Significance and limitations on Free Space Optical Communication Using Wavelength division multiplexing (WDM)

Divya sisodiya, *Microwave and optical communication*, *Delhi Technological University* , India ,44001.

E-mail: divsisnit27@gmail.com

Under the direction of Dr. Gurjit Kaur, *Professor at Delhi Technological University*, India ,44001.

E-mail: gurjitkaur@dtu.ac.in

Abstract -Dealing with wireless communication has been one of the most significant milestones in the history of technology. Free Space Optics is one of the leading wireless communication technologies related to secure data transfer in modern times as well as providing communication flexibility by making it more complex compared to Optical threads. In this paper, the significance of the FSO and its various variables in the various models are presented. Also, free space communication is done using Wavelength division multiplexing (WDM). The behavior of system has been observed for different attenuations in the propagation medium. Simulation is done with the help of Opti system software.

***Index terms*-free space optical communication, WDM, wireless communications, channel capacity;**

Introduction

The demand for heavy data for wireless communication is growing with its growing popularity. The reason for this is because some RF bands cannot be licensed. Therefore, we consider some practical options for wireless communication using additional components of the electrical spectrum. RF bands of 300GHZ and above are near-IR bands and the same waves are used for free space communication. On networks in the metropolitan area (MAN), due to Spectrum scarcity bandwidth is not available. Many options are available to cable users to meet those needs. The first option is fiber-optic cable, but the delay associated with the cost of installing fiber optics makes it economically unsuitable.

The second option is radio frequency technology which is avoided mainly due to the limited frequency and low power consumption. The third option is copper-based technology such as T1, modem cable, or DSL. Although, copper infrastructure is found almost everywhere, it is not yet an alternative method due to a 2 to 3 Mbps bandwidth.

The fourth and most effective decision is free space optics (FSO). This paper deals with FSO channel structures, broadcast and reception facilities. Details of the data limitations of FSO channel data and algorithmic level research activities to approach these limits are discussed. WDM with FSO is used to achieve high transmission rates and maintain the same body parts of the FSO link [2]. FSO can operate in the transmission window i.e., 1550 nm with low spectral attenuation

I. Overview of FSO

Free space communication is not a new process, developed over the last thirty years [3]. It was originally developed by NASA and US troops. For Atmospheric aviation pioneers and soldiers, Free space optic is used to provide secure and fast-moving communication links. As such, it is a line-of-sight technology mainly uses photo-detectors and LASERS to provide visual communication between two points.

For example, in 1998 it was used to manage data within digital computer systems (Gourley et al., 1998) and then used in cross-bar switching. This method was also used for Jahns communications in 1994 and for the optoelectronic sample by Wu and Zhang, 1997.

Free-space optics is also known as fibreless or fiber-free photonics. With the transmission of fixed light beams through the free space (air or atmosphere) broadband connections can be obtained. Generally, LASER beams are used here, but non simulating sources such as LEDs or IR emitting diodes can also be used. FSO is the best solution where there is a need for high bandwidth (anywhere from 1Mbps to 1.25 Gbps) and where optical fiber is not available. This technology is an ideal solution given the bandwidth distribution, speed of delivery, shipping and cost effectiveness. Using FSO, a few seconds of visual detection can be detected. Recent advances in optical technology have developed FSOs in challenging communication systems and are being used as an alternative to RF wireless.

There are other major market drivers behind FSO networks such as beyond bandwidth growth over the past few years; to increase internet traffic, the internet creates a huge demand for large bandwidth on the edge of the network; the rise of e-commerce; high-end desktops; the improvement of metropolitan area networks (MANs) because the use of dense wavelength division (DWDM) based optical metropolitan area networks (MANs) and regenerating them is a direct result of increased edge bandwidth usage; the development of light has also led to the promotion of FSO technology.

FSO has a edge over other technologies as shown

in Table-I:

Features	FSO	FIBER	DSL
Deployment time	Days to weeks	4-12 months	6-12 months
Provisioning time	Immediate	complex	complex
Initial investments for few subscribers	Low	High	High
Reliability	Medium	High	High
Topology/Flexibility	PP, PM, Mesh	PP, PM, Mesh	PP
Distance Limitation	200-2000 m	200 Km	5 Km
Bandwidth/speed	1.25 Gbps	10 Gbps	2 Mbps

Table I: Comparison Chart of FSO with other techniques.

II. FSO TRANSCEIVER

The maximum IR wavelength at which FSO Systems operates is 750-1660 nm. In an FSO communication system, the source produces waveforms and is then transmitted to the optical carrier. This visible field is generated, targeted at a distance through space. On the recipient's side, the field is properly assembled and the photographer converts the visible field into electric power. Finally, to obtain the actual information transmitted at the recipient, the receiver processes the detected electric current. Typical Block diagram of FSO is shown in figure1.

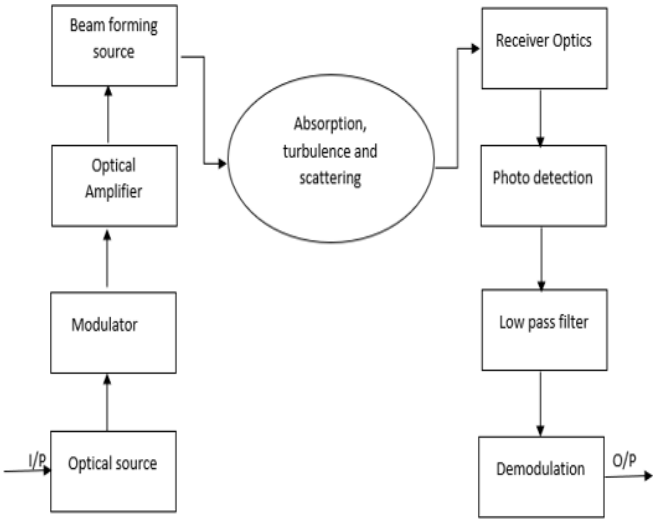

Figure 1: Block diagram of FSO

At transmitter side, Semiconductors Laser diodes are utilized as optical source in FSO Systems, however a few makers additionally utilize high force LEDs. Optical sources are needed to convey high optical control over a wide temperature range. Diodes which work at the Window frequencies should be picked for FSO since these frequencies have most minimal attenuation of 0.2 dB/Km. The three most appropriate Laser Diodes are Vertical cavity surface radiating lasers (VCSEL) which works around 850 nm, Fabry-Perot (FP) and distributed feedback (DFB) are generally utilized for activity at 1550 nm.

At receiver side, we are using non-coherent system. These systems are termed as intensity-modulation direct-detection (IM/DD). Here the photo-detector directly detects changes in the light intensity without any need of local oscillator. For PD, solid-state devices (e.g., PIN or avalanche diodes) are mostly used in commercial FSO system since they have a good quantum efficiency for the commonly used wavelengths. Also, avalanche PD are evaded at the grounds because they need high reverse-bias voltages which is not feasible most of the time. The junction material is made up of Si, IN GaAs, or Ge having extremely short transit time, which prompts faster response in detectors and high bandwidth. Optical pre-amplifiers can also be added before low pass filters (LPF) in the system to improve performance of long-range FSO links e.g., Erbium-doped fiber amplifier (EDFA), semiconductor optical amplifiers (SOAs).

III. FACTORS AFFECTING FSO AND CHANNEL MODEL

The optical power that is sent through channel from transmitter is influenced by different elements like natural clamor, calamities, and air turbulences and dissipating till it shows up at the collector side. This is known as Scintillation(fading)i.e., system fades while adhering to the procedure. The design specifications that are that are as of now characterized by the producers or manufacturers are useful to assess loss in the system. Various types of losses face by system are Geometric loss, Misalignment loss, Atmospheric loss, Atmospheric turbulence induced fading, Ambient noise.

To Evaluate the fluctuations resulting from atmospheric turbulence and air choppiness the scintillation index is frequently used in the literature. It is defined as-

$$\sigma^2{}_I = \frac{E[I^2]}{E[I]^2} - 1 \qquad (1)$$

Where, I denote the intensity of the received optical wave. and, E{.} denotes the expected value.

SI provides a characterization of the turbulence strength based on the first and the second moments of the intensity. To eliminate the turbulences various channel models have been proposed. A portion of the generally acknowledged models are Log-typical for short separations under frail disturbance conditions yet for long-proliferation ways and from moderate to solid choppiness system, this model isn't fitting. Another proposed model is Rayleigh distribution it is for long distances to display restricting instances of air disturbance. The probability density function (PDF) of the received intensity I by this model is given by:

$$p(I) = \frac{2\alpha}{\Gamma(\alpha)}(\alpha I)^{\frac{\alpha-1}{2}} K_{\alpha-1}\left(2\sqrt{\alpha I}\right), I > 0, \alpha > 0 \qquad (2)$$

where, Km(.) is the adjusted Bessel function of second kind and order m, and the parameter α determines the SI by:

$$\sigma_I{}^2 = 1 + \frac{2}{\alpha} \qquad (3)$$

Another huge proposed model is Gamma-Gamma ($\Gamma\Gamma$) approximation for enormous and moderate climatic turbulences. It is a doubly-stochastic model, in measurements this model is a kind of model that emerges in displaying time-arrangement and stochastic cycles. The fundamental thought behind doubly-stochastic model is that a noticed arbitrary variable is demonstrated into two phases.

In $\Gamma\Gamma$ distribution received intensity I is considered as the result of two autonomous gamma arbitrary factors X and Y, which speak to the irradiance fluctuations emerging from enormous and little scope choppiness, individually. The PDF of I:

$$p(I) = \frac{2(ab)^{\frac{a+b}{2}}}{\Gamma(a)\Gamma(b)} I^{a+b/2-1} K_{a-b}\left(2\sqrt{abI}\right), I > 0 \quad (4)$$

Where, the boundaries a and b speak to the successful quantities of huge and little scope choppiness cells, and Γ(.) is the Gamma function. Likewise, the SI by this model is given by-

$$\sigma_I^2 = \frac{1}{a} + \frac{1}{b} + \frac{1}{ab} \quad (5)$$

Beam model can likewise kill the impact of climatic disturbance. General beam types, specifically Gaussian, cos-Gaussian, cosh Gaussian, and annular beams. The best performance is obtained for annular beams when sending over long proliferation separations. While, over short spread separations, the best performance is seen by utilizing cos-Gaussian beams.

IV. Modulation Techniques

The most familiar modulation techniques that are used in wireless communications are ON-OFF Keying (OOC) signaling, Pule phase modulation (PPM), Multi-Pulse phase modulation (MPPM), Pulse width modulation (PWM). In OOK, adjusted information is spoken to by the presence 'on' or nonappearance 'off' of a light pulse in every image span. OOK has moderately poor spectral efficiency energy. PPM is an incredible arrangement when we have to address energy effectiveness, it can achieve close to ideal channel capacity This kind of adjustment is explicitly utilized in deep space communication. MPPM is a reasonable modulation scheme for higher spectral efficiency. As contrasted with PPM, PWM has a better spectral efficiency and it is more resistant to Inter-symbol interference (ISI), especially for a large number of slots per symbol. FSO uses the fundamental modulation technique i.e., OOC.

V. Advantages and Applications

FSO frameworks are used for wide scope of utilizations. FSO for grounds can associate numerous structures and overcome any issues in corporate by supporting super high-speeds without the expense of devoted fiber-optic associations. In video observation and checking can give excellent video transmission. FSO in transmission capacity serious cell phone administrations permit a lot higher throughput. In calamity like circumstances FSO can be promptly sent inside hours in which neighborhood framework could be questionable [5].

Since FSO is fulfilling the most requesting throughput, it is used in top quality TV broadcasting methods (HDTV). For instance, during 2010 FIFA World Cup, UK TV station BBC sent FSO joins for Ethernet-based vehicle of top-notch video between brief studio areas set up in Cape Town, South Africa. These connections give an adaptable option in situations where the fiber optic sending is exorbitant and additionally infeasible.

VI. Simulation

In this paper FSO with WDM [1] is tested in Simulation Software Opti-wave Opti-System.

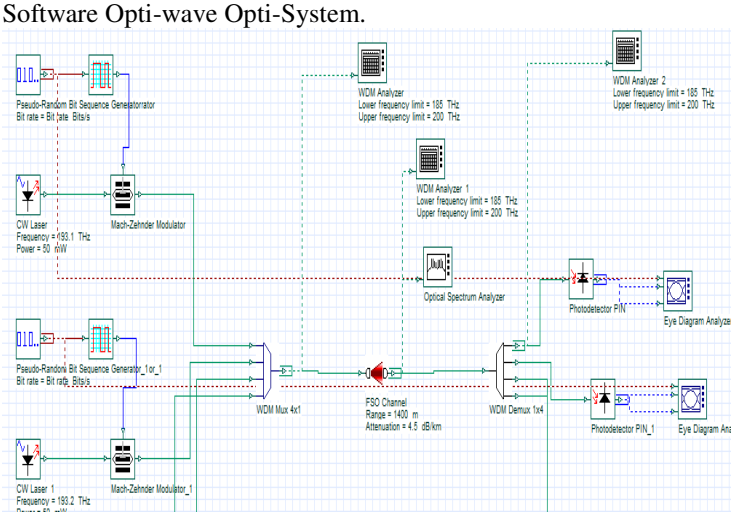

Figure 2: FSO with Wavelength division multiplexing

Primary factor which is affecting the nature of transmission is inspected here that is by dynamically expanding attenuation which reproduced expanding number of aerosol particles in the climate. Pseudo-random bit cycle sequence generator is creating irregular number of pieces, these pieces are additionally handled into NRZ modulator. WDM range has been noticed for four lasers utilized at 193.1THz, 193.2 THz, 193.3 THz, 193.4 THz. Presently, to tweak the accepting pieces and light we have utilized Mach-zander modulator. The utilization of MZM is principally for amplitude modulation changed over by the phase difference created between two waves when voltage is applied across one of its arms. Next, there is a WDM multiplexer that joins all the channel into one-fiber. The freed light is then communicated with the assistance of optic head under the beam angle of 2mrad. The greater part of the set worth compares previously acknowledged single-direct association in the territory of VSB TUO where head are 1400 m far away [2]. In the collector side, the optical sign is limited to the optical fiber and afterward it is separated to 4 channels with the assistance of WDM demultiplexer. The optical range can be examined before WDM demultiplexer as appeared in figure 2(a).

VII. Results

The boundaries of the communicating head were given qualities as 8 cm and of getting head as 20 cm. The attenuation of course is picked in minimal dirtied climate of 4.6 db. During the reenactment the FSO channel is influenced by numerous air impacts, turbulences and haze have the greatest effect. The quality of the signal is noticed for various attenuation rates. As the attenuation rate is expanded the quality of the signal is decaying down that because of extra commotion from the climate and when

attenuation is least, the outcomes have demonstrated great signal with no blunder.

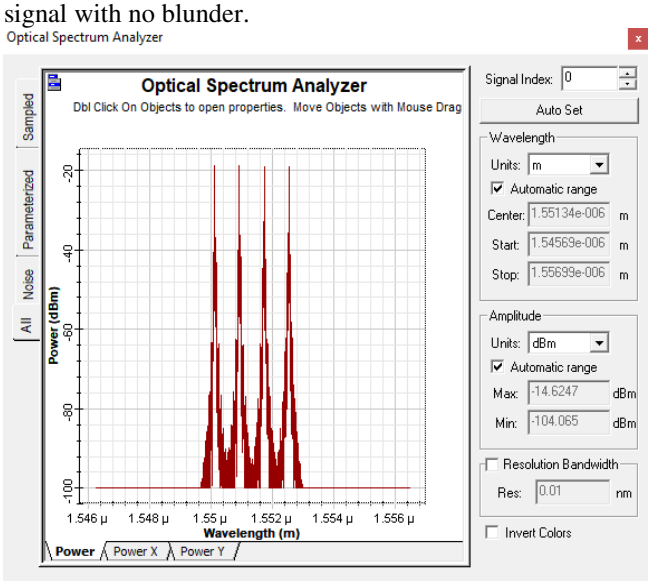

Figure 2(a): Output of Spectrum analyzer

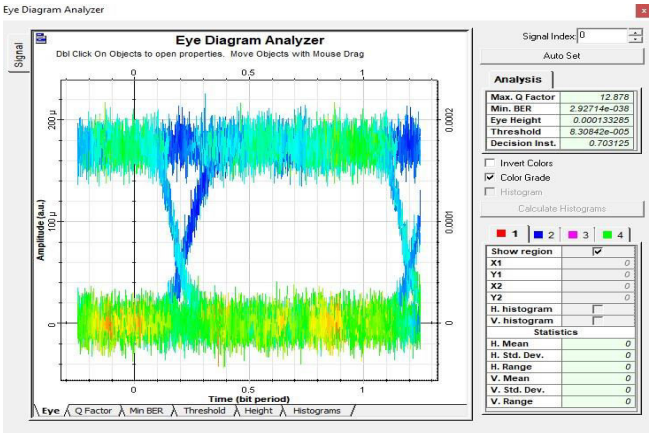

Figure 2(b): Eye Diagram at Attenuation= 1 dB/Km

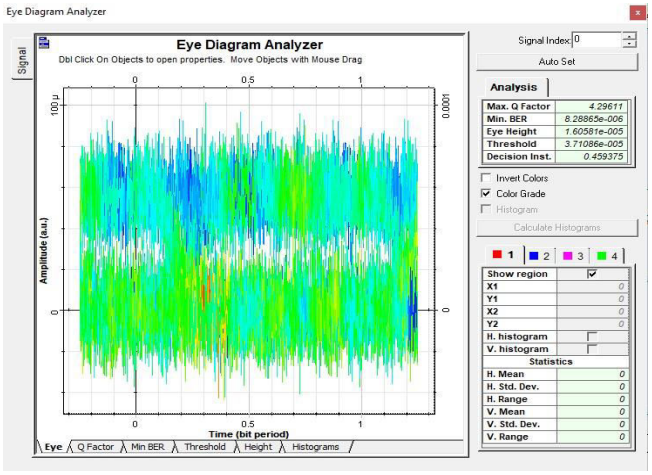

Figure 2(c): Eye Diagram at Attenuation= 4.5 dB/Km

VIII. CONCLUSION

In this paper, we have examined about the centrality of FSO innovation and how it assumes a significant function in the present time to defeat the data transfer capacity impediments. We accept that FSO is a basic part for heterogenous networks. Different channel models are talked about to relieve the impact of turbulences in channel. A few different models for short turbulences have not increased a lot of prominence, the momentum research on the developing zone of FSO interchanges will give integral innovation of RF frameworks to the Future age. Further, FSO with WDM is recreated on Opti system. The blunder in signal on Eye diagram is seen for 1 and 4 dynamic channels. Recreation results lead to the end that blunder in the individual channel or the signal's quality relies upon the quantity of dynamic channels. At one channel dynamic the blunder is less as compared to the blunder acquired under 4 dynamic channels which is brought about by mishearing by WDM demultiplexer. The attenuation rate for NRZ and RZ scopes to 6.3 Db/km. During any turbulences the most ideal decision is consistently BPSK since its attenuation to get better BER is 9.3 dB/Km. To build the transmission power, we can add EDFA amplifier before the FSO channel with the goal that the error rate is more modest.

IX. REFERENCES

[1] Ales Vanderka, Lukas Hajek, Lukas Bednarek, Jan Latal, Jan Vitasek, Stanislav Hejduk, Vladimir Vasinek , "Testing FSO WDM Communication System in Simulation Software Optiwave OptiSystem in Different Atmospheric Environments," VSB-Technical University of Ostrava, Department of Telecommunications, 17. listopadu 15/2172, Ostrava-Poruba, Czech Republic.

[2] Mohammad Ali Khalighi∗ , Murat Uysal∗∗ ∗ Institut Fresnel, UMR CNRS 7249, Ecole Centrale Marseille, Marseille, France, "Overview on Free Space Optical Communication: A Communication Theory Perspective," ∗ Department of Electrical and Electronics Engineering, Ozye ¨ gin University, Istanbul, Turkey, 34794.

[3] Hennes HENNIGER(1) , Otakar WILFERT(2), "An Introduction to Free-space Optical Communications," (1)Institute of Communications and Navigation, German Aerospace Center (DLR), 82230 Wessling, Germany , (2)University of Technology Purkynova 118, CZ-61200 Brno, Czech Republic

[4] Ruijie Li, Jiankun Zhang, and Anhong Dang, "Helpful System in Free Space Optical Communications for Simultaneous Multiuser Transmission."

[5] Bingcheng Zhu, Julian Cheng, Senior Member, IEEE, and Lenan Wu, "A Distance-Dependent Free-Space Optical Cooperative Communication System."

[6] Ruijie Li, Te Chen, Luhai Fan, and Anhong Dang, "Execution Analysis of a Multiuser Dual-Hop Amplify-and-Forward Relay System With FSO/RF Links."

[7] C.H. Yeh, C.W. Chow, C.S. Gu, B.S. Guo, Y.J. Cheng and J.H. Chen, "Execution examination of free space optical correspondence traffic incorporated with detached optical organization."

[8] Vincent W. S. Chan, "Free-Space Optical Communications," Fellow, IEEE, Fellow, OSA.

[9] Mostafa Zaman Chowdhury, Moh. Khalid Hasan, Md. Shahjalal, Md. Tanvir Hossan, Yeong Min Jang, "Optical Wireless Hybrid Networks: Trends,

Opportunities, Challenges, and Research Directions," Senior Member, IEEE, Student Member, IEEE, Student Member, IEEE, Member, IEEE, Member, IEEE.

[10] Pratiti Paul, Manav R. Bhatnagar and Anshul Jaiswal, "Sticking in Free Space Optical Systems: Mitigation and Performance Evaluation," Student Member, IEEE, Senior Member, IEEE, Member, IEEE.

[11] Mohammad Ali Amirabadi, and Vahid Tabataba Vakili, "another advancement issue in FSO correspondence framework."

[12] F. Javier Lopez-Martinez, Member, IEEE Gerardo Gomez José María Garrido-Balsells, "Physical-Layer Security in Free-Space Optical Communications," Volume 7, Number 2, April 2015.

[13] Muhammad Salman Bashir, and Mohamed-Slim Alouini, "Signal Acquisition With Photon-Counting Detector Arrays in Free-Space Optical Communications," Member, IEEE, Fellow, IEEE.