Performance Comparison of NRZ, RZ and CSRZ in ISOWC System for Different Optical Windows and Power Levels at 10 GBPS

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Abstract: Simulation analysis of 45×10Gbps DWDM IsOWC system has been done by incorporating concept of reduced channel spacing of 50GHz. Performance comparison of NRZ, RZ and CSRZ has been evaluated. Further effects of power and distance are studied on system. Three optical windows are analyzedto check performance of the system for optimal optical window.

Keywords: DWDM, IsOWC, CSRZ, RZ, NRZ.

Introduction

An inter-satellite optical wireless communication (IsOWC) system offers enormous bandwidth and high data speeds which make them an attractive mode of meeting the constantly rising demand of broadband services [1]. Optical wireless communication (OWC) communication contributes the high rate of information transmission which is four times the magnitude of radio frequencies.[2] As the optical frequency range is much higher so the optical wireless communication will enable the use of unemployed frequency reservoir [3]. OWC system is based on the use of lasers as signal carriers. This is considered to be the key technologies for realizing an ultra-high speed and large capacity aerospace communication [4]. The Optical wireless communication systems are based on the basic principle of data transmission through air and using light as the carrier. The signal carryinginformation is being modulated on a laser which acts as a light source and istransmitted to another satellite in the free space. On the receiver side, this lightsignal is detected using a photo detector and then converted back into electricalsignal. Depending on the type of communication required, the number of satellitesused can be increased or decreased and the satellites' positions in their orbits can beadjusted accordingly to form a communication network. Satellites are theobjects which revolve around any other object in the space. Depending upon thedistance of the satellite from the earth's surface, satellites can generally be classifiedas LEO, MEO, HEO and GEO i.e. Lower Earth Orbit, Medium Earth Orbit,Highly Elliptical Orbit and Geosynchronous earth Orbit respectively. An intersatellite link is a communications link that connects two separate satellites directly.One satellite could have several links to numerous other satellites. Inter satellitelinks are very important for communication of two satellites in same orbit or twodifferent orbits like communication between a LEO and GEO satellite. Dependingon the type ofapplication a LEO or a GEO satellite can be used for the purpose ofcommunication [5]. The number of satellites is increasing every year to fulfill the increasing demandfor more applications. Optical wireless communications are thus providing analternate for the bandwidth hungry communications [6]. Thus the deployment ofDWDM in hybrid optical and wireless communication systems has increased in thepast few decades. The inherent properties like huge bandwidth, no requirement oflicensing and easy deployment make these systems to be used efficiently forbroadband services. Yet the systems suffer from many setbacks like bandwidthinefficiency, noises and errors in transmission, thus leading to a degraded or less competent communication system.The previously reported works have undergone transmissions up to 5000 km andthat too at data rates below 10 Gbps [7].

In this article, Performance of different modulation formats such as NRZ (non return to zero), RZ (return to zero) and CSRZ (compressed spectrum return to zero) is evaluated in terms of Q-factor and bit error rate. Three optical windows (wavelength) are taken into consideration 850nm, 1310nm and 1550nm to check the performance of the system in order to get optimal optical window wavelength for operation. Moreover, the role of EDFA is evaluated which does the task of amplification.

System Description

In the work, IsOWC system is designed in Optisystem. WDM scheme is used over 45 channels, each having data rate of 10Gbps and modulated over laser source of 0dBm.Lasers operating at wavelength of different bands with the channel spacing of 50 GHz through a Mach-Zehnder modulator (MZM). The 45 channels are multiplexed by means of dual spaced MUX with no losses. Multiplexed channels are analyzed with help of optical spectrum analyzer.

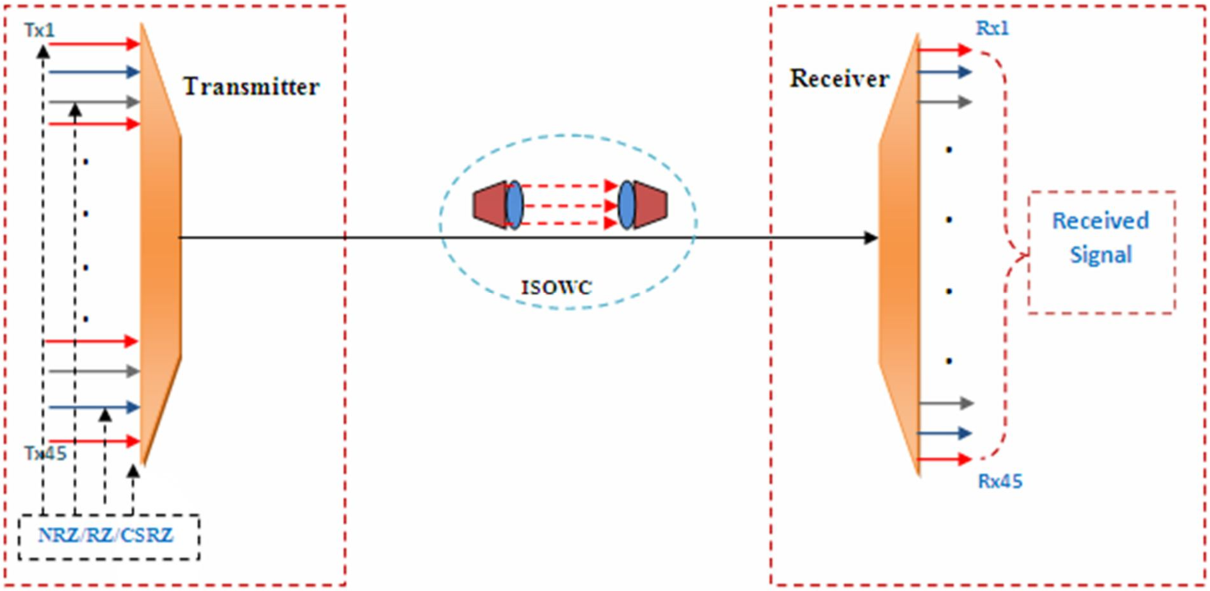
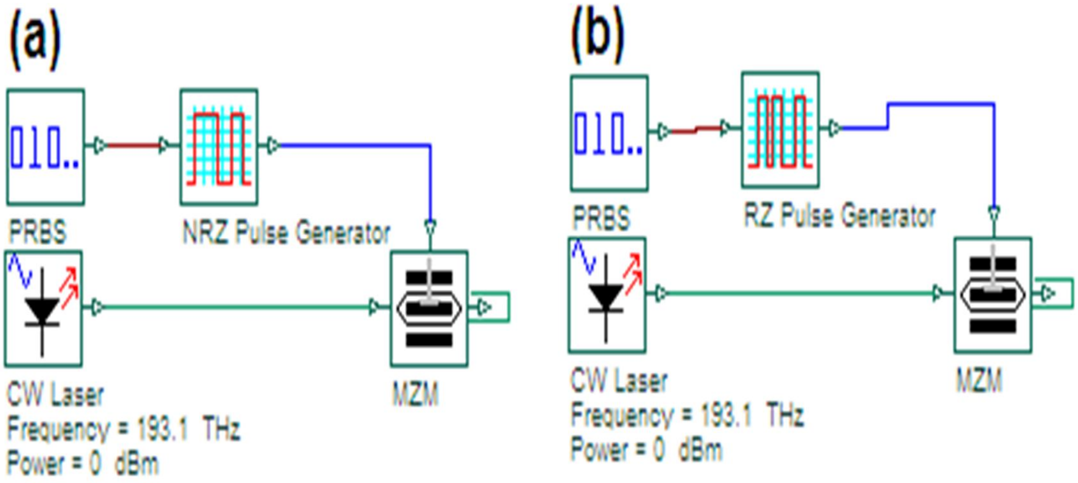


Figure 1.1: Depiction of 45 Channel NRZ IsOWC system

The channels are passed through the EDFA optical amplifier of gain 30dB and noise figure of 4dB to compensate any losses. EDFA is recommended for optical inter-satellite systems which operate at long distances. These amplified channels are transmitted through optical wireless channel (OWC). The OWC channel comprises of transmitter and receiver antenna having aperture diameters of 20cm and 25cm respectively. The antennas are assumed to be ideal and their optics efficiency is assumed to be 1. The pointing error angles of both the transmitter and receiver are assumed to be 0μrad. As the system assumed to be ideal so the additional losses and propagation delay are assumed to be 0dB/km and 2ps/km respectively.The receiver side of IsOWC system consists of a WDM demultiplexer which demultiplexes the channels and is further detected by PIN photo detector followed by low pass Bessel filter of order 2 and having insertion loss of 0 dB. Work of PIN is to convert optical signal to electric signal and LPF is used to remove the noise in the received signal. Bessel filter is to convert and remove the noise to improve the signal quality. It depends upon the filter order and here filter order 2 is considered.



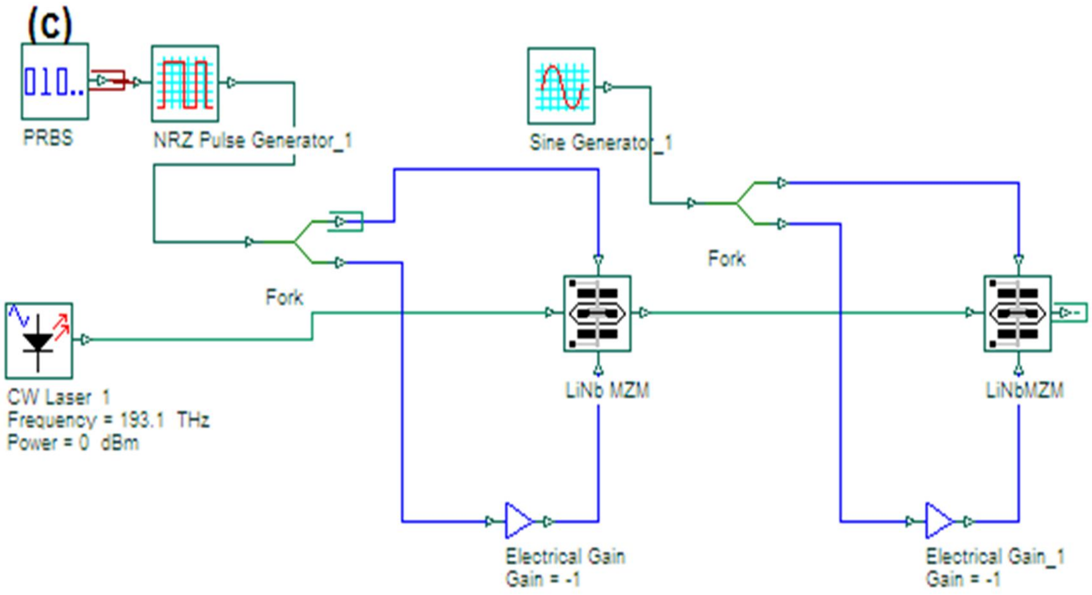


Figure 1.2 Simulation illustration of (a) NRZ (b) RZ (c) CSRZ modulation formats

Results and Discussion

Proposed system is evaluated with the premier optical simulation tool Optiwave Optisystem. Here, the results of the proposed simulated system of WDM IsOWC System have been discussed. As the system consists of an EDFA optical amplifier so the system is analyzed using EDFA at 50 GHz channel spacing at 45x10Gbps data rate. Three differentpulse shapes are studied in the system such as NRZ.RZ and CSRZ. System parameters are given in table.1.1.

Table.1.1 System specifications

Parameters	Values
No. of channels	45
Frequency spacing	50GHz
Bit rate	10Gbps
Transmitter power	0dB,10dB,20dB,30dB
Distance	5000Km
Modulation type	NRZ,RZ,CSRZ
Transmitter wavelength	850nm,1310nm,1550nm
Channel wavelength	1550nm
Amplifier used	EDFA

Table.1.2 Distance Vs Quality factor

Distance(Km)	NRZ	RZ	CSRZ
1000	19.09	16.9	21.18
2000	18.93	16.38	20.78
3000	18.8	15.64	20.74
4000	18.61	14.9	18.69
5000	17.93	14.52	18.42

Table.1.3 Q-factor at different optical wavelengths

Distance(Km)	850nm	1310nm	1550nm
1000	21.18	21.54	30.01
2000	20.78	21.52	29.88
3000	20.74	21.42	29.86
4000	18.69	21.32	29.66
5000	18.42	20.64	22.92

Analysis has been taken on 0dB and varied distance in the interval of 1000km, 2000 Km, 3000 Km, 4000 Km and 5000 Km. Optical wireless channel of 250 Km is connected to EDFA of gain 30dB and noise figure 4dB. For one loop iteration, distance covered is 250 Km and multiple iterations are set to increase the link length. Loop iterations are 4, 8, 12, 16, and 20 in which each iteration covers 250 Km. Results are observed in terms of Q-factor and BER. It is observed that as the distance is increased, quality of the signal decreased as shown in table.5.2. Effect on bit error rate is opposite to quality. BER increases as distance increased and introduce more noises. Q-factor inversely varies with distance, data rate and linewidth. On the contrary BER is directly proportional to distance, data rate and linewidth.

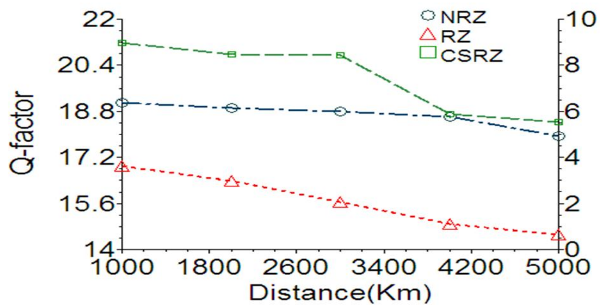


Figure 1.3 :Graphical representation of NRZ, RZ and CSRZ at different distances

From the figure.1.3 it is clear that CSRZ performs better that NRZ and RZ in terms of received quality. Maximum degradation has been seen in case of RZ and minimum incase of CSRZ. NRZ performs better than RZ due to reason that it is bandwidth efficient and thus exhibit better quality and less error. Now CSRZ is further analyzed for different optical windows and wavelengths of these regions such as 850nm, 1310nm and 1550nm. Performance is carried out for different optical power levels. Power level of 0dB-30dB is examined over the system and it is clear from the results that as we increase launched power, Quality also increase. However results increase upto 20 dB and after this power level Q-factor s almost same as that of 20dB. So it is better to consider 20dB power level for the system and provide less BER.Table.1.4 depicts the values of CSRZ at 5000Km for different optical wavelengths in order to find out best operational band for intersatellite optical wireless communication. These results are taken on 10dB input power for 850nm, 1310nm and 1550nm.

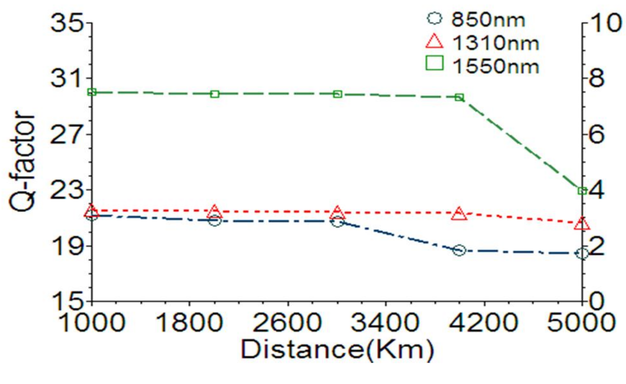


Figure 1.4: Representation of Isowc system for different optical wavelengths at 10dB

Figure.1.6 depicts that 1550nm is best for the system transmission due to fact that very less attenuation and dispersion can be seen here. Major Advantage is that c-band exhibit very less scattering. Scattering efforts are more in 1310nm and 850nm. System operated at 850nm shows worst performance due to more losses and scattering effects.

Table.1.4 Q-factor Values of CSRZ at 5000Km for different optical wavelengths at 20dB

Distance(Km)	850nm	1310nm	1550nm
1000	30.22	41.47	51.66
2000	28.89	41.22	51.17
3000	28.88	40.63	42.98
4000	24.15	40.59	41.23
5000	23.76	36.99	38.17

As seen in the table.1.4 and table.1.3 as we increase power, quality factor also increase. CSRZ is the best modulation type for this system. Now if we further increase power level to 30dB, no significant improvement is noted. Thus 20dB power level is better for CSRZ system at 5000Km.

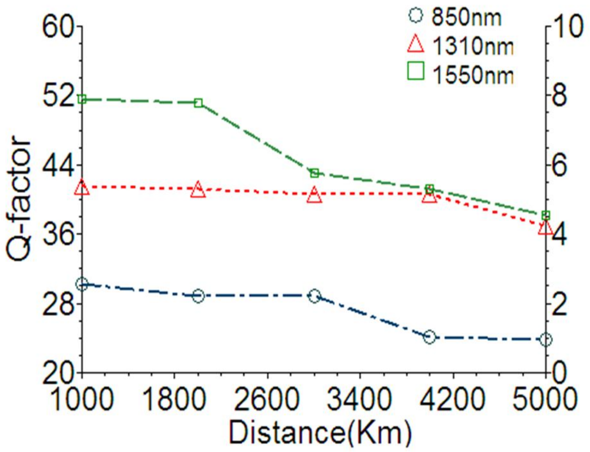


Figure 1.5: Representation of Isowc system for different optical wavelengths at 20dB

Table.1.5 Variation of Q-factor with power for NRZ,RZ and CSRZ

For 10dBm input power	**NRZ**	**RZ**	**CSRZ**
Q-factor	18.63	17.95	22.92
BER	7.9x10^-77	8.6x10^-74	1.3x10^-116
For 20dBm input power			
Q-factor	18.6	18.23	38.17
BER	4.63x10^-78	1.24x10^-74	3.9x10^-319
For 30dBm input power			
Q-factor	18.7	18.24	39.1
BER	4.6x10^-79	1.01x10^-76	201x10^-321

Table 1.5 shows the comparison based on the variations in the levels of input power for the three modulation formats. From the table, it is very clear that CSRZ format outperforms the NRZ format for all the three levels of input power i.e.10 dBm, 20 dBm and 30 dBm as well. And out of the three power levels it is advisable to use 20 dBm for both CSRZ as well as other two modulation format as it produces almost similar results as obtained for 30 dBm input power.

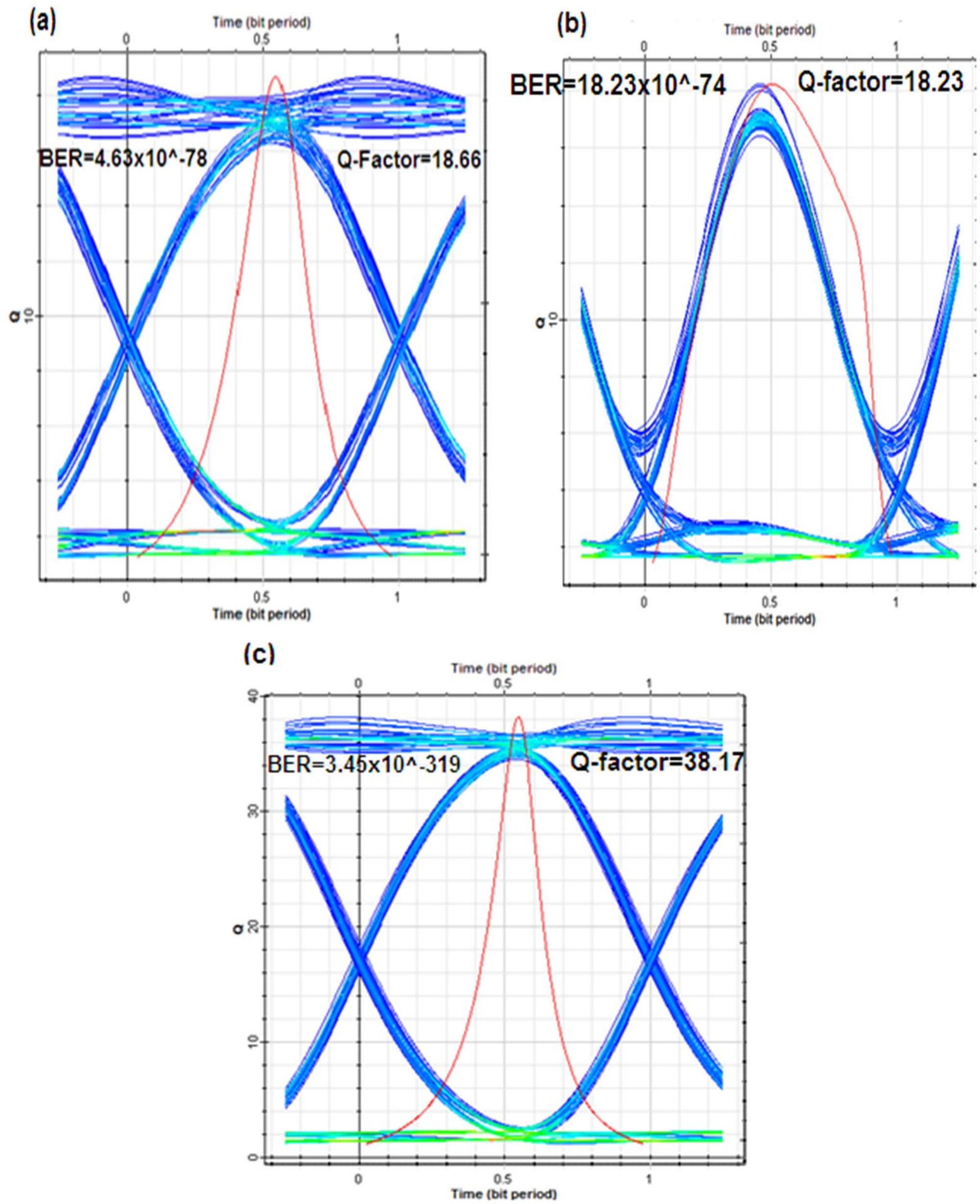


Figure 1.6: Representation of 5000Km Isowc system for (a) NRZ (b) RZ (c) CSRZ at 20dB

Conclusion

The proposed system consisting of 45 channel IS-OWC system operating at 10 Gbps at reduced channel spacing of 50GHz using different modulation formats NRZ, RZ and CSRZ for varying levels of input power. The system is designed to cover a long distance of 5000 kilometers and the results have been verified using Optisystem.Three optical windows are taken into consideration 850nm, 1310nm and 1550nm to check the performance of the system in order to get optimal optical window wavelength for operation. It is observed that due to less scattering 1550nm comes out to be best optical wavelength and 20dBm most excellent optical power. The comparative analysis discloses that the CSRZ scheme performs better than the RZ and NRZ schemes in terms of system efficiency due to attainment of a high Quality factor and a low BER. Moreover, the role of EDFA is noteworthy which does the task of amplification efficiently and made the system to work over a transmission range of 5000 km with acceptable Q-Factor and BER.

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