International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 04, April-2015

WDM based FSO System for Long Haul Communication

Nitin Thathai
P.G. Student, Dept. of E.C.E
GZS PTU Campus
Bathinda, Punjab, India

Jyoti Saxena
Professor, Dept. of E.C.E
GZS PTU Campus
Bathinda, Punjab, India

Neel Kamal
Asso. Professor, Dept. of E.C.E
GTBKIET Chhapianwali
Malout, Punjab, India

***Abstract*---Today's demand is a communication link with good performance and minimum errors. Free Space Optics (FSO) is one of the growing fields of optical communication because of its wider bandwidth, high security and easy installation. FSO system is license free, easily deployable and provides high data rate. However the performance of FSO system is affected by turbulent atmosphere. In this paper, the performance of Wavelength Division Multiplexing (WDM) based FSO system has been tested for different weather conditions such as clear weather, light haze, heavy haze, light rain, medium rain and heavy rain based on Bit Error Rate (BER) and communication link range using Optisystem software. Experimental results show that a WDM based FSO system can transmit an optical signal of 2.5Gbps with 1550nm wavelength up to 155km at clear weather condition with BER of 10^{-12}.**

Keywords---Optical communication, WDM (Wavelength Division Multiplexing), FSO (Free Space Optics)

I. INTRODUCTION

Over the last decade, communications between mobile devices have attained a drastic speed with the use of wired links and wireless RF links. However these communication links have limited band width. To increase the band width Optical Fibre Cables (OFC) are being used. But OFC is not an economical channel due to huge expenditure on maintenance of joints by splicing, unavailability of free land for laying of OFCs and also due to topographical reasons [1]. Now a days FSO is preferred due to its advantages like lower cost and easier installation as compared to Optical Fibre System besides advantages like high bandwidth, high data rates. FSO is an optical communication system that uses light signal to transmit data in free space. It is a line of sight (LOS) technology that uses lasers and diodes to make a connection for voice, video & data communication. It allows 2.5Gbps of data rate which can be increased up to 10Gbps using Wavelength Division Multiplexing [2]. However, the quality of service of a FSO system is affected by weather conditions [3]. In free space the transmitted light is reflected, refracted or absorbed by various objects like mist, dust particles haze, rain fall (light, medium, heavy), water droplets etc in mid way. All these conditions influence the performance of a FSO system [4]. Moreover the performance of FSO system is also dependent on a
Where R is link range (km), T(R) is transmittance in the range R (km), P(R) is laser power in range R, P(O) is laser power at source and β is scattering coefficient (Km^{-1}).

number of parameters like optical amplifier gain, aperture size, responsivity of photo diode and type of filter used [5]. In this paper, the above mentioned parameters have been varied to study their effect on performance of FSO system. These parameters have been adjusted in the order of priority as given in Fig. 1. In this paper the performance of WDM based FSO system has been tested for different weather conditions based on Bit Error Rate and Communication link range. The remaining part of this paper is divided as follows: Section 2 describes the Atmospheric effects on FSO. Section 3 involves System description. Section 4 represents Results and discussion & finally, Conclusion is reported in section 5.

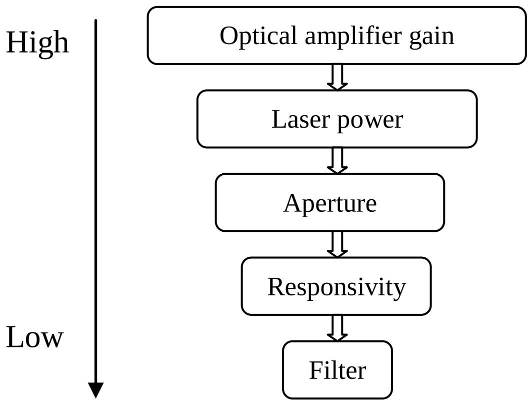

Fig. 1. Priority wise Effect of parameter of WDM FSO system [5].

II. ATMOSPHERIC EFFECTS ON FSO

The quality of FSO system is mainly determined by atmospheric attenuation. Every weather condition has different value of attenuation (dB/km). So it is necessary for FSO system to take weather conditions into considerations, such as, rain (light, medium, heavy) and haze (light, heavy) [7].

A. Rain

Rain intensity factor affects the performance of FSO system because attenuation linearly increases with rain intensity factor (rain fall rate) [2]. Table 1 shows the rain fall rate for different types of rain. The attenuation for various types of rain is described by Beer's law [5]:

$$T(R) = P(R) / P(O) = e^{-\beta R} \qquad \text{……. (1)}$$

Stroke' law is used to calculate the scattering coefficient of beam due to rain drop [5]:

$$\beta_{rain\ scat} = \pi a^2 N a Q_{scat}(a/\lambda) \qquad \text{....... (2)}$$

Where 'a' is radius of raindrop (0.001–0.1 cm), Na is rain drop distribution, Q_{scat} is scattering efficiency, λ is wavelength of the rain drop distribution.

By using equation (1 & 2), rain drop distribution 'Na' is calculated as.

$Na=Za/ [4/3(\pi a^3)] Va$ ……… (3)

Where Za is the rainfall rate (cm/s), a is droplet radius and Va represent limit speed precipitation. The raindrop Limiting speed is also given as per equation (4).

$VA= (2a^2\rho g)/9\eta$ ……… (4)

Where ρ is water density (g/cm^2), g is gravitational constant and η is air viscosity. The constant values of these parameters are given in Table 2.

Table 1. Rain Fall Rate

Type	Cm/s
Light	$7.22x10^{-4}$
Medium	$1.11x10^{-3}$
Heavy	$2.22x10^{-3}$

Attenuation for light rain is recorded as 6.27dB/km, 9.64dB/km for medium rain and 19.28dB/km for heavy rain at 1550nm wavelength [5].

Table 2. Constant values of parameters

Gravitational Constant, g	980 cm/s^2
Water density, ρ	1g/cm^2
Viscosity of air, η	$1.8x10^{-4}$(g/cm)
Droplet radius, a	.001-01cm
Wavelength, λ	1550nm
Scattering efficiency, Q_{scat}	2

B. Haze

Haze gives more serious degradation on FSO system's performance because it remains for longer time in the environment. The attenuation produced by haze is represented by Kim & Kruse model [5, 7]:

$\beta= (3.91/V) (\lambda/550)^{-q}$ ……. (5)

Where β represents haze attenuation, V represents visibility in kilometre, λ represents wavelength in nanometre and q represents the size of distribution of the scattering particles. [8]

Attenuation for light haze is recorded as 0.55dB/km and 2.37dB/km for heavy haze at 1550nm wavelength [5]. In clear weather condition the atmospheric attenuation is very less i.e. 0.233dB/km [5, 7]. It has been assumed that there is no beam spreads.

III. SYSTEM DESCRIPTION

The basic block diagram of WDM based FSO system is shown in Fig. 2. FSO block diagram is divided in to three parts Transmitter, Receiver and Channel. In transmitter part a CW laser, Pseudo-Random bit generator, Mach-Zehnder modulator, NRZ Pulse Generator and Optical Amplifier have been used. Whereas in receiver part to detect the optical signal an Avalanche Photodiode (APD) and low pass Bessel filter has been used. Bessel filter has better shaping factor, flatter phase delay and flatter group delay than any other filer of the same order [6]. In channel, FSO path link has been used. For measuring outputs & visualizing the results, tools such as Optical spectrum analyzer and BER analyzer are used.

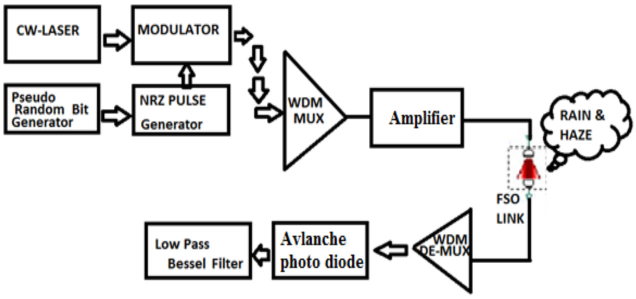

Fig. 2. Basic block diagram of WDM based FSO system

IV. RESULTS AND DISCUSSION

In this work, we have used 10dBm laser power, 16cm receiver aperture size and other parameters as shown in Table 3.

Table 3. Values for Different Parameters

S.no.	Parameter	Value taken
1	Data Rate	2.5Gbps
2	Wavelength	1550nm
3	Tx. Aperture Diameter	5cm
4	Tx Loss	5dB
5	Rx Loss	5dB
6	Additional Loss	5dB
7	Laser Power	According to weather condition
8	Aperture Size	According to weather condition
9	Amplifier Gain	According to weather condition

By subjecting to the attenuation values for clear and light haze weather conditions under above mentioned parameters, we have observed that WDM based FSO system can transmit an optical signal up to 155km. Results are mentioned in Table 4.

Table 4. Optimization for the communication link of 155 km

Weather condition	Attenuation	Bit Rate	Laser Power	Aperture size	Amplifier Gain	BER	Q factor
Clear	0.233dB/km	2.5Gbps	10dBm	16cm	No	$5.83799e^{-012}$	6.78333
Light haze	0.55dB/km	2.5Gbps	10dBm	16cm	50dB	$4.6412e^{-014}$	7.45009

For the clear weather condition, we have not used any optical amplifier but for light haze condition, we have used an optical amplifier of 50dB gain. Fig. 3 and Fig. 4 show BER performance for clear and light haze weather condition respectively.

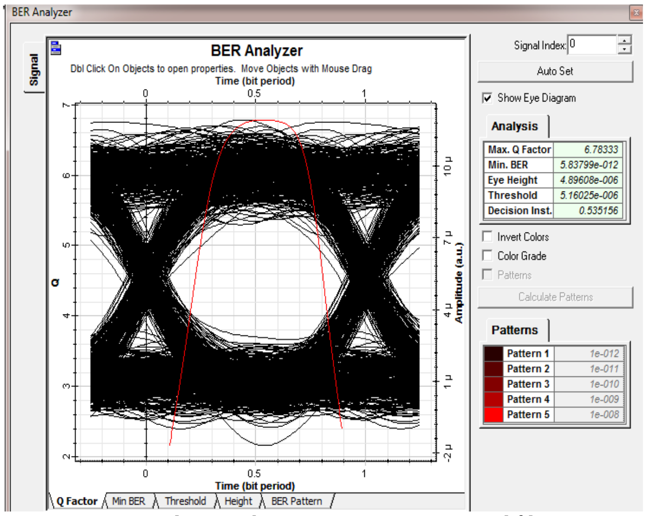

Fig.3. At clear weather up to 155Km using Bessel filter.

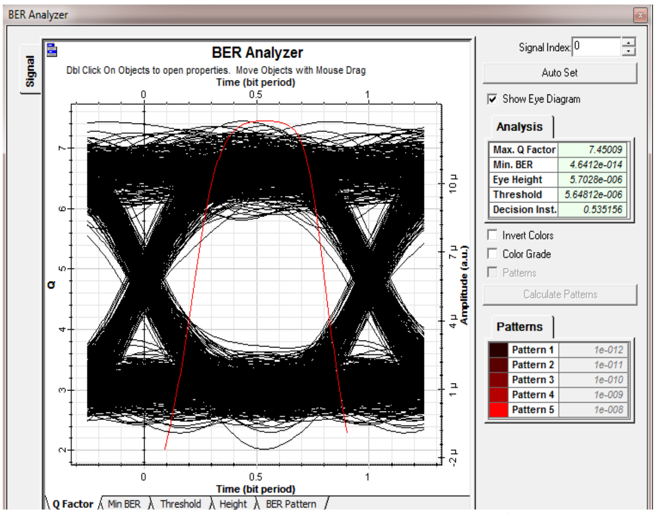

Fig. 4. At light haze up to 155Km using Bessel filter.

In bad weather condition, data rate and communication link range decreases due to increase in attenuation. The worst case happens in very heavy rainfall where attenuation reaches to 19.28dB/km and communication link range falls below than 7km. During heavy haze and rain conditions, visibility reduces and it is not possible for the laser beam to travel up to the 155km or we can say that communication link range is inversely proportional to weather condition. So for heavy haze and rain conditions, another set of optimized parameters was taken. Here we changed the receiver aperture size from 16cm to 35cm and laser power from 10dBm to 30dBm. Also for getting good BER value, we decreased communication link range. By subjecting to the attenuation values for heavy haze and different rain intensities, we have observed different results as mentioned in Table-5. For heavy haze, WDM based FSO system can transmit an optical signal of 2.5Gbps up to 50.7km. Fig-5 shows BER performance for heavy haze condition. For light, medium and heavy rain, communication link range is up to19.1km, 12.4km and 6.2km respectively. Fig. 6, Fig. 7 & Fig. 8 shows BER performance for light, medium and heavy rain respectively.

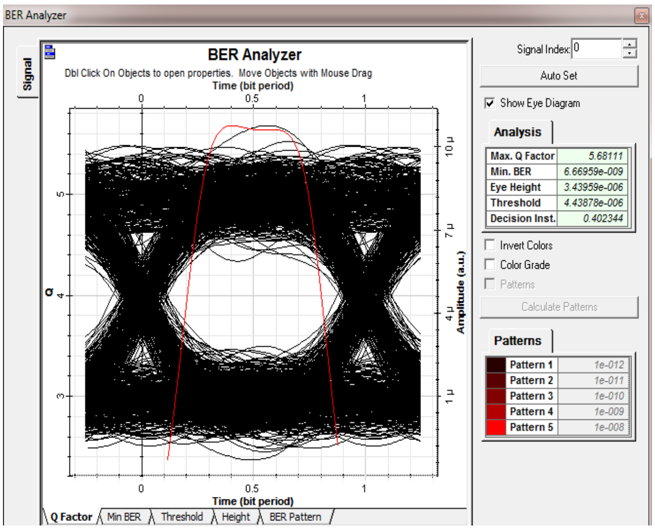

Fig. 5. At heavy haze up to 50.7km using Bessel filter.

Table 5. Speatial case link analysis

Weather condition	Attenuation (dB/km)	Data Rate (Gbps)	Laser power(dBm)	Amplifier Gain (dB)	Aperture size (cm)	BER	Link range (km)
Heavy haze	2.37	2.5	30	50	35	6.66959e^{-009}	50.7
Light rain	6.27	2.5	30	50	35	2.55441e^{-010}	19.1
Medium rain	9.64	2.5	30	50	35	3.29451e^{-011}	12.4
Heavy Rain	19.28	2.5	30	50	35	3.29451e^{-011}	6.2

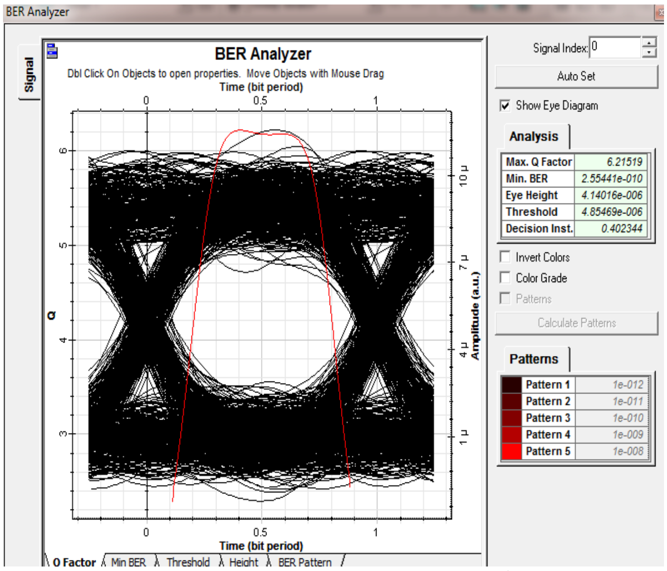

Fig. 6. At light rain up to 19.1Km using Bessel filter.

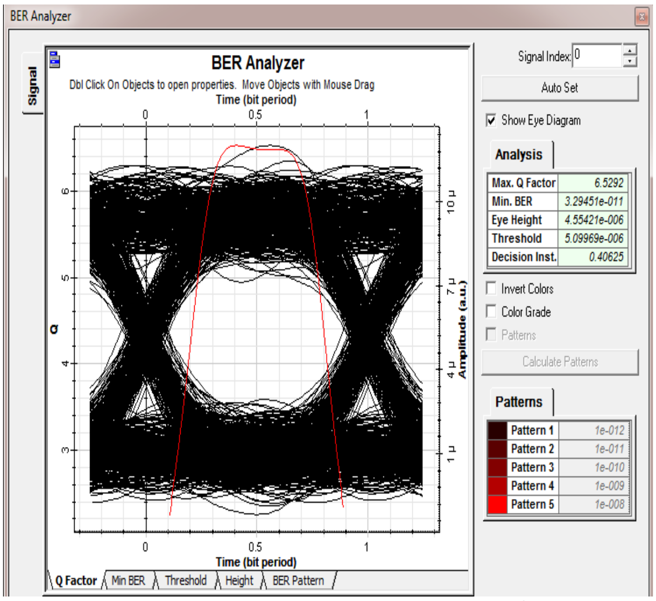

Fig. 7. At medium rain up to 12.4Km using Bessel filter.

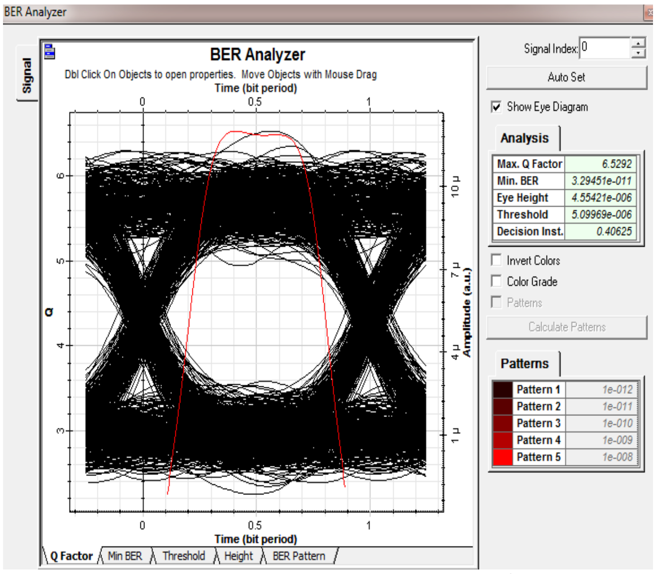

Fig. 9. At heavy rain up to 6.2Km using Bessel filter

V. CONCLUSION

In this paper, a WDM based FSO system has been investigated successfully for different weather conditions. It has been observed that performance of a WDM based FSO system is influenced very much by rain and haze conditions. The atmospheric effects on FSO link has been presented experimentally using OptiSystem version 10. Experimental results show that in clear weather condition, a WDM based FSO system can transmit an optical signal of 2.5Gbps up to 155km with BER value of 5.83799e^{-012}. Also in heavy haze condition, the observed BER value is 6.66959e^{-009} for link range of 50.7km and under heavy rain condition, the observed BER is 3.29451e^{-011} with a link range of 6.2km.

REFERENCES

[1] V. Kumar and D. Rajouria, (2012), “Fault Detection Technique by using OTDR: Limitations and drawbacks on practical approach of measurement”, International Journal of Emerging Technology and Advanced Engineering (IJETAE), Vol.2, pp. 283-287.

[2] G. Singh, T. Singh, V. Kant and V. Kanshal, (2011), “Free Space Optics: Atmosphric Effect & Back Up”, International Journal of Research in Computer Science (IJORCS), White Globe, Vol. 1, pp. 25-30.

[3] M. Gebhart, E. Leitgeb, S.S. Muhammad, B. Flecker, C. Chlestil, M.A. Naboulsi, H. Sizuni, F.D. Fornel, (2005), “Measurement of Light Attenuation in Dense Fog Conditions for Optical Wireless Links”, Proceedings on The International Society for Optical Engineering SPIE Conference, Vol. 589, pp 1-5.

[4] K. Singh and B. Kaur, (2012), “Study of WDM Based FSO System for Different Weather Conditions”, Proceedings on International Conference on Electrical and Computer Engineering (ICECE), pp. 1-7.

[5] H.A. Fadhil, A. Amphawan, H.A. B. Shamsuddin, T. Hussein Abd, H.M.R. Al- Khafaji, S.A. Aljunid and N. Ahmed, (2013), “Optimization of Free Space Optics Parameters: An Optimum Solution for Bad Weather Conditions”, International Journal for Light Electron Optics (IJLEO), Optik, Elsevier, pp. 1-5.

[6] J.G. Proakis and D.G. Manolakis, (2012), “Digital Signal Processing”,Prentice-Hall International, Pearson, pp. 614-724.

[7] N.A. Mohamed, A.N.Z. Rashed and A.E.M. El-Nabawy, (2012), “The Effects of the Bad Weather on the Transmission and Performance Efficiency of Optical Wireless Communication Systems”, International Journal of Image, Graphics and Signal Processing (IJIGSP), Modern Education and Computer Science (MECS), Vol. 7, pp. 68-83.