PERFORMANCE IMPROVEMENT OF INTERSATELLITE OPTICAL WIRELESS COMMUNICATION WITH MULTIPLE TRANSMITTER AND RECEIVERS

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Abstract

Multiple transmitters/receivers (TX/RX) architecture for IsOWC links is becoming a more viable solution to improve the quality of the IsOWC communication system. Received power level of the IsOWC system is one of parameter used to determine the link performances This work will make use the multiple TX/RX i.e. multiple laser beams within a IsOWC link based unit to analyze its communication link performances. The effort here is to model the multiple TX/RX FSO link based on the commercial FSO equipment that are on an experimental site as well as measure the IsOWC received power. The performance analysis will be in terms of measured received power, eye diagram and simulated BER. The objectives are to design the multiple TX/RX FSO link and analyze its performance. Here number of TX/RX varies ftrom 1 to 8.Power received in each case is calculated .Investigations are done on bit rates for different number of TX/RX and it is observed that data rate of 18 Gbps is achieved with 8TX.

Keywords*: Free Space Optics (FSO), line of sight (LOS), geometrical losses, link margin, multiple TX/RX FSO*

1. Introduction

All man For years, many researchers have been done to propose alternatives to improve the IsOWC link performances. Some of the techniques are multiple transmitted beams and/or multiple receivers, aperture averaging, adaptive optics, and MIMO . Here we proposes the usage of multiple transmitters/receivers (TX/RX) architecture for IsOWC links. Multiple transmitters/receivers (TX/RX) are used to improve the quality of intersatellite optical wireless communication system. With the current needs of this technology for longer distance, the qualitative analysis of the system has become essential .Since the received power (PR) is one of the parameters to determine the IsOWC link performances. In this work, the received power level (PR) and bit error rate (BER) are considered to determine the IsOWC link performance. The relationship between the two parameters are investigated and analyzed. Furthermore, the received power for various numbers of TXs and RXs are experimentally measured and analyzed.

The IsOWC communication system has a number of advantages. First, no licensing is required [2] in terrestrial communication link. Another advantage is the immunity to the radio frequency interference or saturation [3] has added the security features in this technology. The point-to-point laser signal is extremely difficult to intercept [4], making it ideal for stealthy communications, such as in quantum optics field known as Quantum Key Distribution (QKD). With a narrow beam angle for several miliradians, it is very hard to jam or tap the IsOWC link. Environmental wise, FSO does not pollute the environment with electromagnetic radiation on RF since the wavelength of IsOWC is only from 850nm to 1500nm. Commonly IsOWC systems used single transmitter and receiver to transmit the optical signal but it is possible to incorporate more than one transceiver to improve the system performance. This work proposes the usage of multiple transmitters/receivers (TX/RX) for terrestrial IsOWC links. The effort here is to focus on the most important parameters used to determine the IsOWC link's performance of multiple transmitters/receivers and to simulate their behavior using the accurate mathematical relations that has been derived and improved by previous researches.

2. System Model

The main title (on the first page) should begin 1-3/8 Multiple TX/RX system is modelled for the performance of IsOWC link with analysis by using the OptiSystem Version 7.0 by Optiwave. Figure1 shows the layout model for 8TX and 8RX combinations**.** A typical IsOWC system consists of transmitter, a channel and the receiver..The output signals coming out from the power combiners are then sent to the OWC channel which is the reproduction of the free space channel. It is a subsystem of two telescopes with the FSO channel between them. The apertures of the TX and RX are set to 25 cm. The distance of the channel is set to 5000 km, since the distance between LEO-LEO satellites is about 5000 km..

2.1 Transmitter

The role of the optical transmitter is to convert the electrical signal into optical form [5]. The transmitter takes information from satellite's telementary, tracking and communication (TT&C) system. The electrical signal from TT&C system and optical signal from the laser will be modulated by an optical modulator before it is transmitted out to space. An optical modulator varies the intensity or amplitude of the input light signal from ILD according to the electrical signal. Continuous wave laser whose power is set at 12 dbm and whose line width is 10 MHz is used here for modulating the incoming signal. A Mach Zehnder modulator modulate electrical signal coming from NRZ pulse generator and light signal from CW laser. The NRZ. pulse generator a non return to zero coded signals. The rise and fall time of NRZ pulse generator is 0.05 bit. The Mach Zehnder modulator has an extinction ratio of 30 dBm The frequency of the TX is set to be 193THz or 1550 nm in wavelength and the power is 12 dBm. The output of the TX is connected to the fork which is a component used to duplicate the number of output ports so that each of the signals coming out from the fork's output has the same value with the output signal from the previous component connected to it. First fork connected to the TX will produce a multiple laser beams from one source. Then, each of the output signals will be connected to another set of forks to produce another set of multiple laser beams. The multiple laser beams produced are then combined together with a power combiner before it is sent to the OWC channel.

2.2 Optical Wireless Channel.

In the OptiSystem software, the OWC channel is between an optical transmitter and optical receiver with 15cm optical antenna at each end. The transmitter and receiver gains are 0 dB. The transmitter and receiver antennae are also assumed to be ideal where the optical efficiency is equal to 1 and there are no pointing errors

The optical wireless channel is modeled by mathematical equation. The optical power P_R received by the receiver satellite is [3]:

$$P_R = P_T \eta_T \eta_R \left(\frac{\lambda}{4\pi \cdot Z}\right) G_T G_R L_T L_R$$

Where P_R is transmitter optical power; η_R is the optics efficiency of the receiver; η_T is the optical efficiency of the transmitter; λ is the wavelength; Z is the distance between the transmitter and the receiver; G_T is the transmitter telescope gain; G_R is the receiver telescope gain; and L_T, L_R are the transmitter and the receiver pointing loss factor, respectively where the pointing loss factor L is given by:

$$L = \exp(-G_T . \theta^2)$$

Where **θ** is the radial pointing error angle. This factor defines the attenuation of the received signal due to inaccurate pointing

2.3 Receiver

All the multiple signals coming out from the OWC channel are then once again combined using the power combiner before received by the RX. The two visualize used in the simulation is the optical power meter and the BER analyzer. The first power meter is used to measure the transmit power signal coming out from the TX output port and the second power meter is used to calculate and display the average received power at the RX. The receiving end of the inter satellite optical wireless communication link signal consists of a photodiode, a low pass filter, regenerator and a visualizer. A photodiode detects the received light signal and converts it into electrical signal. Photo detector used here has a gain of 3, responsivity of 1 A/W and dark current of 10 nA. Avalanche photodiode (APD) is used in long distance free space optical data transmission due to its characteristics of producing high amplification for low or weak light signals. Then signal is passed through low pass Bessel filter whose cutoff frequency of 0.75*bit rate to limit the bandwidth. The 3R regenerator is the subsystem use to regenerate electrical signal of the original bit sequence, and the modulated electrical signal as in the transmitter to be used for BER analysis. The output of the 3R regenerator is connected to the eye diagram analyzer and to satellite's TT&C system for further signal processing. The eye diagram analyzer gives the value of maximum Q factor, minimum BER, eye height and threshold.

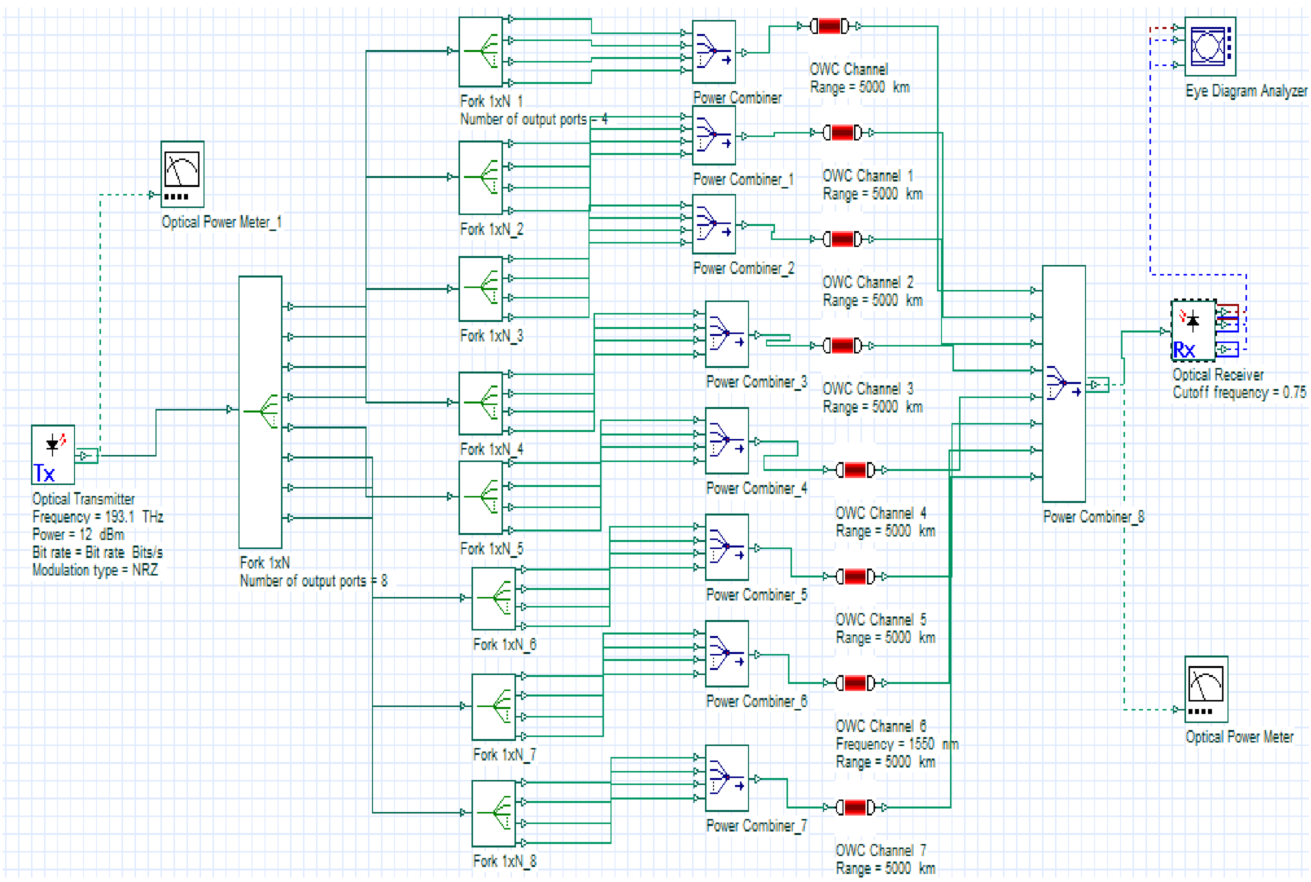


Figure1. Simulation Model of 8 Multiple Transmitter and receiver.

4. Results and analysis

By varying the combinations of TX and RX, the multiple laser beams system can be measured and analyzed for its performances in terms of received power and BER using fixed parameters' values of FSO channel, optical TX and optical. By looking at Table 1, it is investigated that, when we increase the number of TX and RX, it effectively increase the received power. It is examined that when only single transmitter and receiver is used in the IsOWC link of 5000 km, communication breaks. In this case the received power is very less and BER is very high. So when we double the transmitter and receiver (2TX/RX), the communication link start working successfully and power received now calculated is -25 dBm, which in other case it is only -34 dBm. So here it is investigated that on increasing the number of TX/RX , the quality of IsOWC link improves and received power also increases. As the number of TX/RX increase , the Q factor and received power both increases, we have calculated the received power and Q factor values for 8TX/RX. Table1. shows the values of 8 TX/RX ranges from 1to 8. It is observed that a combination of 8TX/RX gives highest value of received power, and the 1Tx/Rx gives least value of received power. By looking at Table 1, doubling the number of TX and RX can effectively increase the received power resulting in 3 dB/octave of gain. For two TXs and two RXs the received power increases by 3 dB, from -25 dBm to -22.57 dBm and from four to eight TXs and RXs, the received power gain is from -22.57 dBm to -19.56 dBm, another 3dB gain.

Table 1. Theoretical values of Received Power by increasing the number of TX and RX.

Number of TX/RX	Power Received (dBm)	Q factor
1	-34	2.36
2	-25	20.09
3	-23.82	29.65
4	-22.57	38.63
5	-21.60	46.93
6	-20.87	56.13
7	-20.14	65.36
8	-19.56	74.57

A graph is plotted between power received and the number of TX/RX. It is examined through graph that as number of TX/RX increases, the received power increases. The number of TX/RX is taken from 1- 8 and the received power takes value from -34 to -19.56 dBm.

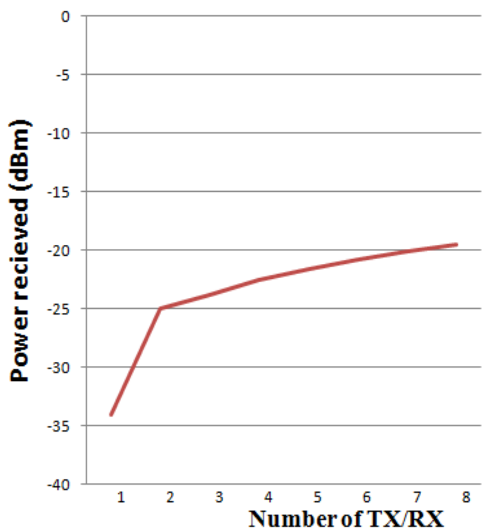
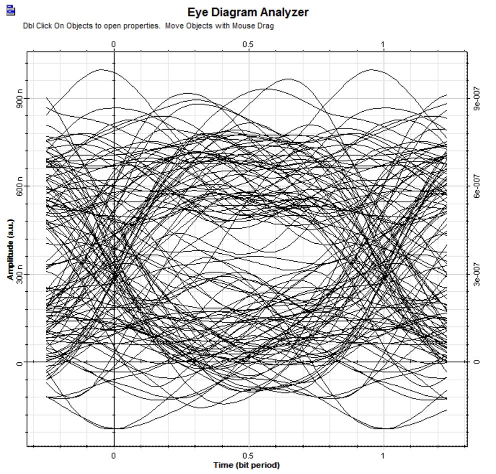


Figure 2. Graph showing relationship between power received and number of transmitter and receivers.

By analyzing the display of the eye diagram, the system performances can be evaluated and measured. Figure 5 shows the eye diagram for the 1TX/1RX, 2TX/2RX, 3TX/3RX, 4TX/4RX, 5TX/RX, 6TX/RX, 7TX/RX and 8TX/RX combinations. From Fig.2, the increment in the number of TX and RX will produce less jitters of the signal and increase the size of the eye opening. The significance of a wider eye opening is: it will reduce the potential occurrence for data errors, the wider the eye opening, the better the system performance, in the figure below, we noticed that as the number of transmitter and receiver increases the size of eye opening increases and jitter decreases. It is noticed that for a single TX/RX system, means there is no splitting of power takes place, the size of eye opening is very small and in this case there is no communication link is established. So as the number of TX/RX increases the quality of IsOWC link improves.



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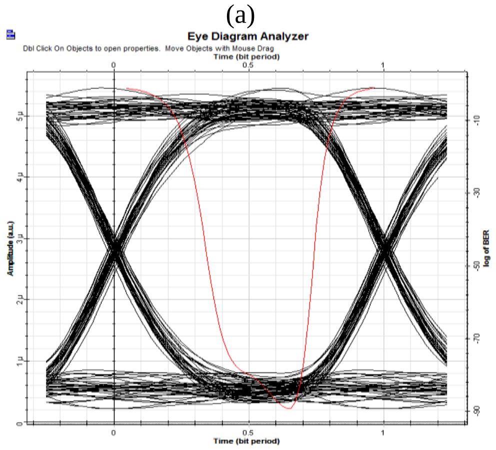

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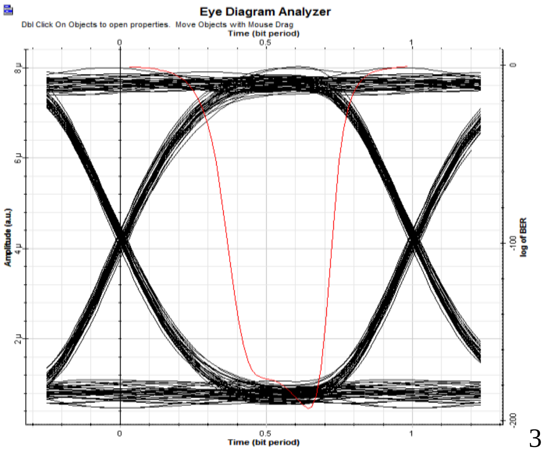

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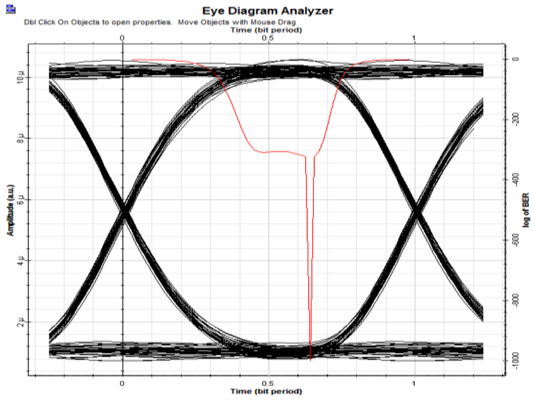

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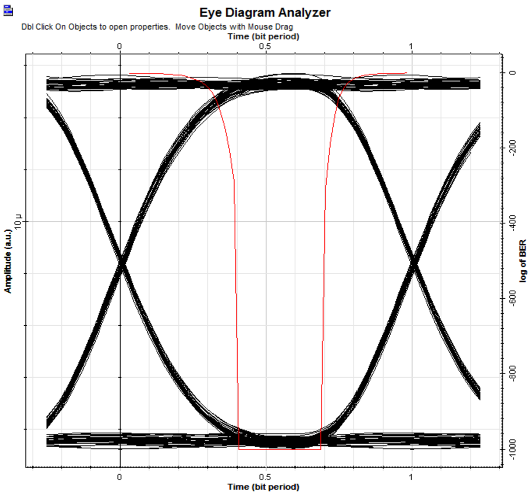

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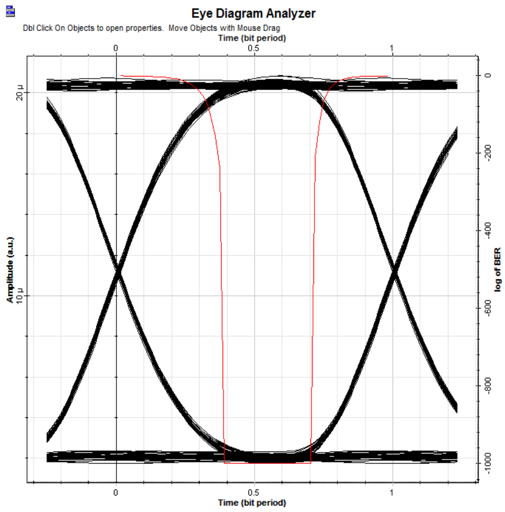

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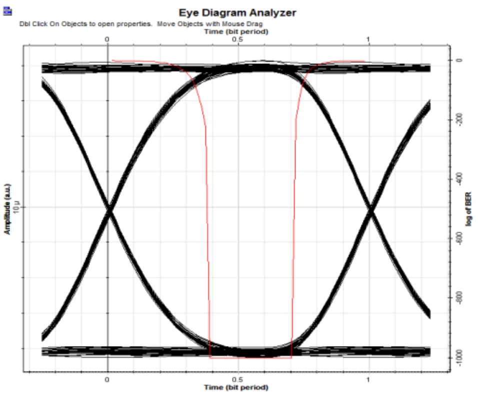

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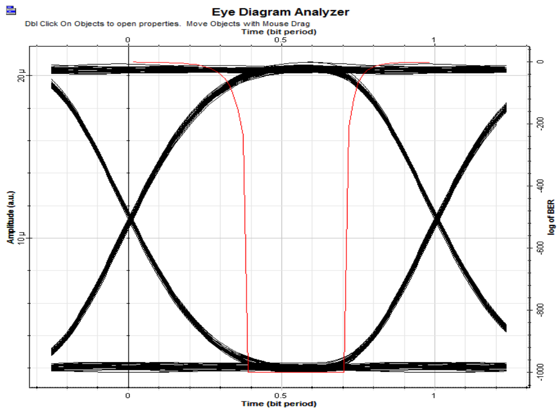

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Figure 2. Eye diagrams for 1 to 8 TX/RX

Further investigations were done on maximum achievable bit rates for different number of TX/RX. In this model we have taken eight number of transmitter and receiver. We have calculated maximum achievable bit rates for different number of TX/RX as shown in figure . It is investigated that as the number of TX/RX increases the bit rate of the IsOWC link also increases. For 8TX/TX IsOWC link, 18 Gbps bit rate is achievable. So data is sent with high speed and with minimum delay. This is the maximum bit rate of 8TX/RX IsOWC link. When we further increase the bit rate beyond this value,the communication link breaks. The bit rate for a single transmitter and receiver is only 18 Mbps. So when we double the transmitter and receiver, the bit rate of IsOWC link jumps to a value of 1.2 Gbps. It is concluded that by using multiple transmitter and receiver, we get a high data rate IsOWC link. In the table below values for maximum achievable bit rate of 8TX/RX is listed in table 2.

Table 2. theoretical values of maximum achievable Bit Rate for different number of TX/RX.

Number of TX/RX	**Maximum achievable Bit Rates (Gbps)**	**Min. BER**	**Q factor**
1	0.018	2.06×10^{-9}	5.78
2	1.2	3.9×10^{-9}	5.76
3	2.8	8.17×10^{-9}	5.64
4	4.8	4.7×10^{-9}	5.74
5	7	1.9×10^{-9}	5.84
6	11	9.9×10^{-9}	5.61
7	14	3.3×10^{-9}	5.79
8	18	2.69×10^{-9}	5.83

4. Conclusions:

Our main goal is to analyze the effect of multiple transmitters and receivers on IsOWC link. It is investigated that by utilizing the multiple Transmitter and receiver, the IsOWC link performance is improved. The measured received power follows the theory of diversity i.e by utilizing multiple transmitter and receiver, the performance of IsOWC link is improved. A higher combination of transmitters/receivers gives further improvement in terms of power received and link margin. The received power value increases as the number of TX/RX increases. It is observed that for a single TX/RX IsOWC link, communication is not possible but when 2TX/RX is used, the communication link start working. The highest calculated received power for 8x8 combinations is -19.55; meanwhile the lowest is 34 dBm for 1x1 combinationss. Next it is examined that as number of transmitters and receivers is increased, the bit rates also increased. A very high data rates up to 18 Gbps is achieved with 8TX/RX IsOWC link. When data rate is increases from this value, the communication link breaks.

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