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Performance Evaluation of Multiple Transceiver Optical Wireless Communication System

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Abstract

Optical wireless communication (OWC) system is considered as a promising solution to meet the increasing demands of high data transmission rates and channel bandwidth over a long link distance. The Optical wireless communication system can be used in various applications such as inter-satellite links, inter-aircraft links, terrestrial links etc. In this paper, the performance of an optical wireless communication link with varying number of transmitters and receivers is evaluated. The performance of the system has been analyzed on the basis of BER, Q Factor, SNR, and total power of the received signal. The results show that by using multiple transceiver technologies, the quality of the received signal is enhanced for long distance links operating at high data transmission rates.

Keywords*: Optical Wireless Communication (OWC), Multiple Tx/Rx, BER, Q Factor, SNR, Received Power*

1. Introduction

Optical Wireless Communication (OWC) is a line-of-sight (LOS) technology which requires a direct line of sight between the transmitter and the receiver to transmit information signal [1]. OWC technique is a part optical communication technology because the information is transmitted between two points using optical signals as information carriers and a part wireless communication technology because the medium of propagation of information signal is free air/vacuum [2]. OWC technique is a very effective solution to connectivity problems where a physical connection is not possible due to higher cost consideration or some other considerations [3]. Since the medium of propagation of information signal is free air, the signal degradation due to atmospheric effects is inevitable. These disturbances in signal propagation will severely affect the performance of the communication system. The disturbances caused due to atmospheric conditions will result in large variations in the amount of received power and degrade the system quality. OWC communication technique is still considered as a new technology as compared to optical fiber communication technology which is been adopted widely in the telecommunication industry.

Manmade satellites have been deployed for communication and research purpose and for the benefits of mankind. A satellite is defined as an object which revolves around other objects in outer space. The satellite may be positioned in one of the orbits namely the low earth orbit (LEO), medium earth orbit (MEO), geosynchronous orbits (GEO), and highly elliptical orbits (HEO) [3]. The communication between two satellites orbiting in the free space is possible by deploying inter-satellite communication links. One satellite can be simultaneously connected to multiple satellites at the same time. Inter-satellite communication links are very crucial for data transmission between two satellites orbiting in different orbits [4]. In order to transmit the information signal at high data transmission

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rates over long link distance, data should be transmitted at high transmission power levels and large antenna aperture diameter should be used. High transmission power levels are not permissible to prevent any harm to human skin and eyes. Also, large antenna aperture diameter increases the payload of the satellite system [5]. Therefore, in order to faithfully transmit the information signal in optical wireless communication link over a long distance, multiple Tx/Rx technology can be used to enhance the performance of the communication links. In this paper, the performance of a multiple transceiver optical wireless communication system has been analyzed by varying the number of Tx/Rx pairs. Performance has been analyzed on the basis of Quality Factor, BER, SNR, and total power of the received signal.

Rest of the paper is organized as follows- In Section 2, system design and simulation parameters are presented. Results are presented and discussed in Section 3. The conclusion is given in Section 4.

2. System Design and Considerations

In this paper, the performance of multiple transceiver OWC system has been simulated and analyzed by varying the number of Tx/Rx pairs. The system modeling, design, and simulations have been performed using OPTISYSTEM simulation software. Though, the satellites are capable of communication in a full duplex mode using optical information signals carriers, in this paper a simplex mode of data transmission has been considered for the sake of simplicity. Fig. 1 presents a simplex optical wireless communication link consisting of a single Tx/Rx pair. A 4Tx/4Rx OWC link is presented in Fig. 2. Simulation parameters in this proposed model are presented in table 1.

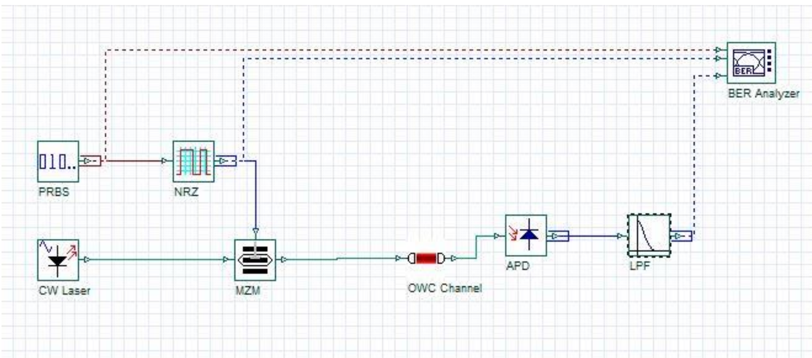

Figure 1. A Single Tx/Rx OWC Link

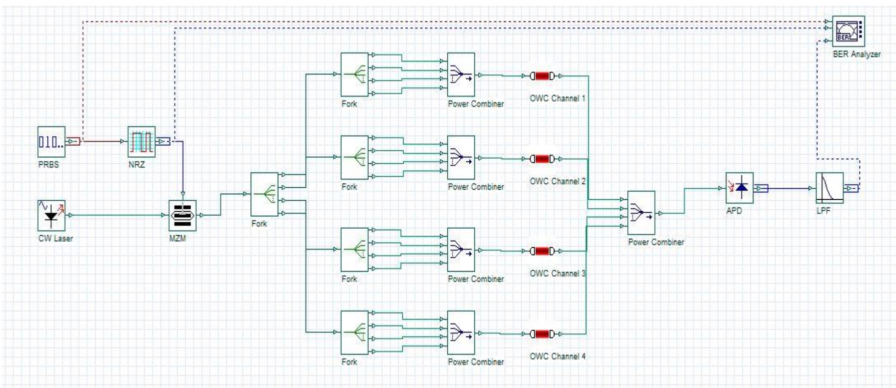

Figure 2. A Multiple Tx/Rx OWC Link

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Table.1 Simulation Parameters

Serial No.	Parameters	Value/Type
1.	Transmission rate	5 Gbps
2.	Link Distance	1200 Km
3.	Operating Wavelength	1550 nm
4.	Modulation Type	NRZ
5.	Antenna Aperture Diameter	20 cm
6.	Beam Divergence	2 mrad
7.	Photo detector	APD
8.	Transmitting Power	6 dBm

A typical optical wireless communication link consists of a transmitter section, propagation channel, and a receiver section. The optical transmitter section further consists of 4 subsections. Pseudo random bit sequence (PRBS) generator produces the information signal to be transmitted in the form binary signals. These binary signals are directed toward NRZ pulse generator which converts the binary signals into electrical signals. The electrical signals are then modulated with an optical carrier signal produced by continuous wave laser operating at a central wavelength of 1550 nm using a Mach Zender modulator (MZM). The optical information signal is transmitted in the free air using transmitting antenna. The medium of propagation is vacuum/free space. The transmitted optical signal is received using a receiving antenna. The optical signal is converted to electrical signal using Avalanche photodiode (APD). The low pass filter (LPF) removes any high frequency noise and the quality of the received signal is evaluated using BER analyzer.

3. Results and Discussions

In this paper, the performance of the OWC system has been evaluated by comparing the Q Factor, SNR, BER, and total power of received signal for each case under consideration. Maximum BER has been evaluated for performance comparison from the maximum Q Factor using the equation:

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

Figure.3, 4, and 5 depicts the Q Factor, SNR and total power of received signal respectively for a different number of Tx/Rx pairs for a link distance varying from 200 Km to 1200 Km.

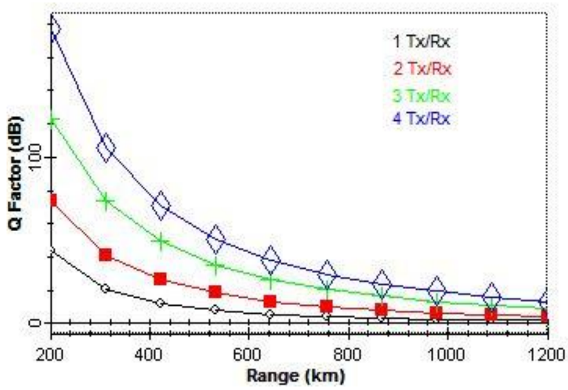

Figure 3. Q Factor v/s Range

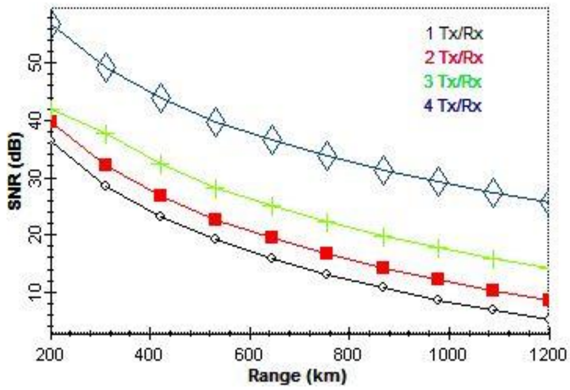

Figure 4. SNR v/s Range

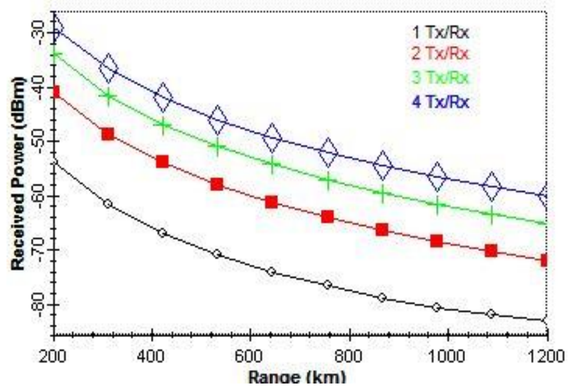

Figure 5. Received Power v/s Range

From the results, it can be seen that the Q Factor lies in the range [170, 121, 78, 42] dB to [21, 12, 6, 2] dB for link distance ranging from 200 Km to 1200 Km for 4Tx/4Rx, 3Tx/3Rx, 2Tx/2Rx, and 1Tx/1Rx pair respectively. Similarly, SNR value of received signal changes from [56, 41, 39, 36] dB to [31, 23, 11, 6] dB for link distance ranging from 200 Km to 1200 Km for 4Tx/4Rx, 3Tx/3Rx, 2Tx/2Rx, and 1Tx/1Rx pair respectively. Alternatively, the received power varies from [-30, -36, -41, -54] dBm to [-57, -61, -72, -80] dBm for link distance ranging from 200 Km to 1200 Km for 4Tx/4Rx, 3Tx/3Rx, 2Tx/2Rx, and 1Tx/1Rx pair respectively.

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Figure.6, 7, 8, and 9 show the eye diagram of the received signal at a link distance of 1200 Km using 1Tx/1Rx, 2Tx/2Rx, 3Tx/3Rx, and 4Tx/4Rx pair respectively. TABLE 2 presents the performance comparison of different systems for a 1200 Km OWC link.

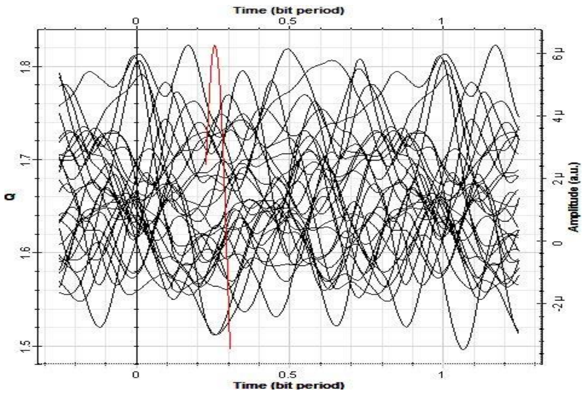

Fig.6 Eye Diagram of Received Signal with 1Tx/1Rx

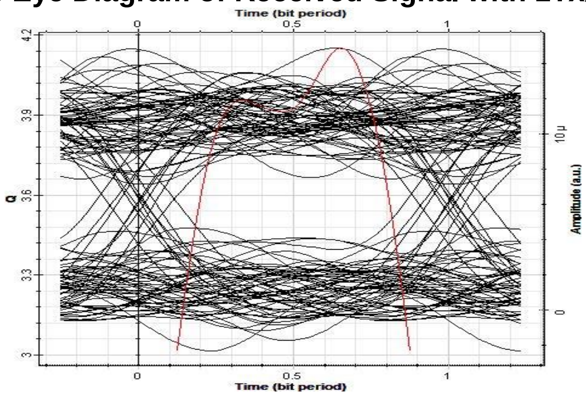

Figure 7. Eye Diagram of Received Signal with 2Tx/2Rx

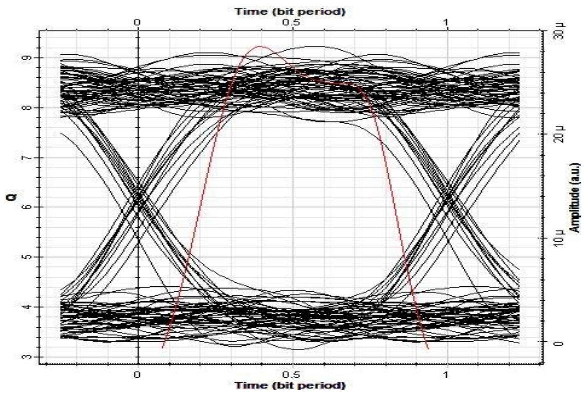

Figure 8. Eye Diagram of Received Signal with 3Tx/3Rx

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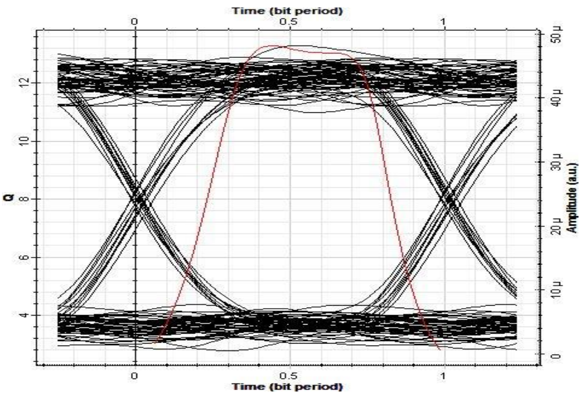

Figure 9. Eye Diagram of Received Signal with 4Tx/4Rx

The width of the eye in the eye diagram of received signal determines the maximum time difference over which the sampling of the signal can be done without any distortion from inter symbolic interference. The height of the eye in the eye diagram is inversely proportional to the amount of amplitude distortion in the received information signal. From the eye diagrams of the received signals presented above for different cases, it can be observed that on increasing the number of Tx/Rx pairs in an OWC communication link, the performance of the system is enhanced by minimizing the amount of amplitude distortion as the eye height is increasing with increase in the number of Tx/Rx pairs.

Table 2. Performance Comparison of Different Systems at 1200 Km

Parameter	1Tx/1Rx	2Tx/2Rx	3Tx/3Rx	4Tx/4Rx
Q Factor	1.82	4.15	9.22	13.28
BER	3.41 e-002	1.64 e-005	1.41 e-020	1.38 e-040
Eye Height	-2.17 e-006	2.67 e-006	1.49 e-005	2.97 e-005

4. Conclusion

In this paper, the performance of an optical wireless communication link has been evaluated under a different number of Tx/Rx pairs by comparing the quality of the received signal for each system by analyzing the Q Factor, BER, SNR, and total power of the received signal. From the results presented above, it can be concluded that as the number of Tx/Rx pair is increased from 1 to 4, the performance of the communication system is enhanced. The Q Factor increases from 1.82 dB to 13.28 dB and the BER reduces from 3.41 e-002 to 1.38 e-040, when the number of Tx/Rx pair is increased from 1 to 4 for a transmission distance of 1200 Km and a 5 Gbps data transmission rate. Thus, it can be concluded that the performance of the optical wireless communication link can be significantly improved using multiple transceiver technologies.

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