INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X

Impact factor: 4.295

(Volume3, Issue3)

Available online at www.ijariit.com

Performance Analysis of Data Transmission in Free Space Optical (FSO) Communication

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Abstract: Free space optical (FSO) communication has become a viable technology for a broadband wireless application which offers the potential of high bandwidth capacity over unlicensed optical wavelength. Atmospheric turbulence has most significant impact on the quality of laser beam propagating through the atmosphere over a long distance. For optical wireless communication system, most frequently used system is dense wave division multiplexing (DWDM). We are applying 150m channel spacing with 40 GHz bandwidth and 1550nm laser source. FSO channel work like Afocal scheme, it can reduce the size of the laser beam, and expected longer free-space transmission in FSO communication, receiver side equal gain combining technique in presence of strong atmospheric turbulence. The signal to noise ratio (SNR), good bit-error-rate (BER) performance and clear eye diagram are obtained and will be evaluated numerically for different system parameters. Such as DWDM FSO communication in provided the long transmission distance and high transmission rate, it useful for high-speed light based Wi-Fi and Li-Fi applications

Keywords: FSO Channel, Dense- Wavelength-Division Multiplexing, Opt system V.14.

I. INTRODUCTION

Free space optical communication transmit high-speed data rate, a high-quality signal with laser light propagation in free space link. FSO communication is high directivity, unlicensed bandwidth, easy setup, and flexibility through a free space link, isolation from other interferences and using by multiple applications with FSO link [1-2]. It has several advantages over the traditional radio frequency (RF) based wireless communication. In this, a 150m-160Gbps FSO communication with FSO channel like afocal scheme and dense-wavelength-division-multiplexing (DWDM) is using and wavelength is 1550nm CW laser source. Free space transmission distance is greatly increased by the afocal scheme transmission rate is significantly increased by DWDM technology. By afocal scheme which is reduce the size of the laser beam, it provides long free space transmission distance in FSO communication [2]. DWDM FSO communication different optical wavelength to transfer data is to be useful for providing higher transmission rate. The simulation of FSO communication by using 16 channel of CW laser source with 193.1 THz frequency with 20 dBm power source and each channel carried out of variation of 0.1 THz, with 150-m free space link with total transmission 160Gbps with the help low noise amplifier (LNA) and clock/data recovery at the receiving end, and we see the good bit-error rate and eye diagram. But issue faced by atmospheric turbulence like as (rain, haze, fog, dust etc), and advantage of optical wireless communication high transmission rate high-speed light based Wi-Fi and (Li-Fi) application [4] as well.

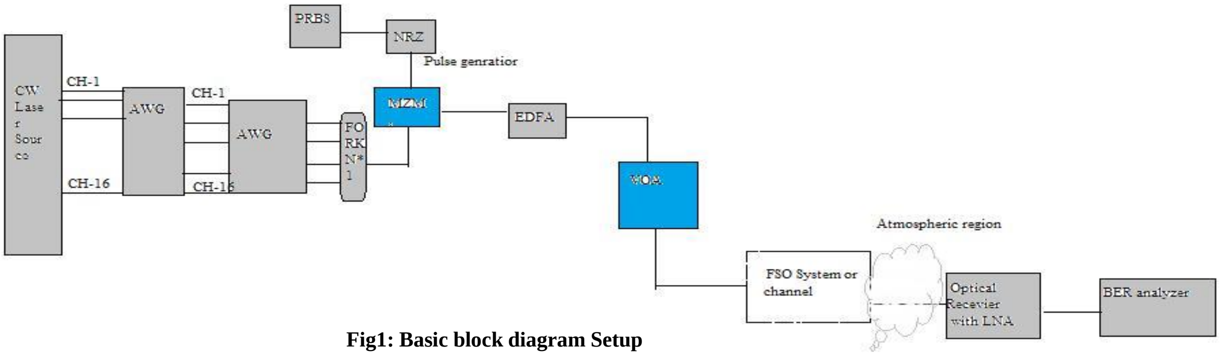

Fig1: Basic block diagram Setup

II .PROBLEM STATEMENT

In free space optics, simulation setup configuration of 150-m DWDM FSO communication, Continuous laser source (CW) efficiently split into 16 channels setup with 193.1 THz frequency with 20 dbm power on each channel, 1x16 arrayed wave guided grafting (AWG) de-multiplexer (DMUX) with channel spacing 50 GHz Sixteen wavelength of λ1 to λ16 and bandwidth is 0.32 nm or 40 GHz output of AWG multiplexer (MUX) is 16x1 transmitted into a mesh Zehnder modulator (MZM) with extinction ratio of 40 db with Pseudorandom binary sequence (PRBS) bit sequence with (0001011011101011) generated by PRBS generator or input data sequence ,transmitted over 16 channels ,after this data will go through the erbium doped fiber amplifier (EDFA) it is amplified the signal pump with forward and backward laser is 1550 nm then, the second stage is a variable optical attenuator (VOA) start the optical power launch into FSO channel with attenuation 0.55 db, optimized to the best transmission performance in 1550 region with DWDM FSO communication wavelength. In the FSO channel we are configured with free space length is 150-m and attenuation is 2.77db/km in this region of FSO channel transmitter aperture diameter is 10 mm and beam divergence is 0.00137 mrad, with 1db additional transmission loss. Transform the divergent beam into the parallel beam, the function of afocal scheme is reduce the size of the laser beam and the second stage of lens focuses the reduced parallel beam into a point. Over 150-m space link receiver diameter is 8mm. Data received with optical receiver, with PIN Photodiode component is used to convert an optical signal into an electrical current based on the device‘s responsively of 1 mA/mW (at 1550 nm) with gain is 3 db bandwidth of 0.32 nm and ionization ratio is 0.9, in this little noise as possible, LNA amplification data stream is recovered or regenerate by bit error rate analyser

But in this situation, we can face challenges like atmospherics turbulence (rain, haze, fog, dust etc).because of this natural disaster we are not able to receive the data we found the error. Due to this reason, we are not able to get the exact speed for which we are looking

2.1The Received photodetector current at the presence of Atmospheric Turbulences

The received optical signal level is highly dependable on the FSO channel parameters.

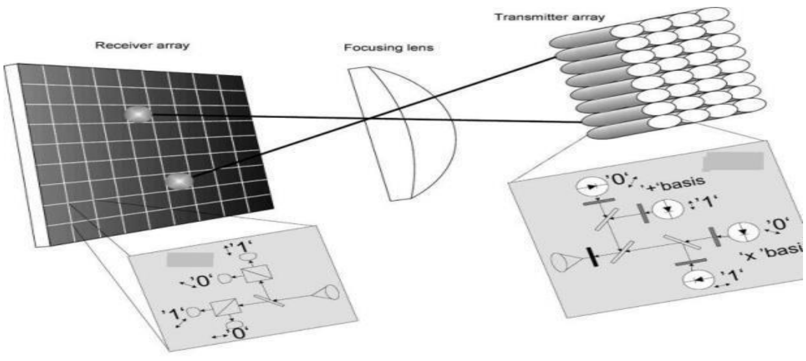

Fig2: photo Detector

For a PIN diode, a photodetector current Ip will be generated based on

$$I_P = \Re P_{rx} = \Re P_{tx} L_{tx} G_{tx} L_P L_R G_{rx} L_{rx} \quad (1)$$

Where ***R*** is responsivity of PIN diode, ***Prx*** is received power, ***Ptx*** is transmitted power, ***Ltx*** is transmitted optics efficiency, ***Gtx*** is transmitted gain, ***Lp*** is pointing loss, ***LR*** is range loss, ***Grx*** is receiving gain and ***Lrx*** is receiving optics efficiency. Assuming accurate beam pointing, values of these parameters are fixed except the range loss, which depends on the distance.

Considering signal shot noise, dark current shot noise and thermal noise in the detection Process, noise current ***noise***, is given by

$$i_{nois} = \sqrt{\left[2q\left(i_{p+i_{dark}}\right)\right] + \left[\frac{4kTB}{R_{eq}}\right]} \quad (2)$$

Where **dark** is dark current, i**shot** is shot noise current; i**thermal** is thermal noise current, **B** is signal bandwidth or data rate, **k** is Boltzmann constant, **T** is temperature and **Req** is the equivalent resistance.

$$\Delta f = \frac{1}{2\pi C_t R_{eq}} \quad (3)$$

Equn(3) gives the frequency response, ***f***, of a PIN diode ***Ct*** is the terminal capacitance of the PIN. Thus, for any wideband operating PIN, the required low ***Req*** will cause high thermal noise and therefore thermal noise is the dominating noise source.

And for, AWGN calculation we use;

AWGN= σ^2 thermal + σ^2shot (4)

$$\sigma^2 thermal = \frac{4KTB}{RL}; \quad (5)$$

2.2 Bit Error Rate (BER)
Standard transmission error rate of a media such as copper wire, coaxial cable, or fiber-optic cable. Used as a measure of transmission quality, it is the ratio of error bits received to the total bits sent. BER is expressed usually as a negative power of ten. Threshold detection concepts are illustrated in Figure 2.2

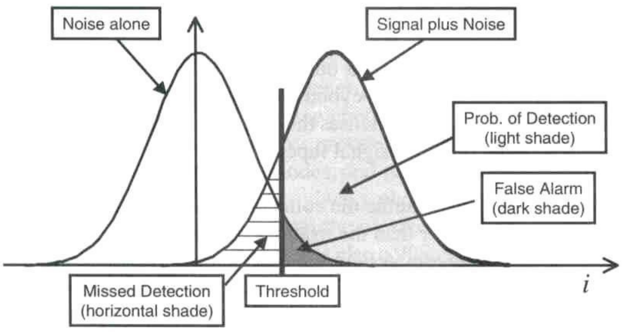

Fig3: Probability of detection and false alarm.

$$BER = \frac{1}{2}(P_{av} + P_{xro})$$

$$= \frac{1}{2}\left[P\left(i_N < -\frac{1}{2}\right) + P\left(i_N > \frac{1}{2}\right)\right] \quad (6)$$

Can be written as,

$$BER = \frac{1}{2\sigma\sqrt{2\pi}}\left(\int_{-\infty}^{\frac{I}{2}} e^{-x^2/2\sigma^2} dx + \int_{I/2}^{\infty} e^{-x^2/2\sigma^2}\right)$$

$$= \frac{1}{2} erfc\left(\frac{1}{2\sqrt{2}}\sqrt{\frac{S}{N}}\right)$$

$$= \frac{1}{2}\left[\frac{1}{2} erfc\left(\frac{2}{2\sqrt{2}}\sqrt{\frac{S}{N}}\right) + \frac{1}{2} erfc\left(\frac{1}{2\sqrt{2}}\sqrt{\frac{S}{N}}\right)\right]$$

7)

2.3 LOGNORMAL TURBULENCE MODEL

The atmospheric turbulence impairs the performance of an FSO link by causing the received optical signal to vary randomly thus giving rise to signal fading. The fading strength depends on the link length

$$\sigma_1^2 = 1.23 c_n^2 \left(\sqrt[6]{K^7 L^{11}}\right) \tag{8}$$

We use the value of $.1<\sigma l^2<.9$w
$Cn^2 \leq 10$^-14 weak turbulence
$Cn^2 \geq 10$^-14 strong turbulence
K=2Π/λ
L=Distance between Tx & Rx

The log-normal models assume the log intensity *l* of the laser light traversing the turbulent atmosphere to be normally distributed with a mean value of – *$\sigma l^2/2$*.Thus, the probability density function of the received irradiance is given by the following equation

$$P_1 = \frac{1}{\sqrt{2\pi\sigma_l}}\frac{1}{I}exp\left\{-\frac{(ln(I/I_0)+\sigma_l^2/2^2)}{2\sigma_l^2}\right\} \tag{9}$$

III. EXPERIMENTAL APPROACH

In the free space optics, we are applying the 16 channel of CLW laser source and given the source in terahertz frequency like 193.1 THz. With each channel variation of different- Different laser power source. All power go through the array wave grating (AWG) with 16 channel work like as demux and power source and second is work like as mux and all power is going on and discuss output ports. In PRBS when we give the input like binary sequence of 14 digit bit/s, binary sequence is applying non-return to zero NRZ, then modulated the power source EDFA length 1 m, and forward and backward laser source is 1550nm, all power is transfer in variable optical attenuation (VOA), attenuation factor is 0.55 db. We are applying the FSO channel in free space link length is 150-m, additional losses 1 db in channel transmission aperture, we are using the optical receiver in this 3 db losses of difference NRZ modulator factor and the system of fallowing at 1550 nm region. In this applying 5 iteration in a system at giving good bit error rate and clear EYE diagram

Optimum System Parameters will be determined for a given system BER (10^-7)

Parameter	**Values**
Data rate, ***Rb***	(1 -150) Gb
Laser wavelength,**λ**	850nm (used in simulation) 1360nm
PIN photodetector Responsivity, ***R***	0.8 or 1**
Receiver Sensitivity	-45 dBm
Lognormal variance,**σl^2**	$0.1< \sigma l^2<0.9$ ** $1< \sigma l^2<2$
Number of antennae ,**L**	6-8
Number of sub-carrier	16
Used modulation scheme	**BPSK-** **SIM**
Used Subcarrier power for desire communication	(22-25) dBm week turbulence & (10-12) dBm strong turbulence

Used photodetector	InGaAs PIN (used in simulation) **InGaAs APD
Tx to Rx distance	1m-1Km
Optical modulation index, ξ	IξI $\leq$ 1
Transmit Lens diameter, **Dtx**	10 mm each
Receiver Lens diameter, **Drx**	8 mm each

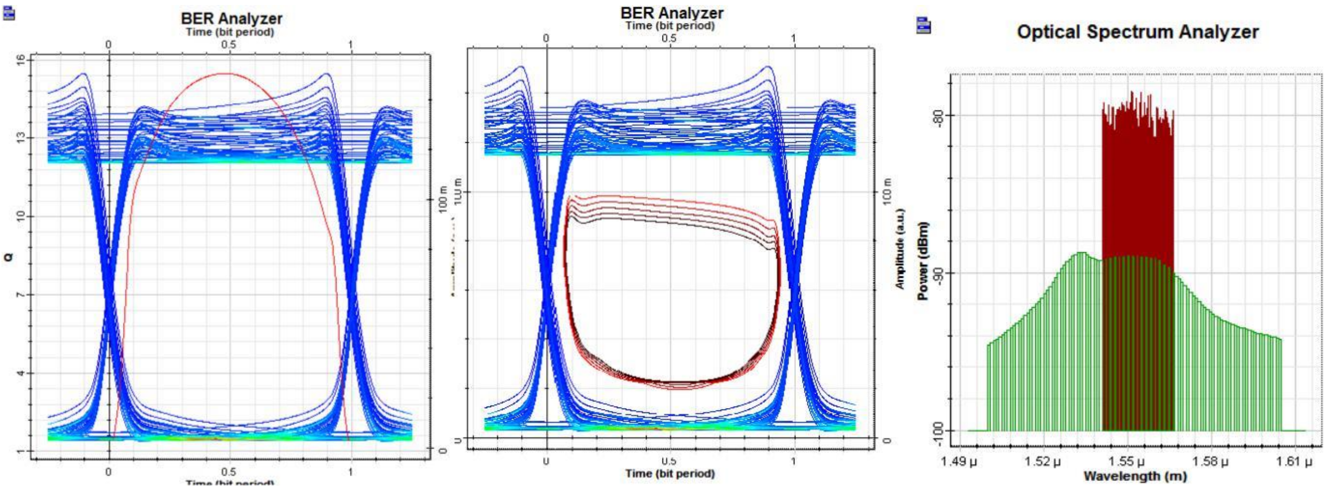

Fig. 4 Measured EYE diagram and EYE pattern of DWDM FSO Communication at data stream

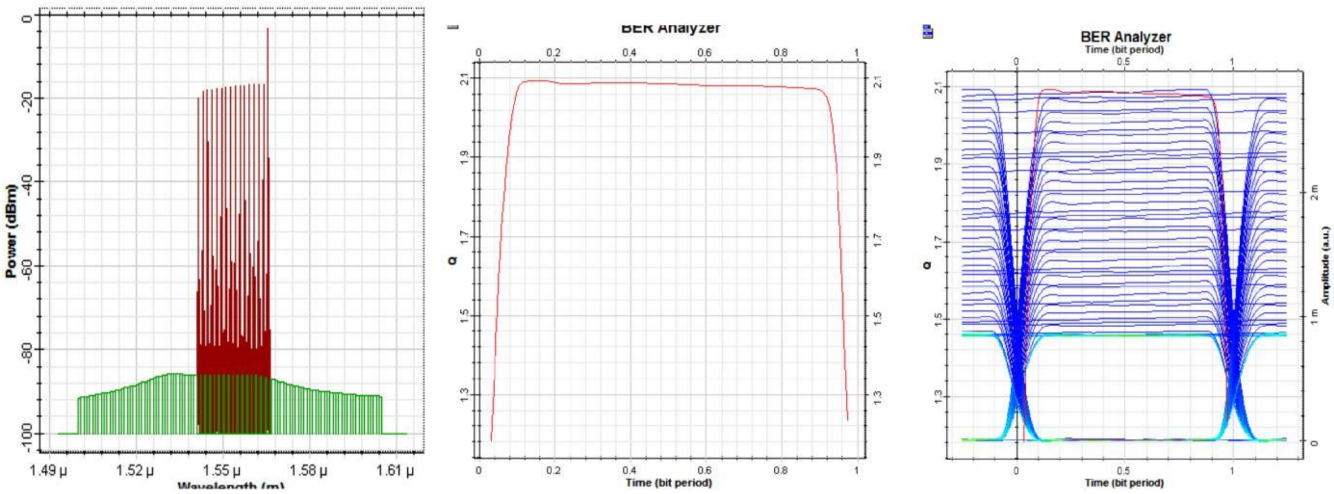

Fig. 5 Measured BER Analyzer and RF Spectral Analyzer Q- factor and EYE diagram of FSO communication

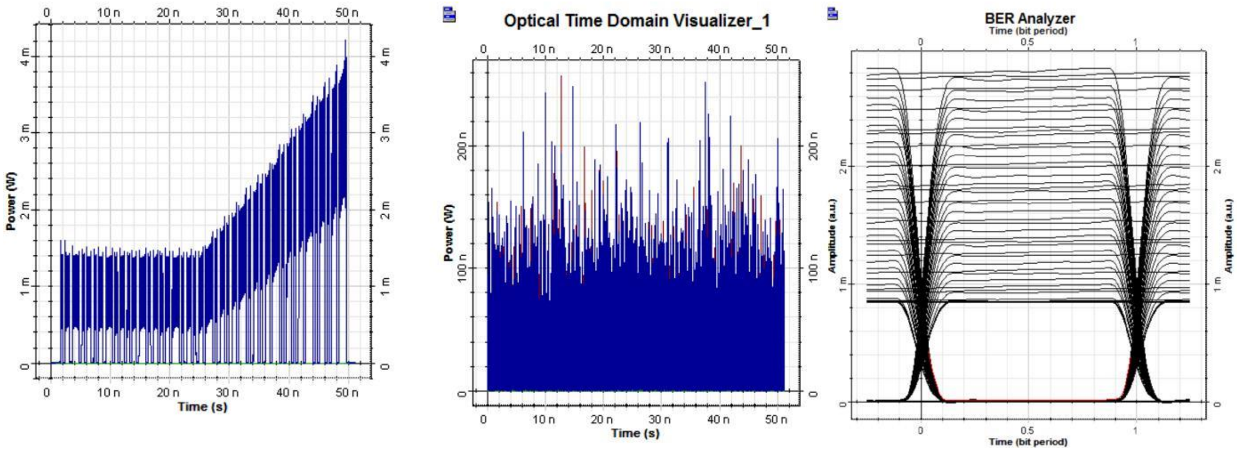

Fig. 6 Measured BER pattern, RF analyzer, OTDR visualizer and EYE diagram.

CONCLUSIONS

As proposed the basics FSO communication but for better performance, we used maximum ratio combination technique. We try to analysis to find out the expression of the signal & photodetector currents in presence of strong atmospheric turbulence for the MIMO FSO system as far as possible considering all the parameters which are efficiently practical to the system. The signal to noise ratio (SNR) and the unconditional BER was evaluated numerically for different system parameters. The degradation in system performance due to the channel effect and improvement in receiver sensitivity were determined numerically. And then we try to plot in the graph and determine the performance for different turbulence condition. Optimum system parameters were determined for a given system BER, and we assume BER $10^{-7.}$ The proposed DWDM FSO communications are simulation demonstrated with low Bit Error Rate (BER) operation and clear eye diagram. The findings demonstrated that such a DWDM FSO communication can provide the advantages of optical wireless links for long transmission distance and high transmission rate. But in this, we found some data losses and Errors like Atmospherics Turbulence Such as (Haze, Thunderstorm, Rain, fog, and Dust).

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