Simulative Investigation on Free Space Optical Communication with Optical Amplification Based on 4X4 Transmitter/Receiver Combination

Harneet Kaur[1], Himali Sarangal[1]
[1]*Guru Nanak Dev University, Amritsar, Punjab, India*

***Abstract* -** FSO technology provides an effective solution for increasing demand of higher bandwidth and high data rate. Free Space Optics systems suffer from various limitations such as sensitivity on local weather conditions .The main objective of this article is to improve the quality of data transmission using multiple transmitters/receivers integrated with optical amplification. By using feasible parameters such as transmitted power, transmitted wavelength, amplifier gain and APD responsivity for this system, FSO quality can be improved. In this work, 20 Gbps data stream is transmitted for different weather conditions and performance is analyzed .The maximum distance of 405 km is achieved under clear weather condition, for 1550nm wavelength within acceptable received power.

***Keywords* -** *Free Space Optics, APD Avalanche photodiode, PIN photodiode, Bit Error Rate, Multiple TX/RX FSO.*

I. INTRODUCTION

FSO is now day's major topic of research in the world of optical communication. This type of cable less optical communication technology has attracted significant attention recently in high data rate wireless link. FSO technology require no license frequency band allocation, immune to interference and is easy to install [1]. FSO provides secure transmission high capacity and low deployment cost [2]. FSO technology can be used for LAN services and is a better solution for last mile access problems [3]. Fiber optics is quite popular these days but high cost of laying down fiber cables and cost of digging is high. Whereas FSO provides point to point high speed wireless optical communication. Other popular technologies such as microwave, RF, copper have many disadvantages such as interference, expensive, dispersion effects, low data rates and limited capacity. So FSO technology is the most practical option for secure, high data rates and low cost communication systems. FSO is a better solution for broadband networks where optical fiber deployment is not feasible. Despite of the fact FSO has many advantages, there are many limitations that effects the system link performance .Different weather condition, building sway, [4] atmospheric turbulence and scintillation are the major challenges for FSO technology [5][6]. .Heavy rain in tropical regions is also the major problem faced by FSO system. The atmospheric condition such as fog, haze and rain severely effects the link performance [7, 8].

Multiple TX/RX which is also called diversity technique improves the quality of performance. [9] .By doubling the transmitters/receiver pair, the received power is increased by 6db.Here in this work, 4X4 TX/RX pair is used. This work focuses on the two performance parameters BER and maximum achievable link distance. Optical amplification enhances the performance of 4X4 multiple transmitter/receiver pair. [10] The optical amplifier is applied at the transmitter thus known as the pre amplification. Transmission distance and BER performance for system is analyzed based on simulations. Section II describes the simulation set up and system parameters. The section III discusses the results and the paper is concluded in the section IV.

II. SIMULATION SETUP

The software platform uses optical communication package optisystem 7.0 of Optiwave Company. The study establishes a 20Gbps high speed atmospheric optical communication model based on multiple transceivers integrated with optical amplification. Fig. 1 shows the block diagram for the FSO system with 4TX and 4RX combination integrated with optical amplifiers. It consists of optical transmitter connected to fork. A fork is a component used to duplicate the number of output ports so that each of the signals coming out from fork's output has the same value with the output signal from the previous component connected to it .The first fork produces the multiple beam and this fork is connected to another set of forks which also produces multiple laser beams .These laser beams are combined by the power combiner. An optical amplifier is applied before output is given to FSO channel. At the receiver side power coming from the FSO channels is again combined by power combiner and then fed to the optical receiver .The three visualizers are used in simulation is the optical power meter, optical spectrum analyzer and BER analyzer .The BER analyzer calculate the BER value and display the eye diagram of the system. Table 1 shows the system parameters used in the FSO model. Table 2 shows the attenuation offered to the 1550nm wavelength for various weather conditions [10].

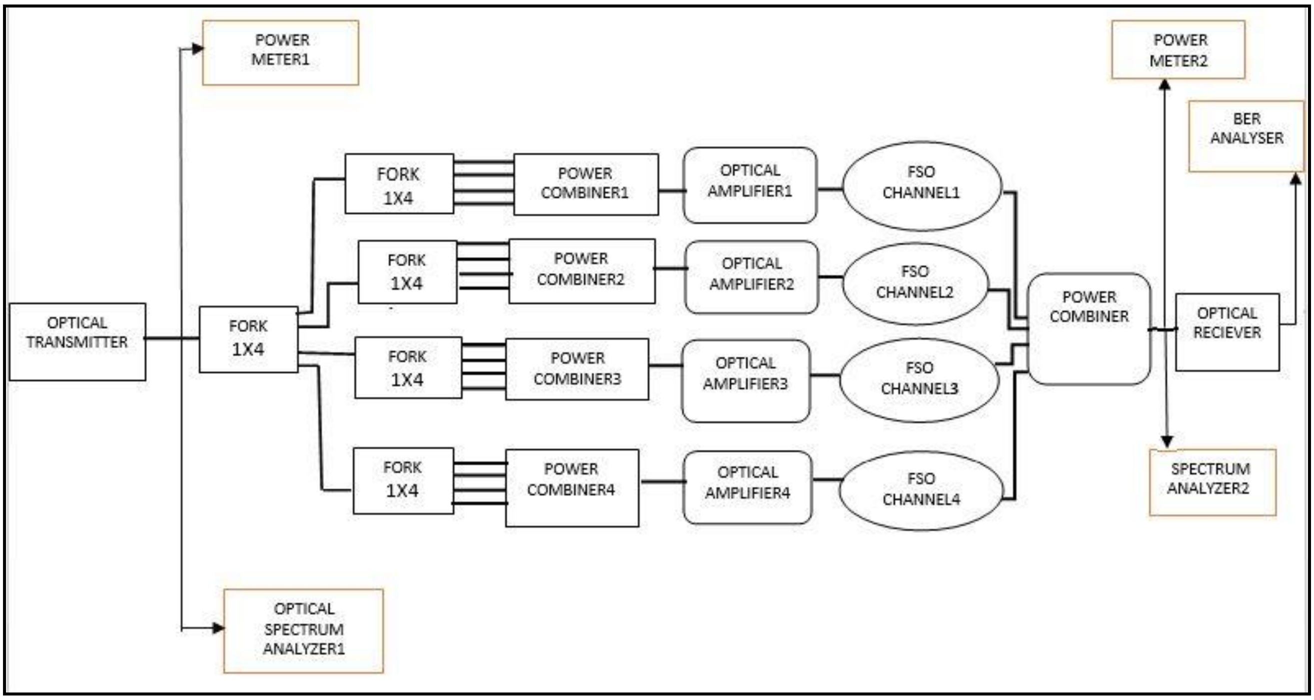

Fig.1: Block Diagram of FSO system

TABLE 1: FSO system parameters

Parameter	Value
Transmitted Wavelength	1550 nm
Data Rate	20 Gbps
Transmitter Aperture	2.5 cm
Receiver Aperture	45 cm
Transmitted Power	25 dBm
APD Responsivity	52 A/W
PIN Responsivity	0.85A/W
Amplifier Gain	30 dB
Transmitter loss, Receiver loss	1.8 dB, 1.8 dB
Receiver Sensitivity	-45 dBm
Beam Divergence	2 mrad

TABLE 2: Atmospheric attenuation at different weather conditions for 1550 nm wavelength

Weather Conditions	Visibility (km)	Attenuation(dB/Km)
Clear air	23	0.1
Haze	2	4.2
Light Fog	0.8	15.5
Moderate Fog	0.6	25.5

III. RESULTS AND DISCUSSIONS

Multiple transceivers improves the received power at the receiver and thus increasing the link range. Maximum range which can be transmitted at minimum BER is increased by using optical amplification. Table 3 and table 4 shows the results for various weather conditions for APD and PIN receiver respectively. The two types of receivers are used PIN and APD.Maximum link distance is calculated at acceptable received power at acceptable minimum BER values for different atmospheric conditions. With the data rate of 20 Gbps at clear weather condition using 1550 nm wavelength, link range can be highly improved. By using 4X4 TX/RX combination with optical amplifier and APD receiver, maximum range of 405 km is achieved at an acceptable received power and at a very high data rate. In moderate fog condition good range of 3.24 km is achieved at $3.84e^{-009}$ BER. With PIN receiver at clear weather condition, maximum range of 330 km is achieved at BER $7.57e^{-010}$ with received power of -35.5 dBm Fig.3 shows the eye diagram of APD receiver with maximum range of 405 km and BER of $9.34e^{-010}$ and fig.4 shows the eye diagram for PIN receiver at maximum Range of 330 km at BER of $7.57e^{-010.}$

TABLE 3: Results for APD receiver at different weather conditions

Weather Condition	Maximum Range	Received Power	Received BER
Clear Air	405 km	-44.8 dBm	$9.34e^{-010}$
Haze	16.3 km	-44.87 dBm	$1.4e^{-009}$
Light Fog	5.05 km	-44.53 dBm	$1.18e^{-010}$
Moderate Fog	3.24 km	-45.0 dBm	$3.87e^{-009}$

TABLE 4: Results for PIN receiver at different weather conditions

Weather Condition	Maximum Range	Received Power	Received BER
Clear Air	330 km	-35.5 dBm	$7.57e^{-010}$
Haze	14.4 km	-35.82 dBm	$2.697e^{-009}$
Light Fog	4.55 km	-35.87 dBm	$3.406e^{-009}$
Moderate Fog	2.9 km	-35.40 dBm	$4.02e^{-010}$

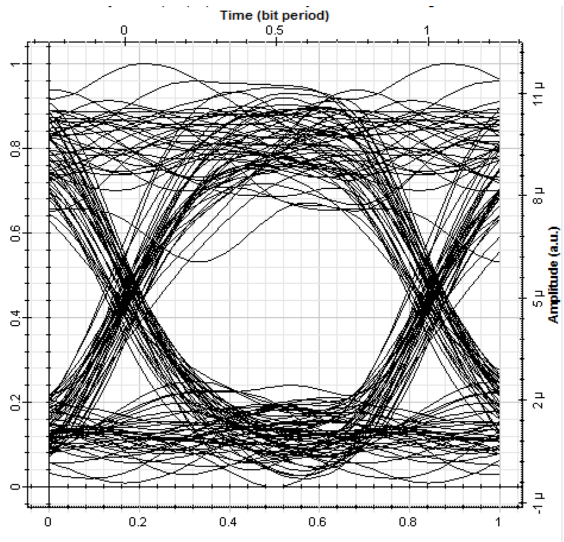

Fig. 3 Eye Diagram for APD receiver

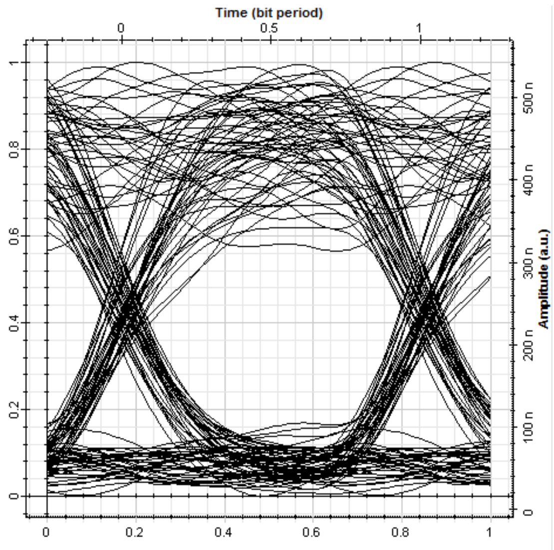

Fig. 4: Eye Diagram for PIN receiver

IV. CONCLUSION

Different weather conditions is the major problem to operate FSO link such as fog, haze and rain. So in this work, a novel system for 20Gbps diversity based FSO system is designed with integration of optical amplification. It is concluded that with the use of multiple transceivers and pre amplification with APD receiver, FSO system can work up to 405km with acceptable received power and BER .With the increase of atmospheric attenuation as the weather condition gets worsen, the maximum achieved distance can be extended upto 3.2 km and 2.9km for APD and PIN receivers respectively with acceptable received power and BER.

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