Performance Analysis of Optical Wireless Communication Link By Multiple Tx/Rx with and Without Amplifier

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Abstract – optical wireless transmission system is presented as a solution for the increasing demands of high speed & high bandwidth channel with higher data rate transmission over longer distance. Optical wireless communication links can be used for satellite-to-satellite cross links, up and- down links between space platforms- aircraft, ships, and other ground platforms, and among mobile and stationary terminals within the atmosphere. This paper analyze free space optical link by varying number of transmitter and receiver. Multiple TX/RX improves the quality of the signal over a large distance at high data rates (Gbps). Optical wireless communication is analyzed in terms of received power, eye diagram and Q-factor.

Keywords: Optical Wireless Communication (OWC); Multiple TX/RX.

I. INTRODUCTION

Optical wireless communication (OWC) is a communication technology that uses line of sight (LOS) path propagating in free space for transmission of signal/data/information between two desired points for telecommunications or computer networking [1]. The OWC is based on the optical communication with only difference that this system does not use solids as a transmission medium such as optical fiber cable or optical transmission line. OWC is basically adopted when the physical connection is not practically possible due to high cost or other consideration [2]. Hence, this technology employs air as the medium of transmission, the vulnerability towards atmospheric phenomena is inevitable. These disturbances will significantly affect the OWC transmission performances. The atmospheric turbulences will cause the rapid fluctuation of received power and eventually will reduce the system quality. Moreover, the interruption of the laser beam such as bird flap will also disturb the communication channel strength which can be improved by using amplifier [3]. OWC link is still considered as a relatively new technology though fiber-optic communication has been widely used in worldwide telecommunications industry. For the research and communication purpose for the benefits of the mankind, the manmade satellites have been developed .A satellite is an object that orbits around another object in space. The satellite may reside in one of the several orbits- low Earth orbit (LEO), medium Earth orbit (MEO), highly elliptical orbit (HEO) and geosynchronous orbit (GEO) [3]. An intersatellite link is a communications link that connects two separate satellites directly. One satellite could have several links to numerous other satellites. Intersatellite links are very important for communication of two satellite in same orbit or two different orbits like communication between a LEO and GEO satellite [2]. In this paper, we are considering the communication by varying multiple TX/RX as large transmitter power and aperture diameter are needed for communication at high data rates over large distance communication, so multiple TX/RX are used to improve the performance of OWC link. The need of high speed communication system is increasing day by day free space optical communication became more popular. Optical wireless communication is an ultra high speed and large capacity communication which is based on use of lasers as a carrier signal. Optical wireless communication is preferred over RF communication because of having narrower beam width due to use of lasers and other advantages like reducing the size of antenna, used hence reducing the weight of the satellite, minimizing the power used for the communication system, and offering higher data rate [3],[4],[5].

II. SYSTEM DESIGN

Wavelength available for OWC channel are 850 nm and 1550 nm, here we are using the transmitter wavelength as 1550 nm. The attenuation due to Rayleigh scattering and Mie scattering is inversely proportional to wavelength, 1550 nm is the longest wavelength therefore it is the most preferable wavelength for the communication. Multiple TX/RX system architecture for optical communication has several specifications that have effect on the system performance. Several specifications for the whole system architecture are represented in Table 1.

The satellites communicate in a full duplex mode using optical system. Simplex optical wireless communication is a one way data transmission shown in fig.1. The data is modulated by mach-zehnder modulator using light signal by laser as a carrier signal.

TABLE 1: Multiple TX/RX system for Leo satellite FSO link specification

Parameters	**Values**
Transmission Bit Rate	5.6 Gbps
Link distance	5000 km
Transmitter wavelength	1550 nm
Modulation type	NRZ
Transmitter aperture diameter	50 cm
Receiver aperture diameter	50 cm
Beam divergence	2 mrad
Responsivity	1 A/W
Photo detector Type	APD (Avalanche Photodiode)
Dark current	10 nA

Multiple TX/RX system is model using Optisystem version 12 by optiwave. A typical OWC system consists of a transmitter, a channel and the receiver. The OWC channel is a subsystem of two telescopes with the free space optical communication channel between them and it is considered as the propagation medium for light transmission [3]. The OWC channel in between the transmitter and receiver end has a 50 cm optical antenna aperture diameter. Fig. 2 shows the layout model of multiple TX/RX system, the basic component of the system are the CW laser ,mach-zehnder modulator, fork, power combiner, bit error rate(BER) analyzer, optical power meter.

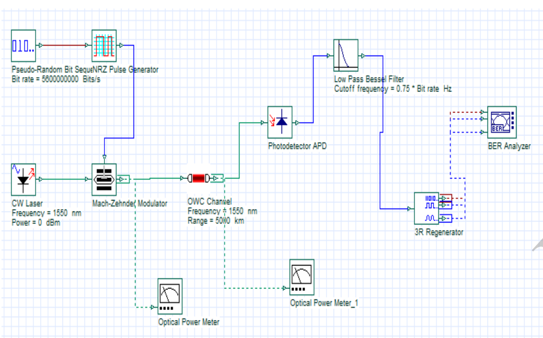


Fig. 1: Simulation Layout of Simple OWC link

Optical transmitter consists of four subsystems. Pseudo random binary sequence (PRBS) generator is the first subsystem which represents the information or data that needs to be transmitted. Non return to zero (NRZ) electrical pulse generator is the second subsystem which encodes data from PRBS generator using NRZ encoding technique. Continuous wave (CW) laser is cascaded form of Fabry perot (FP) and Distributed feedback (DFB) lasers. This cascaded form of two types of lasers generates continuous light emission. Mach zehnder modulator is the last subsystem. It is an interferometer device that interferes between two waves of the same frequency but different phases. It varies the intensity of light source from the laser according to the output of the NRZ pulse generator [3]. Optical receiver system consists of three subsystems. APD or Avalanche Photo detector is the first subsystem which converts the optical signal into electrical form and can provide the requirement of higher bandwidth. Bessel Low pass Filter is the second subsystem which cuts off the unwanted higher frequency signals. 3R (Re-shaping, Retiming, Re-generating) regenerator is the last subsystem which regenerates the electrical signal of original sequence or modulated electrical signal as in the optical transmitter. Fork is a special type of component which can produce multiple laser beams from one laser beam source. Optical power meter and BER Analyzer are two visualizer used in the simulation before and after the optical receiver respectively. Optical power meter is used to calculate the average received power at the optical receiver. BER analyzer is used to calculate the BER value automatically along with the eye diagram display of the designed system.

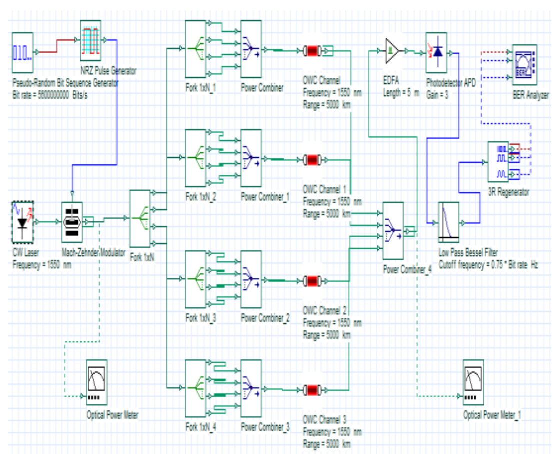


Fig. 2: Simulation Layout of Multiple OWC link with Amplifier

III. RESULTS AND ANALYSIS

A. Performance Analysis through parameters

Parameters like Q-factor, received power, BER and eye height will be used to evaluate the performance of system. Maximum BER is calculated for performance analysis from the Maximum Q factor using the equation (1):

$$BER \approx \frac{1}{\sqrt{2\pi}Q} \exp(-Q^2/2) \qquad \text{... (1)}$$

Where Q=Q factor. It can be seen from Equation (1) that BER is inversely proportional to Q Factor. In other words, higher values of Q Factor ensure lower BER or higher signal to noise ratio (SNR). We observed Fig.1 for simplex OWC and shows that for high data rates in Gbps, the communication for large distance is not possible as needed for LEO satellite communication. With single TX/RX we obtain the value of the parameters: - factor = 0, eye height = 0, minimum BER = 1.

After increasing the number of TX/RX from 1to 8, the parameters : Q-factor and minimum BER takes the value from 0 to 26.811 and 1 to 1.18421e-158 respectively and the received power gain increased by -35.004 to -20.022. It can be seen that increasing the number of TX/RX efficiently increases the received power resulting in 15 dBm of gain.

Table:1 Simulation Output of Multiple TX/RX system with Amplifier in OWC link

No. of TX/RX	Max. Q-factor	Min. BER	Received power (dBm)
1	26.9625	4.50522e-035	- 28.982
2	37.9597	5.18197e-063	- 26.042
3	45.1014	1.51952e-160	-24.042
4	56.1288	9.12243e-316	- 23.174

B. Performance analysis through eye diagram

The Eye pattern technique is used for assessing the data transmitting and receiving capabilities. The system performance of an optical system can be evaluated by it. The significance of wider eye opening is that potential occurrence for data error is reducing because of producing less jitters of the signal. The width of eye opening also determines the time difference over which the received signal can be sampled without error from inter symbol interference. The height of eye opening increases when amplitude distortion in data signal reduces. Sensitivity of the system to time errors is indicated by the rate of eye closing at the sampling time [4], [5].

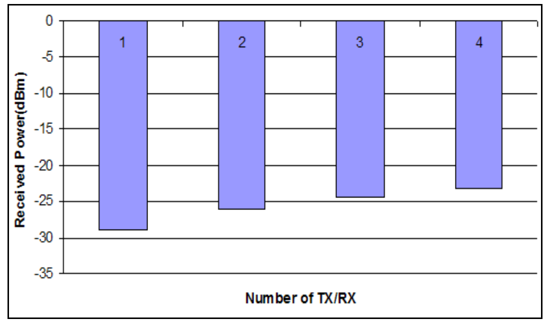


Fig.3. Graphical Representation of Received Power level with the increment of TX/RX (using Amplifier)

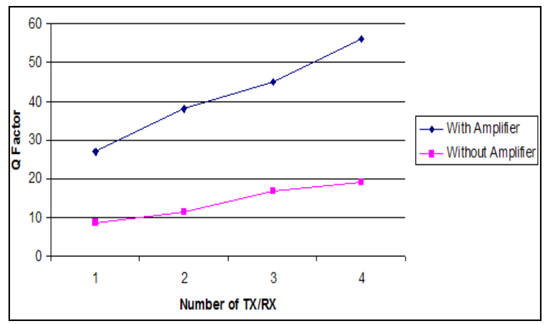


Fig.4. Comparison of Q Factor of Multiple TX/RX system with and without Amplifier

First eye diagram is of simplex or 1 TX/RX system, shows that the amplitude in data signal is completely distorted. In this case we cannot establish any communication link. Comparing Fig. 3, Fig. 4 and Fig.5 it can be predicted that the performance of the system is improved by reducing the amplitude distortion as the eye opening is increasing with the increment of TX/RX numbers. The highest opening is obtained by 8TX/RX system which verifies the improvement in the system performance.

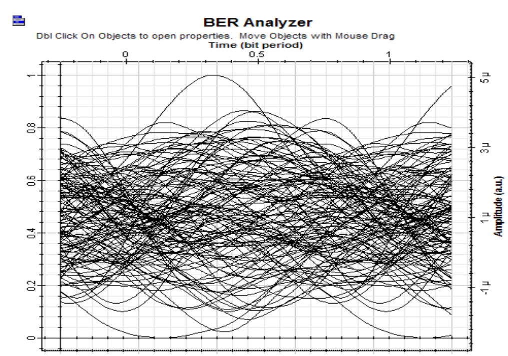
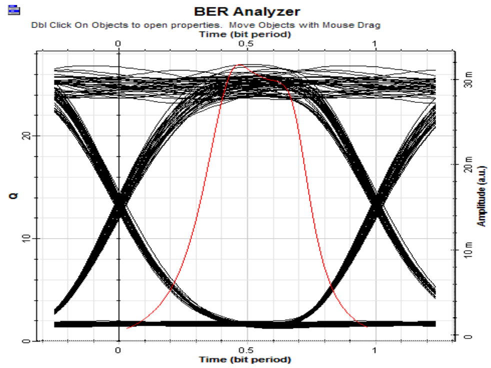
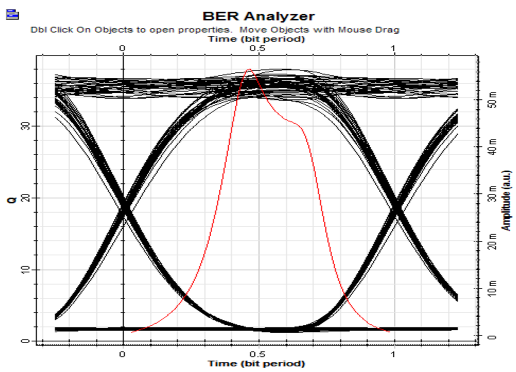


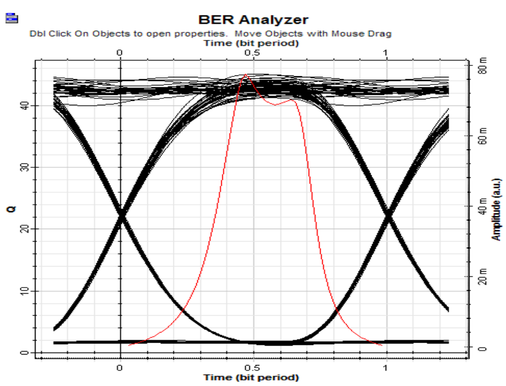
Fig.5. Simulation layout of Simple OWC system in absence of amplifier



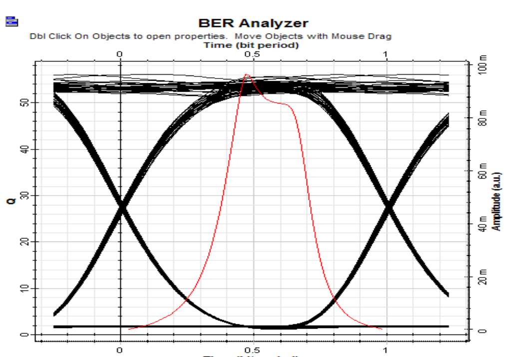
(a)



(b)



(c)



(d)

Fig.6. Simulation Layout of (a) 1TX/RX (b) 2 TX/RX (c) 3 TX/RX (d) 4 TX/RX system with the presence of amplifier in OWC system.

CONCLUSION

Throughout the implementation and simulation results of multiple TX/RX system in optical wireless communication link, it is observed that for simplex TX/RX link the received power calculated is only - 35.004 dBm, it is not possible for large distance of 5000 km. When we use multiple TX/RX system with amplifier, successful communication starts in optical wireless link, the received power has a large value of -28.982 to -23.174 dBm and Q-factor is improved from 26.9625 to 56.1288. It is examined that when the number of TX/RX increases from 1 to 4, data rate up to 5.6 Gbps is successfully achieved.

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