Performance Analysis of 10 Gbps Inter-satellite Optical Wireless Communication Link (IsOWC) using Different Modulation Formats and Transmission Power Levels

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***Abstract*— Optical Wireless Communication is one of the most important techniques for use in satellite communication systems in the future ahead. The Inter-satellite Optical Wireless Communication systems (IsOWC) have became very popular due to its numerous advantages such as large bandwidth, small size, light weight and low power consumption in different atmospheric conditions. In this paper, a performance comparison analysis on the basis of Q Factor of received signal, BER, Eye Height, and RMS value of jitter of received signal in IsOWC system has been done using different modulation formats such as RZ (Return to Zero) format and NRZ (Non Return to Zero) format at different levels of data transmission power levels using OPTISYSTEM simulator between two satellites separated at a distance of 1500 Km in space at a data rate of 10 Gbps.**

Keywords*— *Optical Wireless Communication, RZ format, NRZ format, Q-Factor, BER, Eye Height

I. INTRODUCTION

As the radio frequency spectrum becomes more and more congested due to increasing demand in channel capacity, the optical fiber links provide an attractive solution, providing with large bandwidth, high data transmission rates, and reusable spectrum resources [1]. In Optical Wireless Communication channel information is transmitted from the source to destination through a wireless channel at high data transmissions rates [5]. The indoor and outdoor OWC systems have numerous advantages over other wireless techniques, such as high data transmission rates and ample amount of license-free radio frequency spectrum [4], [7]. Although OWC systems have many advantages over traditional wireless communication channels, the implementation of OWC links is hindered by many challenges such as constraint on line of sight (LOS) condition between transmitter and receiver in many applications, the adverse effect of different weather conditions such as fog, rain, dust, clouds on the performance of the system and also maintaining the power transmission levels such that they are within the safety limits of human eyes [3]. The OWC system also faces some other issues such as ineffective utilization of bandwidth, erroneous information transmissions, constraints on transmission power levels and communication system noise that must be minimized for improvement in the performance of the system.

In this paper, a simulative investigation of the performance comparison of a 10 Gbps OWC system has been done using different data modulation formats namely RZ and NRZ modulation formats at varying levels of data transmission power levels, on the basis of Q Factor of received signal, RMS jitter, and Eye Height values. In Section II, the system description is presented. In Section III, results are analyzed and discussed and in Section IV, a conclusion to this investigative study is given.

II. SYSTEM DESCRIPTION

The OWC link mainly consists of three sections, transmitter section, propagation channel, and the receiver section as shown in Fig. 1.

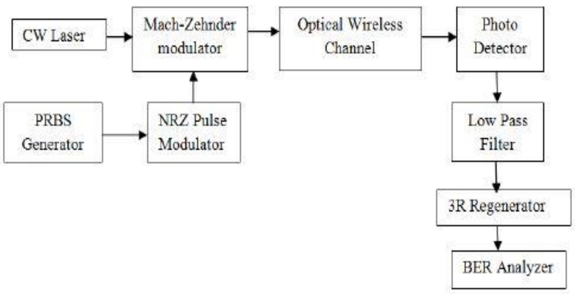

Fig.1: Block Diagram of OWC Link

In OWC communication systems, near- infrared frequency light is used to transmit information between transmitter and receiver [2]. The transmitter section consists of a data source which generates the information signal in binary form. The output from the data source in fed to the input of pulse generator which converts the binary data in the form of electrical pulses. The output from the pulse generator and the continuous wave laser is fed to the MZ modulator which modulates the optical signal. RZ and NRZ pulse generator are used in the investigative study to analyze the performance of IsOWC link. In an optical wireless system, information is transmitted through a wireless medium but transmission takes place in an unguided medium [6]. In OPTISYSTEM simulator, the OWC link between transmitter and receiver consists of an optical antenna with 15 cm aperture at both sides. The channel is modeled using a wavelength of 1550 nm and at a link distance of 1500 Km at 10 Gbps data transmission rate. The receiver side of OWC link consists of a photodiode which converts the optical signal to its electrical form. The sensitivity of receiver end can be improved using low capacitance detectors which are small in size and have an internal gain mechanism such as APD photodiodes. APD photodiodes are capable of providing 10-20 dB improvement over PIN photodiodes. But APD has high cost and a highly complex voltage bias circuit [8]. The output from the photodiode is fed to a low pass filter which removes any high-frequency noise present in the signal. The Q Factor, BER, and Eye Height are analyzed using BER analyzer at the receiver end. The system specifications in this proposed IsOWC link are summarized in Table-1.

Table-1: System specifications

S. No	Parameter	Value
1.	Input Power (dBm)	10-20
2.	Wavelength (nm)	1550
3.	Data Rate (Gbps)	10
4.	Distance (Km)	1500
5.	Modulation Scheme	RZ, NRZ

III. RESULTS AND DISCUSSIONS

In this paper, the performance of an IsOWC link has been analyzed for a link length of 1500 Km operating at a wavelength of 1550 nm using NRZ and RZ modulation formats at varying power levels. In RZ modulation format, the signal drops to zero value in between each pulse. This happens even if consecutive 1's or 0's are present in the signal whereas in NRZ modulation format 1's are represented by a positive voltage and 0's are represented by a negative voltage with no neutral condition present.

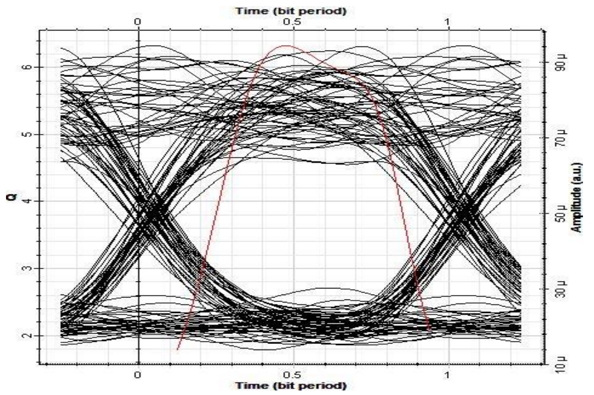

Fig.2(a): Eye Diagram of NRZ modulation for input power of 10 dBm

In Fig. 2(a), the eye diagram of received signal for an input transmission power of 10 dBm at a distance of 1500 Km using NRZ modulation format is depicted. A Q-Factor of 6.324 and BER of 1.17e-010 has been observed in this case which is acceptable to a certain extent for such a long transmission distance. In Fig. 2(b), the eye diagram of received signal for an input transmission power of 10 dBm at a distance of 1500 Km using RZ modulation format is depicted. A Q-Factor of 6.04057 has been observed which is lower as compared to that in case of NRZ modulation format. The BER value of 7.30e-010 has been observed in this case which is higher as compared to that in the case of NRZ modulation format.

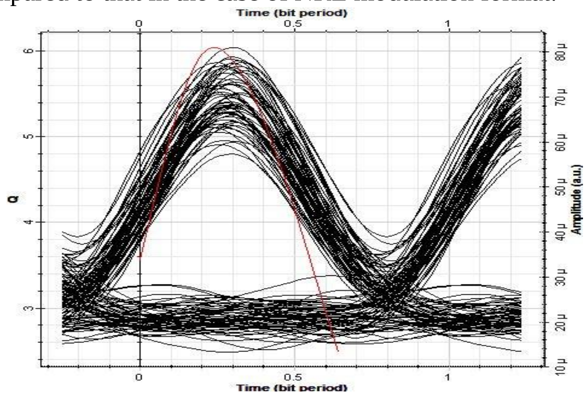

Fig.2(b): Eye Diagram of RZ modulation for input power of 10 dBm

In Fig. 3(a), the eye diagram of received signal for an input transmission power of 15 dBm at a distance of 1500 Km using NRZ modulation format is depicted. A Q-Factor of 13.9259 and BER of 1.83e-044 has been observed in this case which is acceptable for such a long transmission distance. This diagram shows that as the transmission power is increased, the Q-Factor increases and the BER value decreases. In Fig. 3(b), the eye diagram of received signal for an input transmission power of 15 dBm at a distance of 1500 Km using RZ modulation format is depicted. A Q-Factor of 13.4576 has been observed which is lower as compared to that in the case of NRZ modulation format. The BER value of 1.21e-041 has been observed in this case which is higher as compared to that in the case of NRZ modulation format but is better as compared to those obtained for the transmission power of 10 dBm.

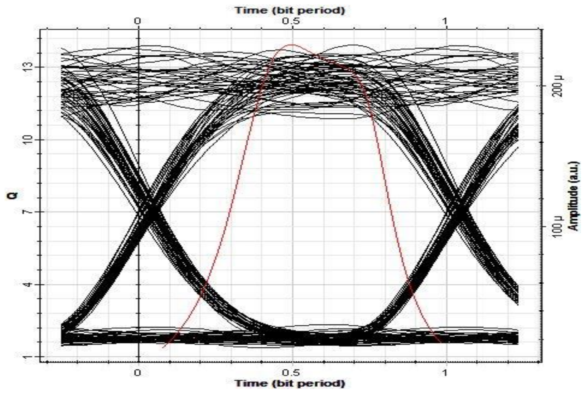

Fig.3(a): Eye Diagram of NRZ modulation for input power of 15 dBm

In Fig. 4(a), eye diagram for transmission power level of 25 dBm at a distance of 1500 Km using NRZ modulation format has been shown. It is observed that as the value of transmission power level is increased to 25 dBm, the value of Q-Factor increases to 28.0612 and the value of BER falls to1.07 e-173. In Fig. 4(b), eye diagram for transmission power level of 25 dBm at a distance of 1500 Km using RZ modulation format has been shown. It is observed that as the value of transmission power level is increased to 25 dBm, the value of Q-Factor increases to 26.6511 which is lower as compared to that in case of NRZ modulation format but higher than that observed in the case when transmission power of 15 dBm is used. The value of BER is observed to be1.07 e-173 which is higher as compared to that in the case of NRZ modulation format but lower than that observed in case when transmission power of 15 dBm is used.

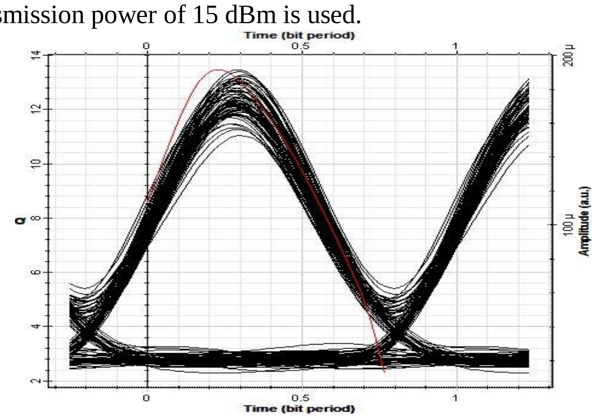

Fig.3(b): Eye Diagram of RZ modulation for input power of 15 dBm

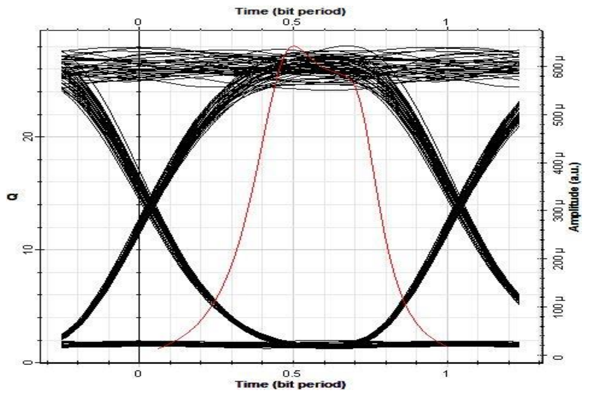

Fig.4(a): Eye Diagram of NRZ modulation for input power of 20 dBm

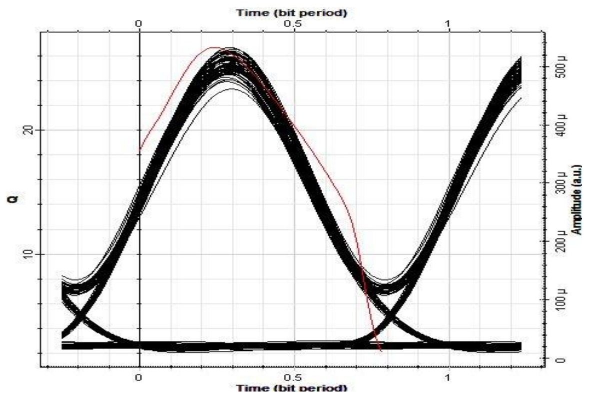

Fig.4(b): Eye Diagram of RZ modulation for input power of 20 dBm

Table-2 shows the comparison between different performance parameters for different levels of input for two modulation formats.

From the Table-2 given above, it can be clearly seen that NZ modulation format performs better as compared to RZ modulation format for all different values of transmission power levels.

Table-2: Comparison of results for different levels of transmission power

Power Level	Q Factor		BER		Eye Height	
	NRZ	RZ	NRZ	RZ	NRZ	RZ
10	6.324	6.04057	1.17e-010	7.38e-010	3.01 e-055	2.41e-005
15	13.9259	13.4576	1.83e-044	1.21e-041	0.000114309	0.000118118
20	28.0612	26.6511	1.07e-173	6.92e-157	0.000515756	0.000428019

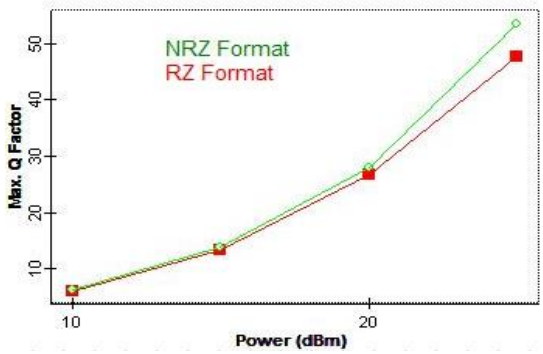

Fig.5: Q-Factor v/s Power for different modulation formats

Figure 5 shows the variation of Q-Factor for different modulation formats when the transmission power is increased from 10 dBm to 25 dBm. In the case of NRZ modulation format, the value of Q-Factor rises from 6.34 to 52.76 whereas in the case of RZ modulation format, the value of Q-Factor rises from 6.4 to 48.87. It is clear from above presented result that the value of Q-Factor is always higher for NRZ format then compared to that in RZ modulation format. As a result, effective improvement in Q-Factor of received signal is achieved in the case of NRZ modulation format which helps in extending the length of IsOWC link between two satellites.

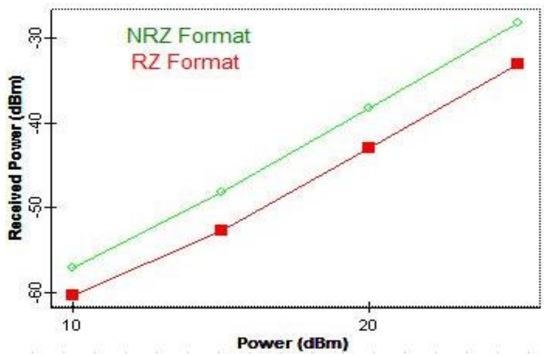

Fig.6: Received Power v/s Transmission Power for different modulation formats

Figure 6 shows the comparison of the value of received signal power when different modulation formats are used by varying the transmission power levels. The value of received signal is increased from -57 dBm to -28 dBm when the transmission power level is increased from 10 dBm to 25 dBm in the case of NRZ modulation format whereas in the case of RZ modulation format the value of received power increases from -62 dBm to -36 dBm. The results presented above clearly show that the performance of IsOWC transmission link is better when NRZ modulation format is considered.

Figure 7 shows the variation of Eye Height for different modulation formats when the transmission power is increased from 10 dBm to 25 dBm. It can be clearly seen from the results that the amount of eye opening increases for both NRZ and RZ modulation format as the transmission power level is increased, but the Eye Height in the case of NRZ format is always higher than that in RZ format.

Figure 8 shows the variation of RMS value of jitter in received signal for different modulation formats when transmission power level in increased from 10 dBm to 25 dBm. It can be seen that the value jitter decreases for both NRZ and RZ modulation formats when the transmission power level increases but the value of jitter is always lesser in the case of NRZ modulation format than that in the case of RZ modulation format.

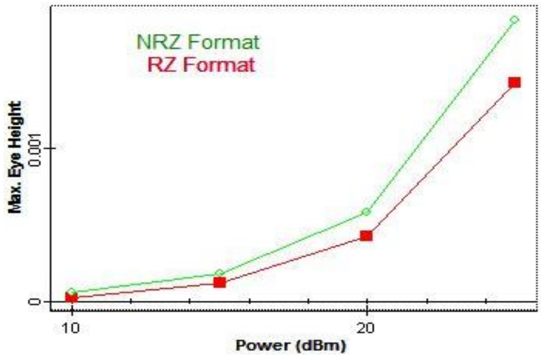

Fig.7: Eye Height v/s Power for different modulation formats

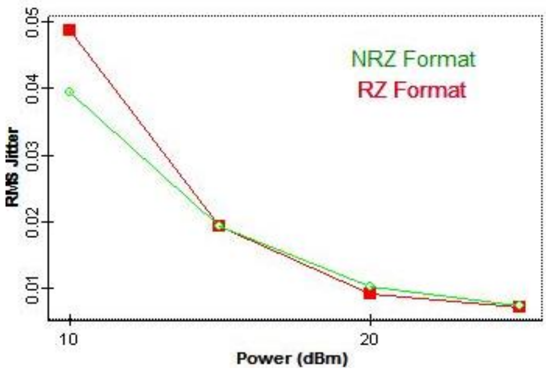

Fig.8: RMS Jitter v/s Power for different modulation formats

Figure 8 shows the variation of RMS value of jitter in received signal for different modulation formats when transmission power level in increased from 10 dBm to 25 dBm. It can be seen that the value jitter decreases for both NRZ and RZ modulation formats when the transmission power level increases but the value of jitter is always lesser in the case of NRZ modulation format than that in the case of RZ modulation format.

IV. CONCLUSION

In this paper, an inter-satellite OWC system has been designed to establish a link of 1500 Km between two satellites at data transmission rates of 10 Gbps for NRZ and RZ modulation schemes. The Q-Factor, BER, Eye Height and RMS jitter values of this IsOWC link were evaluated using OPTISYSTEM simulation software. It is concluded from the results presented in this paper that the values of Q-Factor, BER, Eye Height and RMS Jitter improve as the transmission power levels are increased. However from the results presented in this paper, it can be concluded that NRZ modulation format provides better performance as compared to RZ modulation format which further helps to increase the link length between two satellites.

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