Evaluation and Investigation of Inter-satellite Optical Wireless Communication System for Different Optical Windows in Medium Earth Orbit

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***Abstract*— With ever increasing satellite missions, a wide range of frequencies are required for high capacity WDM optical wireless systems. C-band (1520 nm-1570 nm) is optimal and maximum useable band due to less scattering in this frequency range. But, due to large number of satellite in the earth orbits, C band is experiencing the pressure of large number of satellites in same optical window. In order to provide ultimate solution to this issue, other frequency bands can also be used in IsOWC systems. This work reveals the design and simulation analysis of 45 × 20 Gbps Dense Wavelength Division Multiplexing (DWDM) Inter-satellite Optical Wireless Communication (IsOWC) System by taking into account the concept of reduced channel spacing of 50 GHz for different optical windows. The high capacity system is proposed and its performance analysis is observed for various parameters like transmission range and input power. 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 12500 km with acceptable Q-Factor and BER in different optical windows such as 850 nm, 1310 nm, 1550 nm and 1620 nm window. It is seen the C band performs best and L band worst in terms of Q factor and BER.**

***IndexTerms*—Optical widows, Non-return to zero, Inter-satellite optical wireless communication, Q-factor, BER**

I. 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 [1-4]. Optical wireless communication (OWC) communication contributes the high rate of information transmission which is four times the magnitude of radio frequencies [4-6]. As the optical frequency range is much higher so the optical wireless communication will enable the use of unemployed frequency reservoir [6-10]. 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 [11-14]. The Optical wireless communication systems are based on the basic principle of data transmission through air and using light as the carrier. The signal carrying information is being modulated on a laser which acts as a light source and is transmitted to another satellite in the free space. On the receiver side, this light signal is detected using a photo detector and then converted back into electrical signal [15]. Depending on the type of communication required, the number of satellites used can be increased or decreased and the satellites' positions in their orbits can be adjusted accordingly to form a communication network [16]. Satellites are the objects which revolve around any other object in the space. Depending upon the distance of the satellite from the earth's surface, satellites can generally be classified as LEO, MEO, HEO and GEO i.e. Lower Earth Orbit, Medium Earth Orbit, Highly Elliptical Orbit and Geosynchronous earth Orbit respectively [17]. An inter satellite link is a communications link that connects two separate satellites directly [18]. One satellite could have several links to numerous other satellites. Inter satellite links are very important for communication of two satellites in same orbit or two different orbits like communication between a LEO and GEO satellite. Depending on the type of application a LEO or a GEO satellite can be used for the purpose of communication [19-21]. The number of satellites is increasing every year to fulfill the increasing demand for more applications. Optical wireless communications are thus providing an alternate for the bandwidth hungry communications [22]. Thus the deployment of DWDM in hybrid optical and wireless communication systems has increased in the past few decades. The inherent properties like huge bandwidth, no requirement of licensing and easy deployment make these systems to be used efficiently for broadband services. Yet the systems suffer from many setbacks like bandwidth inefficiency, 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 and that too at data rates below 10 Gbps [23].

II. SYSTEM SETUP

For the realization if proposed work, we have used a premier simulation tool, optiwave's optisystem. WDM scheme has been used over 45 channels each having data rate of 20 Gbps information carried and modulated over laser source of 0 dBm operating at wavelength of different frequency bands with the channel spacing of 50 GHz through a Mach-Zehnder modulator (MZM) as shown in Fig. 1. The 45 channels are multiplexed by means of equal spaced multiplexer with no losses. Multiplexed channels are analyzed with help of optical spectrum analyzer. The channels are passed through the EDFA optical amplifier of gain 30 dB and noise figure of 4 dB to compensate any losses. EDFA is recommended for optical inter-satellite systems which operate at low powers to do the pre-amplification. These pre-amplified channels are transmitted through optical wireless channel (OWC). The OWC channel comprises of transmitter and receiver antenna having aperture diameters of 15cm and 15cm 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 0ps/km respectively. Each IsOWC channel is of 300 km and no. of loops are varied from 10 to 50 with the difference of 10. The receiver side of IsOWC system consists of a WDM demultiplexer which demultiplexes the channels and are further detected by PIN photo detector followed by low pass Bessel filter of order 4 and having cut-off frequency of 0.8×Bit Rate and insertion loss of 0 dB.

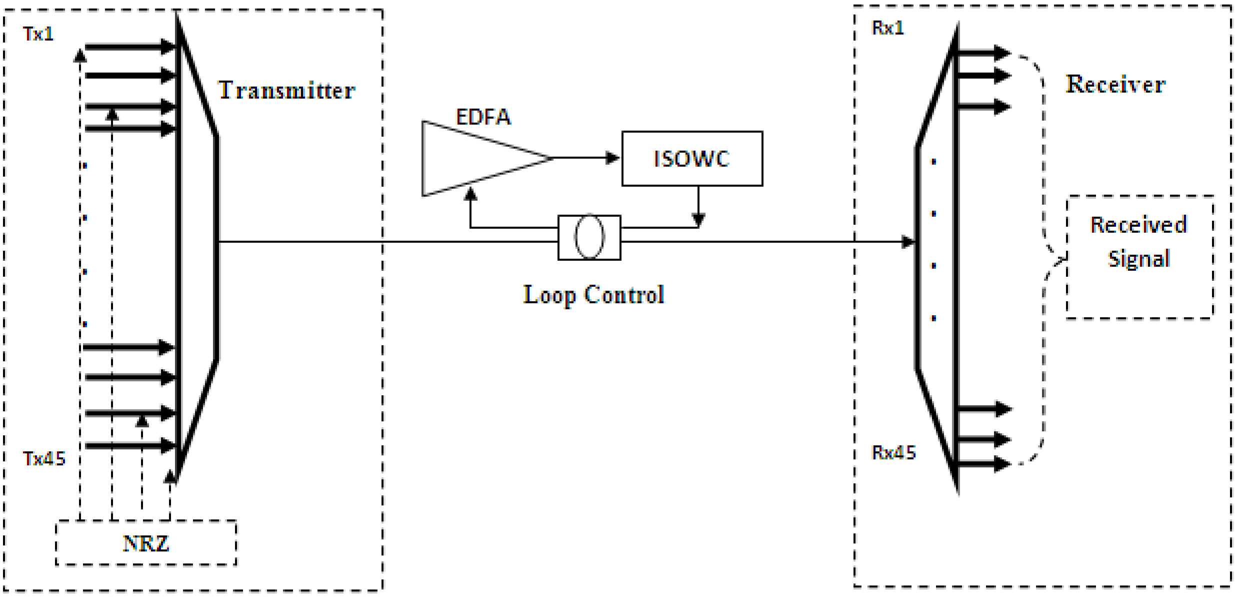


Figure 1 Representation of proposed inter-satellite optical wireless communication system

III. Results and Discussions

In this work, different frequency bands are investigated such as the 850 nm, 1310 nm, 1550 nm and 1620 nm. These optical frequency wavelengths and frequency bands are analyzed in terms of Q factor and BER. In this section, 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 45 x 20 Gbps data rate. Figure 2 depicts the performance of the proposed system for 45 channel WDM IsOWC system at different launched power levels. Channel first and channel 45 is analyzed at 12500 km (MEO) and it is found the performance of each channel is different due to wavelength dependence of optical communication.

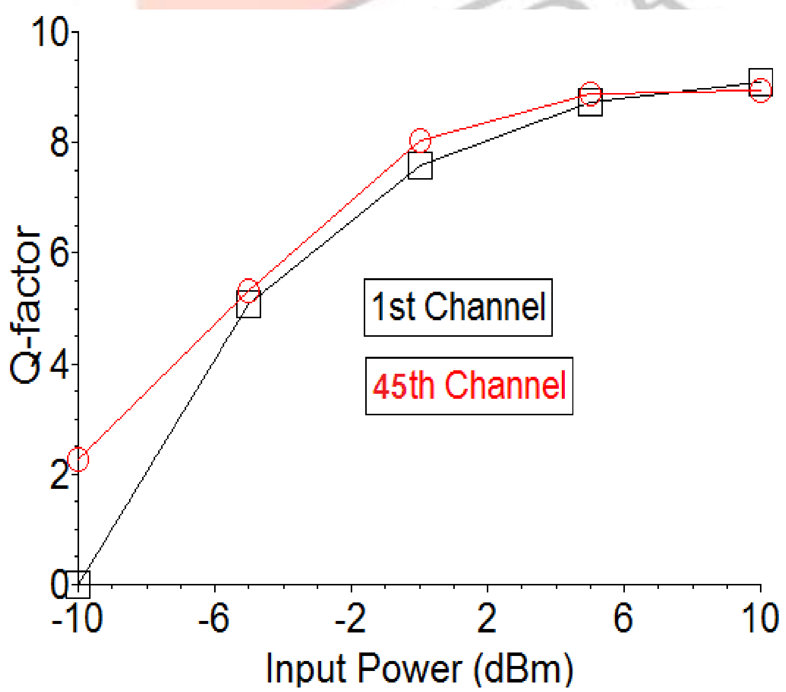


Figure 2 Graphical representations of first and last channels of WDM in terms of Q factor at varied launched powers

It is evident that with the increase in the input power levels, Q factor also enhanced. However, it is also reported that at input power 10 dBm, Q factor does not increase further due to nonlinear effects. It is significant that at high power levels, nonlinear effects degrade the performance of the system. Channel 45 is better that first channel due to wavelength as shown in Table 1. Figure 5.5 depicts the BER at different power levels of laser at distance of 12,500 km. Range of LEO is typically 2500 km to 5000 km and till 36000 km, MEO earth orbit is present. It is observed that the power increase cause less BER. With the increase in input power, BER improved and provide better Q factor and OSNR.

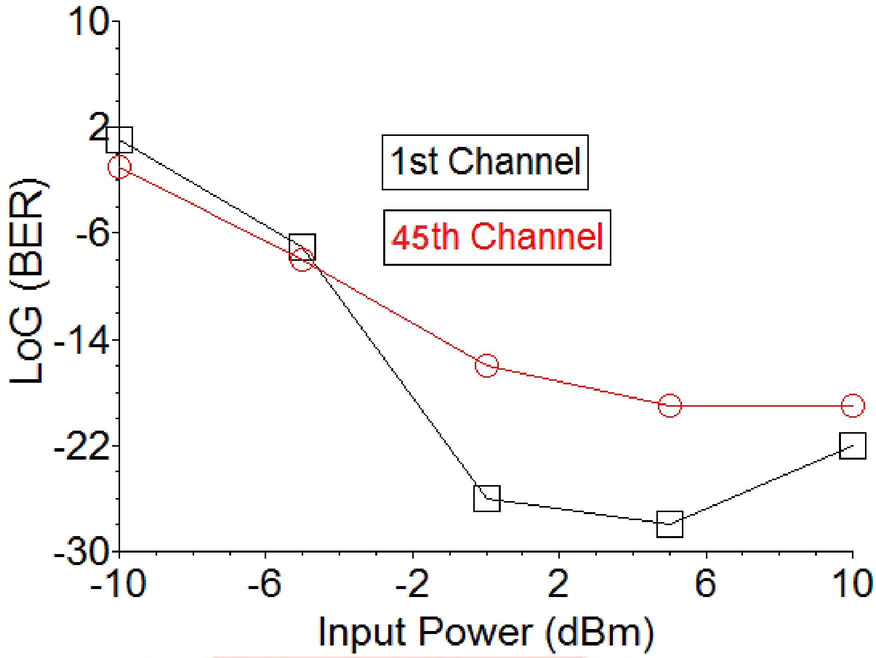


Figure 3 Graphical representations of first and last channels of WDM in terms of LoG of BER at varied launched powers

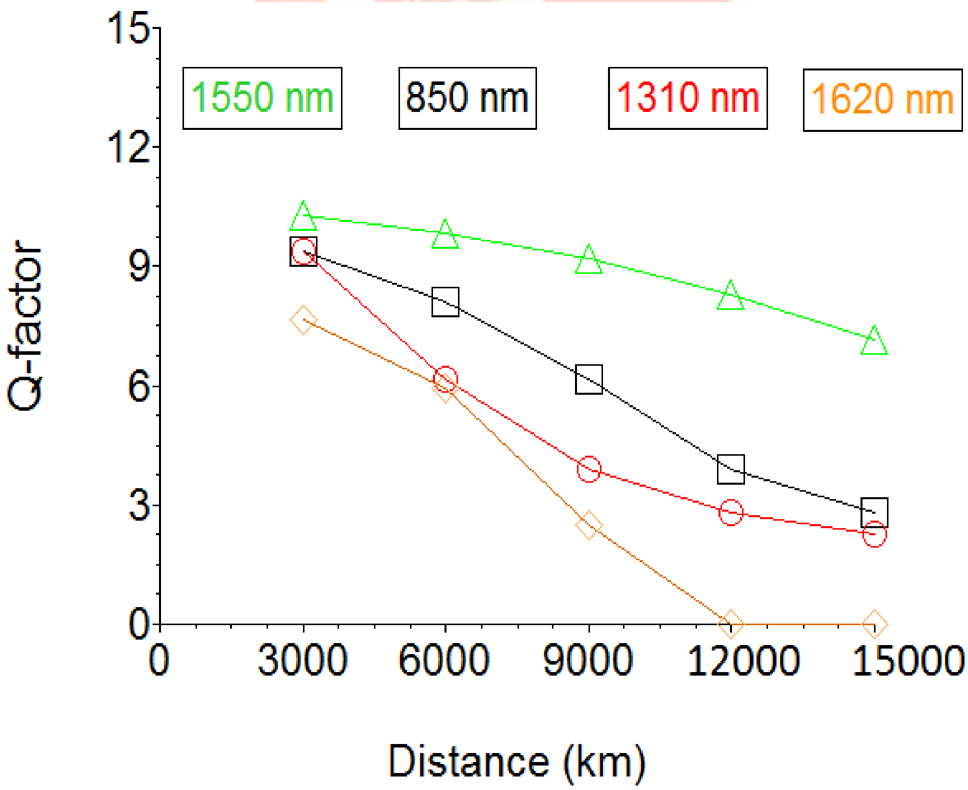


Figure 4 Graphical representation of the proposed system performance at different wavelengths/optical windows

Figure 4 illustrates the Q factor of the system for the different optical windows such as 850 nm, 1310 nm, 1550 nm and 1620 nm. Distance is varied from 3000 km to 15000 km with the difference of 3000 km. This difference is obtained from loop control circulations. EDFA is placed before every 300 km satellite link. It is seen that with the enhancement in distance, Q factor decreases abruptly. This is due the reason that the attenuation, dispersion, geometrical losses, pointing errors and noises decrease the quality of the received signal. WDM cannels also do crosstalk in the channel and deteriorate the performance. Although we have investigated the different optical windows, it is reported that performance is different for each band of WDM-IsOWC system. Best Q factor values over all distances are obtained for the wavelength widow 1552 nm. It is due to the fact that, attenuation and scattering is minimum in this band. Performance of 1552 nm band is followed by 850 nm and suggested in low frequency satellite systems. Minimum results and degradation is reported in the wavelength region of 1620 nm due to maximum attenuation and scattering in this wavelength region as shown in Table 1.

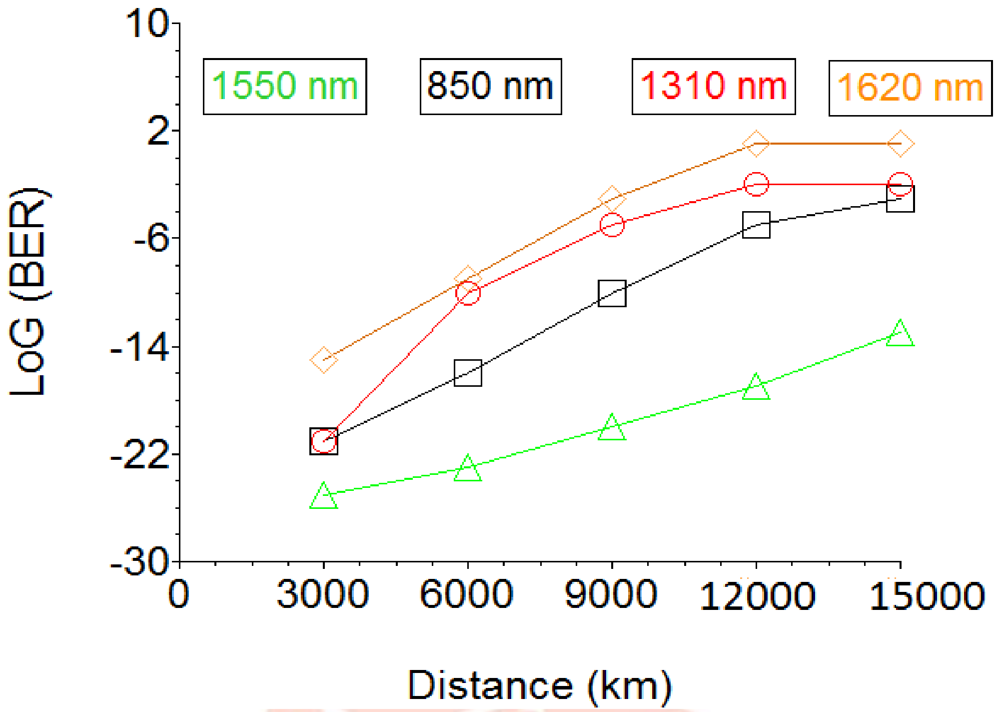


Figure 5 Depiction of LoG of BER versus transmission distance for the performance of the system at different wavelengths/optical windows

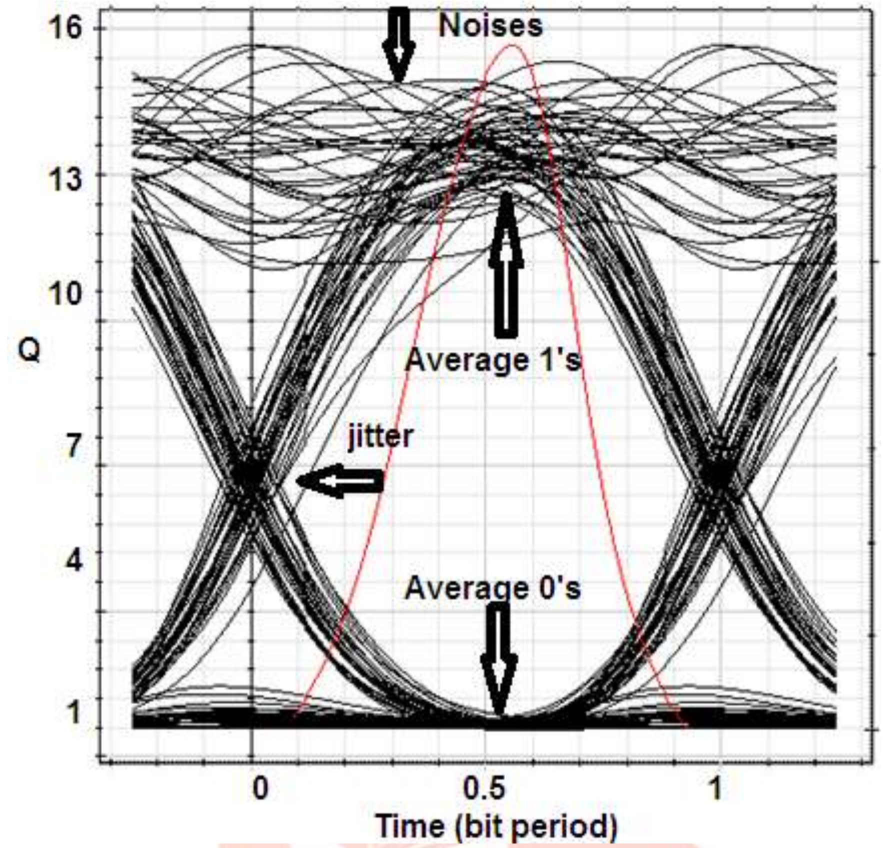
Table 1 Q factor for 1st and 45th channel at varied input power

Launched power	Q-factor for 1st channel	Q-factor for 45th channel
-10	0	2.26
-5	5.07	5.33
0	7.58	8.04
5	8.74	8.89
10	9.09	8.95

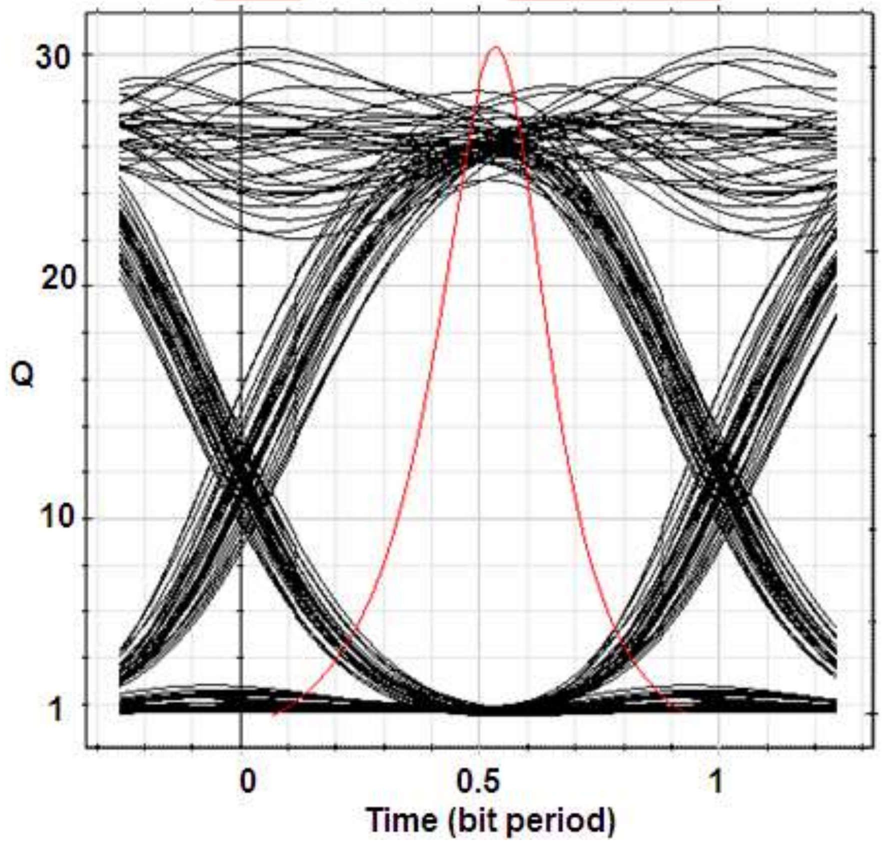
Table 2 Q-factor for different optical windows at different distances

Distance (km)	850nm	1310nm	1550nm	1620nm
3000	9.37	9.38	10.28	7.66
6000	8.12	6.18	9.83	5.93
9000	6.18	3.9	9.2	2.51
12000	3.9	2.82	8.31	0
15000	2.82	2.26	7.17	0

Figure 5 shows the graph between transmission Range and Q-Factor when the system is analyzed for C (1550 nm), O band (1310 nm), S band (850 nm) and L (1620 nm) band. Distance reach is fixed to 12500 km for the eye diagrams. The eye diagrams are shown in Fig. 6 which shows the results of system by using different optical windows such as different frequency band. Eye diagrams are the final and end component of the communication network and depicts the Eye opening and closer, jitter. More the opening of the Eye in the depicter, more the Q factor and less is the BER of the system. It is also seen the Eye opening is more in case of 1550 nm wavelength region and less in 1620 nm region. More eye opening is seen in C-band because of the less attenuation and scattering in this region. In the case of 1620 nm, due to more attenuation and scattering, Eye closer is more. Thus degrade performance is seen in this region of wavelengths with high BER and less OSNR, Q factor.



(a)



(b)

Figure 6 Eye diagram representation of proposed inter-satellite optical wireless communication system for (a) L band window (b) C band optical windows

IV. CONCLUSION

The research work reveals the design and simulation analysis of 45 × 20 Gbps Dense Wavelength Division Multiplexing (DWDM) Inter-satellite Optical Wireless Communication (IsOWC) System by taking into account the concept of reduced channel spacing of 50 GHz. The high capacity system is proposed and its performance analysis is observed for various parameters like transmission range and input power. 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 12500 km with acceptable Q-Factor and BER in different optical windows such as 850 nm, 1310 nm, 1550 nm and 1620 nm window. It is seen that C band performs best and L band worst in terms of Q factor and BER. It is concluded and observed that the 850 nm wavelength region achieves maximum transmission range of 9000 km within acceptable range of BER, 1310 nm successfully obtained 6000 km, 1550 nm reaches up to 15000 km and 1620 nm provide distance 3500 km.

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