fog weather conditions with a minimum Bit error rate of 0 and 15 e =001 and maximum Q-factor of 57 and 0.8 respectively. Furthermore, low distance performance is enhanced by increasing the number of channels and through the use of adaptive optimized channel.

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