Comparison of Different Modulations with Proposed Hybrid WDM-TDM Inter-Satellite Optical Wireless System

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Abstract Capacity requirements increase day by day due to video calling, high speed online games, and high capacity systems etc. Wavelength and time division multiplexing are widely used but suffers from some limitations. Therefore, hybrid multiplexing is an important technique to overcome the limitations of existing wavelength division multiplexing and time division multiplexing. Hybrid multiplexing is a potential method to pack more number of channels in system and also suppress the interferences among adjacent channels. In this research work, 64 channels with ultra dense (50 GHz) channel spacing is demonstrated over inter-satellite optical wireless communication system and data is modulated with diverse modulations such as differential phase shift keying, Chirped and a line coding alternate mark inversion (AMI). Further comparison of modulations and coding is accomplished with proposed hybrid WDM-TDM-DPSK wireless optical communication system at different bit rates such as 10 Gbps, 20 Gbps and 40 Gbps. Variation in link length has been done from 500 km to 2500 km under lower earth orbit and results are taken as Q factor and BER. It is perceived that performance of proposed hybrid system is best among other investigated systems. System works successfully for 2500 km by employing hybrid WDM-TDM-DPSK over IsOWC system.

I. INTRODUCTION

Continuous expand in the requirements of internet services has put burden on limited spectrum of radio communication. Radio communication was widely employed in inter-satellite communication, but it is limited in terms of low data rates, less capacity and more interferences. Optical wireless communication is emerged as an ultimate solution because it provides huge bandwidth as well as high data transfer speeds, no EMI interference, high security and long-distance transmission. Optical wireless communication is competent enough such that it can support bit rates 4 folds more than conventional RF communication [1] [2]. Frequency range of OWC systems is very high and this is because of laser signal carriers [3]. Integration of dense wavelength division multiplexing has ability to load more number of channels and also offer high data rates, and lower bit errors. Numerous research works are studied and reported till now in the literature on IsOWC systems due their benefits [4] [5] [6]. In [7], a 10 Gbps wireless optical system was demonstrated by employing non-return to zero as well as return to zero pulse formats over OWC with 32 wavelength division multiplexed channels. Further, an ultra-dense IsOWC system has been reported with 64 WDM channels using 50 GHz dense spacing over 2500 km using diverse modulation formats such as compressed spectrum RZ, duo binary RZ, modified DRZ [8].

In [9], author analysed chirped, differential phase shift keying and alternate mark inversion in ultra-dense 64 WDM inter-satellite system at 10 Gbps, 20 bps and 40 Gbps. However, from [8], [9], it is evident that modulation formats play vital performance in the total output, but it is also perceived that only change in modulation cannot increase the system capacity and reach to much extent. Crosstalk among adjacent WDM channels is a major issue and this can be solved by using optimal multiplexing.

This research article is accentuated on the design and analysis of high capacity inter-satellite optical wireless system has been proposed using hybrid WDM-TDM multiplexing and results are compared with chirped, AMI and DPSK without hybrid multiplexing.

II. SYSTEM SETUP

For the analysis of IsOWC system, simulation setup is made in Opti system software. To accomplish the work, two different cases are considered (1) Proposed hybrid WDM-TDM-DPSK-OWC system and its comparison with (2) WDM-IsOWC system by incorporating diverse modulations such as differential phase shift keying, Chirped and a line coding alternate mark inversion (AMI). Figure 1 depicts the block diagram of case in which different modulations are used for WDM systems only. Figure 2 represents the block diagram of proposed hybrid 64 channels ultra-dense (50 GHz) IsOWC system. First of all, Laser array of 64 wavelengths is taken in conventional band and frequencies are started from 193.1 THz and spacing between each frequency is fixed to 50 GHz to make system bandwidth efficient. A bit sequence generator is employed for the generation of binary bit streams at data rate of 10 Gbps, 20 Gbps and 40 Gbps in different cases. Further, transmitters of differential phase shift keying, chirped, alternate mark inversion are incorporated for the analysis of different modulations in proposed system. Transmitters of differential phase shift keying, chirped, alternate mark inversion are depicted in Figure 3. DPSK modulation has numerous benefits and chosen for proposed system in which DPSK is incorporated with hybrid WDM-TDM system.

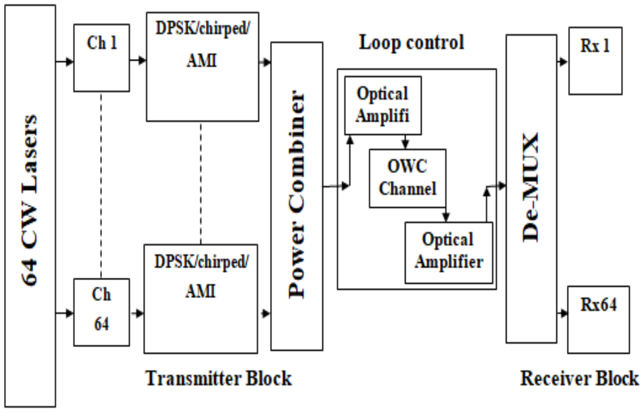


Figure 1 Representation of reported WDM- OWC system for 64 channels

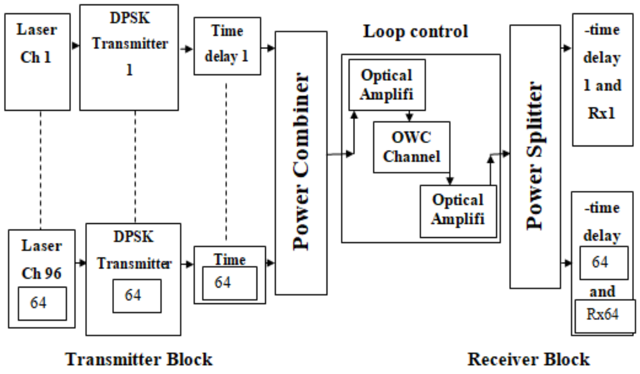
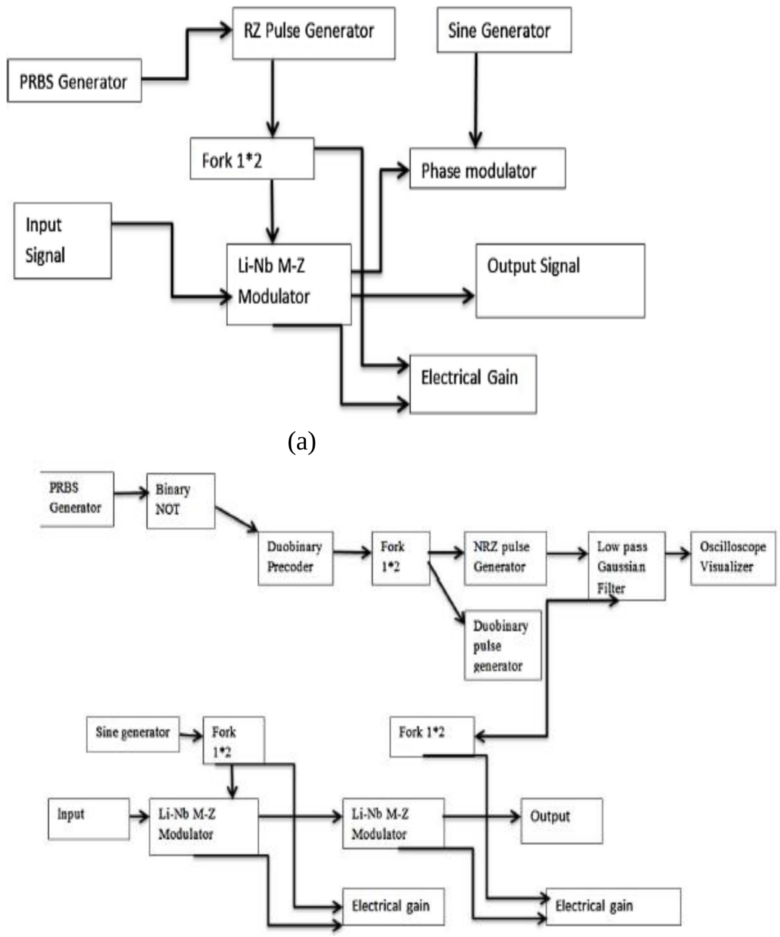


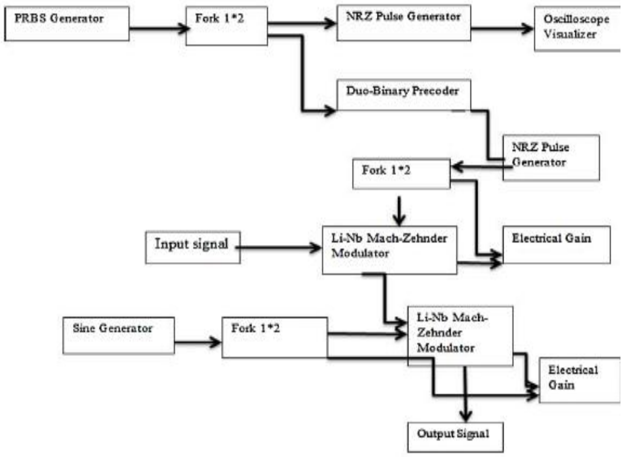
Figure 2 Representation of Proposed Hybrid WDM-TDM OWC system for 64 channel

Internal block diagrams of investigated modulations such as differential phase shift keying, chirped, alternate mark inversions are illustrated in Figure number 3 (a), (b) and (c) respectively. A prominent and highly chosen Chirped modulation is shown in 3 (a). Each modulation has its own benefits and in order to get high signal to noise ration, AMI Modulation is used in this work. Working of AMI is simple such as AMI has binary 0 for zero voltage as well as binary 1 for alternate negative and for positive voltages. AMI can be competently coordinated with wavelength division technology as well as it augments the optical system bandwidth. AMI is employed in wireless optical systems due to the high efficiency to encode bits. For the generations of this pulse shape, NRZ, duo binary precoder as well as duo binary pulse generator are used. Drive of pulse is given to low pass filter and then conversion of sine signal to optical domain is done through first Mach-Zehnder modulator and then connects it with another Mach-Zehnder Modulator.



(a)

(b)



(c)

Figure 3 Block Diagram of (a) Chirped modulation (b) AMI coding (c) DPSK modulation

Fig. 3 (b) shows the block diagram of AMI Modulation at 193.1 THz. Fig. 3 (c) depicts the proposed system's block diagram in case differential phase shift keying that consists of binary bit stream and encoding of these bit streams. It has less complex structure, have high forbearance to Doppler-shift as well as it can cater high bit rates.

After the data modulation with aforementioned modulations and a coding, signals are passed through time delay component. Each channel is provided different time delay for propagation such that time division occurs. Data is delayed by time delay equals to:

$$Time\ Delay = n \times \frac{1}{Bit\ rate}$$

Where n is channel number. Therefore, channel one having time delay of 0.1 ns in case of 10 Gbps and channel 64 having time delay of 0.64 ns. Major goal of this work is to decrease the interferences among adjacent channels of WDM. A power combiner is employed to combine power of different wavelengths with respect to time delays and after 1 x 64 power combiner, signal is fed to inter-satellite optical wireless channel. Length of OWC channel is fixed at 250 km and operated in conventional band i.e. 1550 nm window. Transmission line is shown in Figure 4 Internal simulation structure of DPSK and its decoder is shown in Figure 5 (a) and (b) respectively.

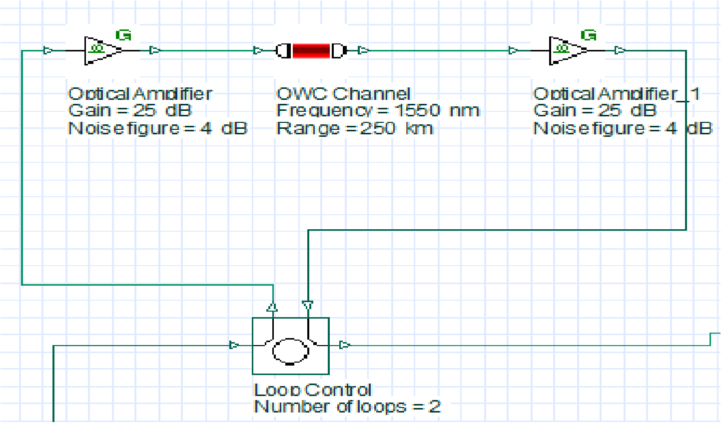
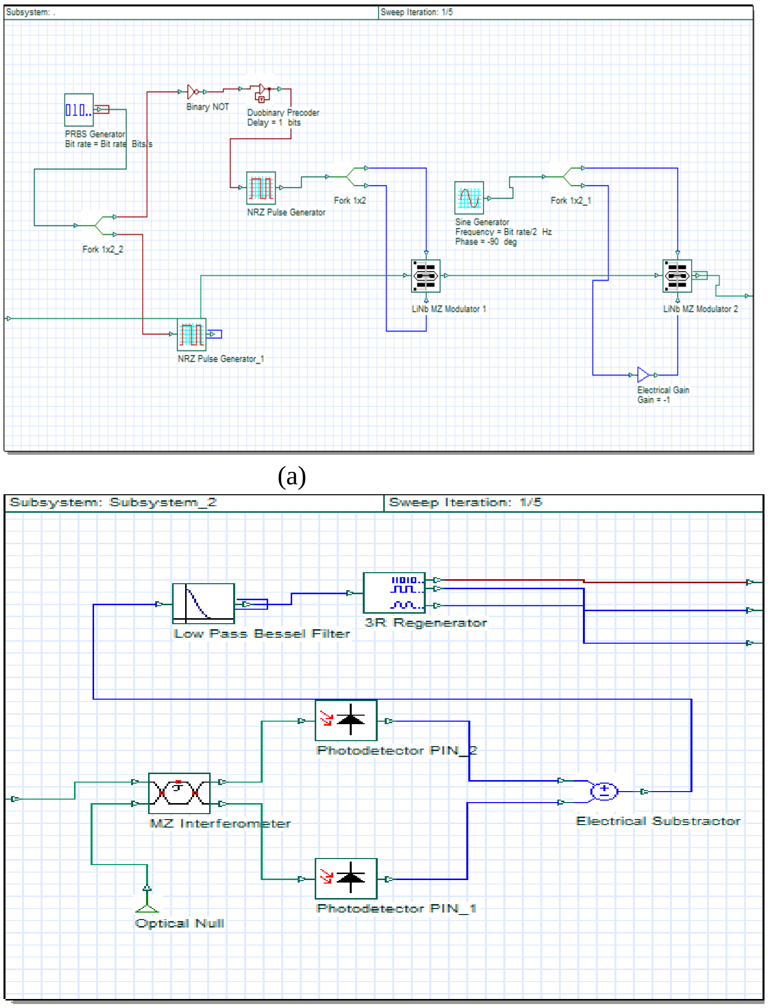


Figure 4 Simulation setup of transmission line



(a)

(b)

Figure 5 Internal simulation structure of (a) DPSK transmitter (b) DPSK receiver

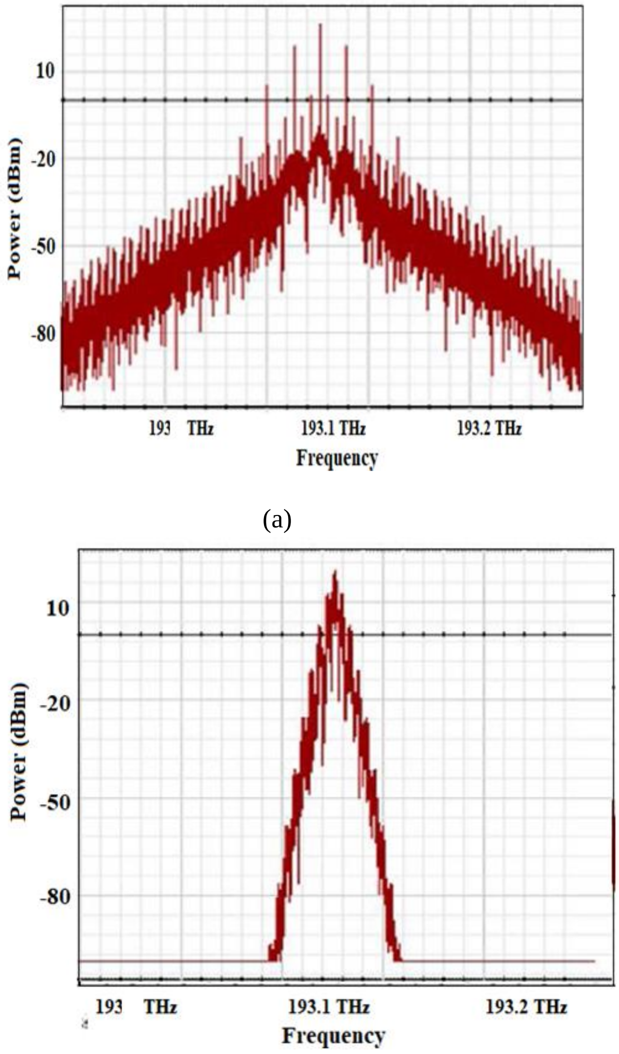
Size of the aperture antenna diameter is 15 cm for the transmitter and also for receiver antenna, 15 cm is taken because in wireless optical communication based on inter-satellite signal transmission there is no air, which means no beam divergence is there. Two erbium doped power amplifiers are employed before and after 250 km OWC channel for the compensation of the amplitude degradation effects. Major work of EDFA amplifier is to boost the weak signals before and after transmission and Gain is used 25 dB and noise figure is 4 dB constant. After transmission channel, signal is passed through wavelength division multiplexed de-multiplexer which has 64 output ports and channel spacing of 50 GHz. It basically route the wavelengths to specific output port according to the transmitted wavelengths. Further each channel is passed through time delay module which is having negative equal delay as given in transmitter side in order to decode the signal at original time by eliminating the TDM delays. Signal then fed to decoder of respective modulation such as decoder of DPSK, Chirped, AMI. System specifications of the proposed work are shown in Table 1.

Table 1 System specifications of the proposed hybrid WDM-TDM-DPSK -IsOWC system

Parameters	Values
Data rate	10, 20, 40 Gbps
Starting Frequency	193.1 THz
Multiplexing	Hybrid WDM-TDM
Number of channels	64
Frequency Spacings	50 GHz
Time Delay	$Time\ Delay = n \times \frac{1}{Bit\ rate}$
Modulation	DPSK
Distance	250 km-2500 km
Power	30 dBm
Amplifiers	EDFA
Photo-detector	PIN

III. RESULTS AND DISCUSSIONS

Investigation of proposed hybrid wavelength and time division multiplexed optical wireless system incorporating differential phase shift keying is presented. Also, 64 channel hybrid WDM-TDM system is compared with 64 channels WDM IsOWC system using Chirped, DPSK and AMI modulations. Results are evaluated in terms of Bit error rate and Q factor at varied distances in LEO orbit. Optical and electrical visualizers plays an important role in the optical communication link design which allow us to access the signals or absence of signal at regular intervals. In order to check the spectrum of the modulations, optical spectrum analyzers are employed at the first channel for depicting spectrum at 193 THz frequency which is frequency of first channel. Figure 6 illustrates the optical spectrums of DPSK, AMI and chirped in WDM-IsOWC system and also spectrum of proposed hybrid WDM-TDM-DPSK system.



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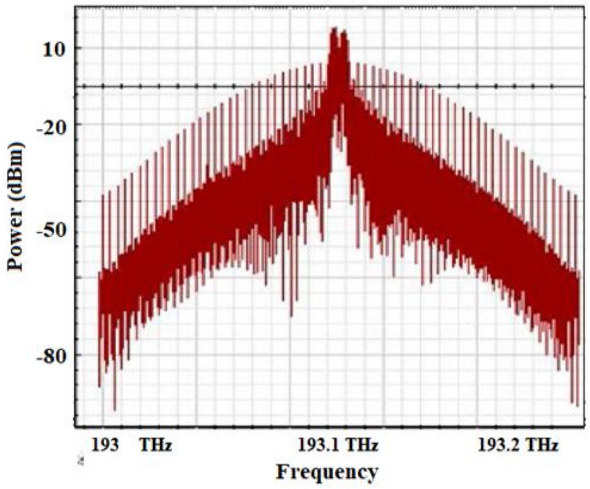

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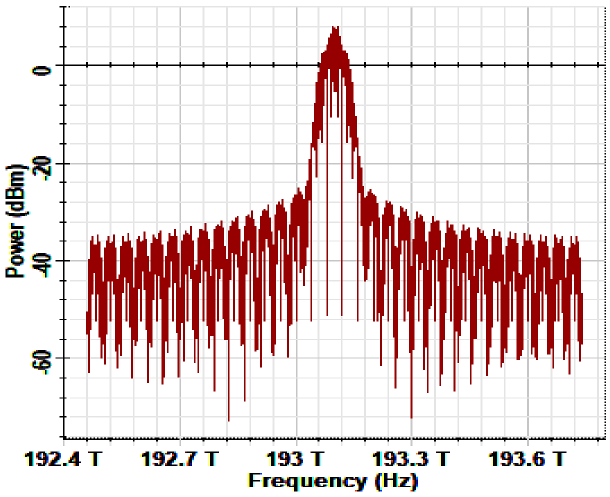
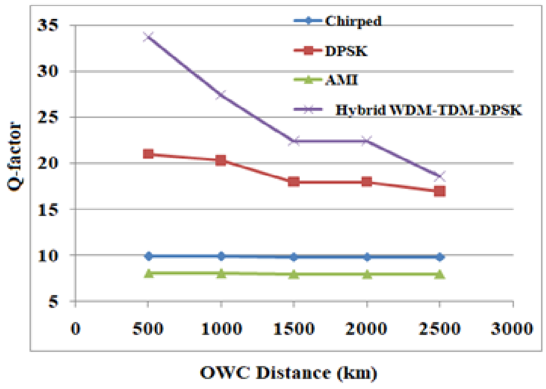


(d)

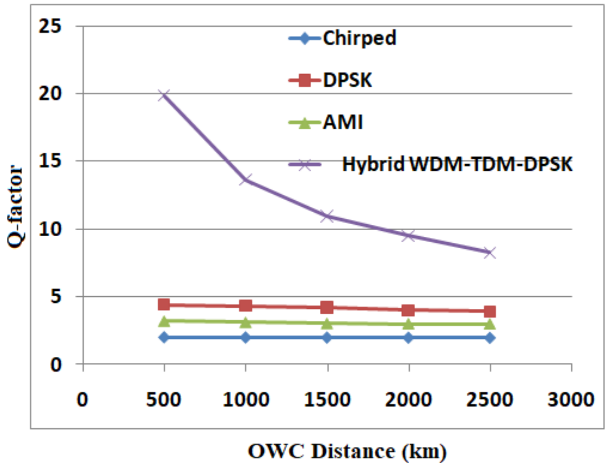
Figure 6 Carrier's spectrum in optical domain of (a) Chirped (b) AMI (c) DPSK (d) Hybrid WDM-TDM DPSK

Power launched from the laser source is kept at 30 dBm and wavelength window is chosen as conventional band due to least scattering effects. Since there is use of wireless optical channel, scattering is an important factor to be considered. Chirped modulation optical spectrum is illustrated in Figure 6 (a) and spectrum with respect to power and its center frequency are shown in Figure 6 (b) for alternate mark inversion. Figure 6 (c) and (d) represents the spectrums of differential phase shift keying and proposed WDM-TDM-DPSK system respectively.

Figure 7 illustrates the performance comparison of the proposed 64 channel hybrid wavelength and time division multiplexed differential phase shift keying system with 64 channel WDM- system over inter-satellite wireless optical system incorporating chirped, DPSK and AMI modulations at 10 Gbps. It is evident from the Figure 7 that deterioration of Quality factor occur when link length of the OWC tends to increase. High Q is attained at shorter distance due to low attenuation and pulse width broadening where, low Q is seen at longer lengths. For the investigation and analysis of the systems, link length of the WOC channel is altered from 500 km to 2500 km and readings are noted after every 500 km link distance. Comparison of systems reveled that there is degradation in every modulation when distance increased but best Q is observed at every distance till 2500 km is for 64 channel hybrid wavelength and time division multiplexed differential phase shift keying system and performance of proposed system is followed by 64 channel WDM- system over inter-satellite wireless optical system incorporating DPSK modulation. Thus, it is noteworthy that at 10 Gbps DPSK modulation performs better in with and without hybrid multiplexing, however, results improved further when hybrid multiplexing is incorporated with DPSK in IsOWC system. Reason for the enhancement is depends upon two factors such as (1) Hybrid WDM-TDM-DPSK reduce the adjacent channel crosstalk (2) Time skew issues i.e time latency is least in OWC systems as compared to optical fiber systems. Least Q is emerged in case of alternate mark inversion case. It is also noteworthy that proposed system and conventional system works for 2500 km within acceptable range of BER and Q successfully.



(a)



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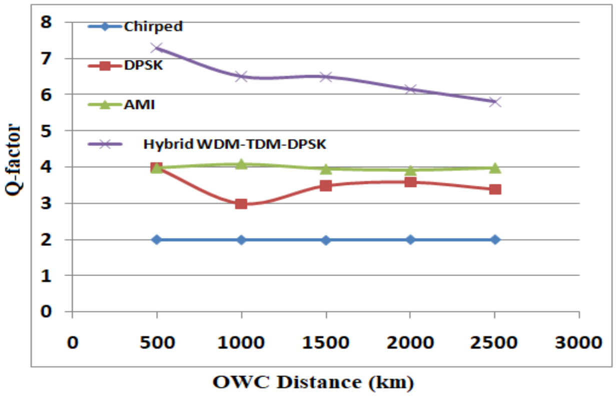
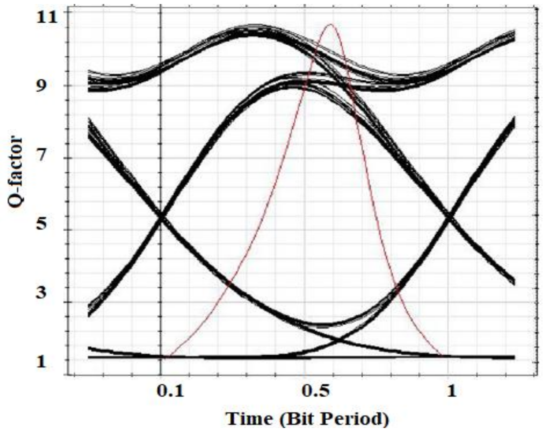


(c)

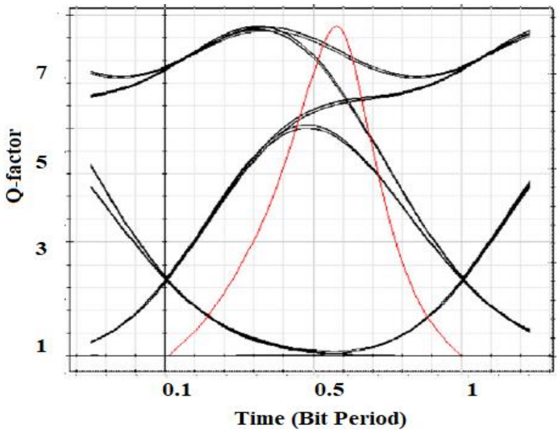
Figure 7 Performance comparison of proposed hybrid WDM-TDM-DPSK system and conventional system at (a) 10 Gbps (b) 20 Gbps (c) 40 Gbps over IsOWC

Figure 7 (b) represents the performance comparison of the proposed 64 channel hybrid wavelength and time division multiplexed differential phase shift keying system with 64 channel WDM- system over inter-satellite wireless optical system incorporating chirped, DPSK and AMI modulations at 20 Gbps. For the analysis of the proposed system and conventional system which is 64 channels WDM-OWC system using Chirped, AMI and DPSK, distance of the WOC channel is varied from 500 km to 2500 km. It is observed from the results that there is degradation in every modulation when distance increased but best Q is observed at every distance till 2500 km is for 64 channel hybrid wavelength and time division multiplexed differential phase shift keying system and performance of proposed system is followed by 64 channel WDM- system over inter-satellite wireless optical system incorporating DPSK modulation. Therefore, it is noteworthy that at 20 Gbps DPSK modulations performs better in, with and without hybrid multiplexing, however, results improved further when hybrid multiplexing is incorporated with DPSK in IsOWC system. Best Q factor value 8.29 and Least Q factor value1. 98 are observed form proposed hybrid multiplexed DPSK system and chirped modulation respectively. Moreover, this is evident that results at 20 Gbps are degraded as compared to 10 Gbps system. It is also concluded that only proposed system works for 2500 km within acceptable range of BER and Q successfully while conventional system fails to achieve even 1000 km at 20 Gbps.

Figure 7 (c) illustrates the performance at data rate 40 Gbps to check the optimal system for inter-satellite optical wireless systems. Modulations and coding are compared with hybrid multiplexing based DPSK IsOWC system and results revealed that hybrid WDM-TDM DPSK system works for 2500 km and provide highest Q factor than chirped, DPSK, AMI WDM-IsOWC system. Performance of WDM-TDM-DPSK is followed by AMI at 40 Gbps and least Q factor is observed in case of chirped modulation over OWC at 40 Gbps data rate. Figure 8 depicts the Eye diagram of proposed 96 channel hybrid wavelength and time division multiplexed differential phase shift keying system, 64 channel WDM- system over inter-satellite wireless optical system incorporating chirped, DPSK and AMI modulations at different data rates for 2500 km. Eye diagram representation provides the information of the average number of ‘1’s and ‘0’s in the binary data stream. Figure 8 (a) (b) (c) (d) illustrates the Eye diagrams of chirped, AMI, DPSK and hybrid WDM-TDM-DPSK at 10Gbps for 2500 km respectively. Results revealed that Eye is wide open in Figure 8 (d) and this is for hybrid WDM-TDM-DPSK system. Eye closure is maximum for alternate mark inversion.



(a)



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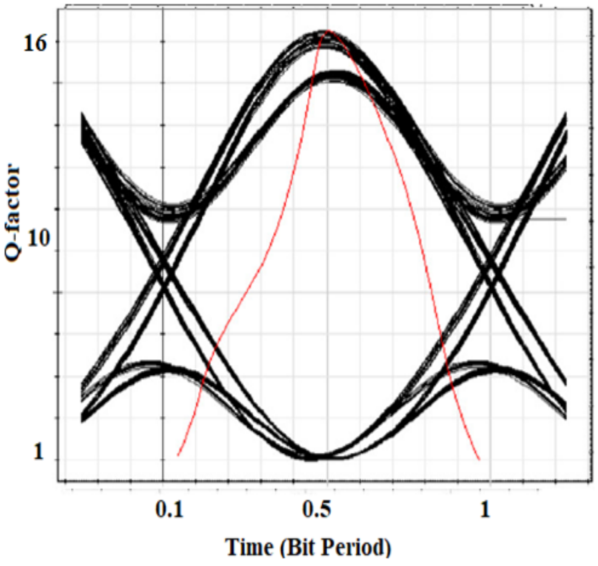

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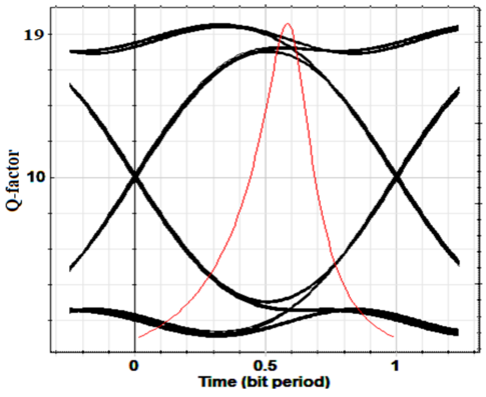
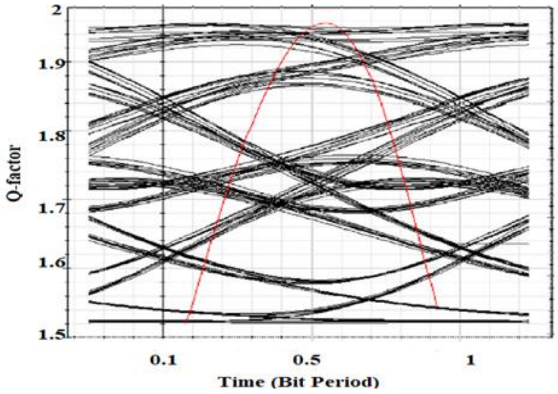
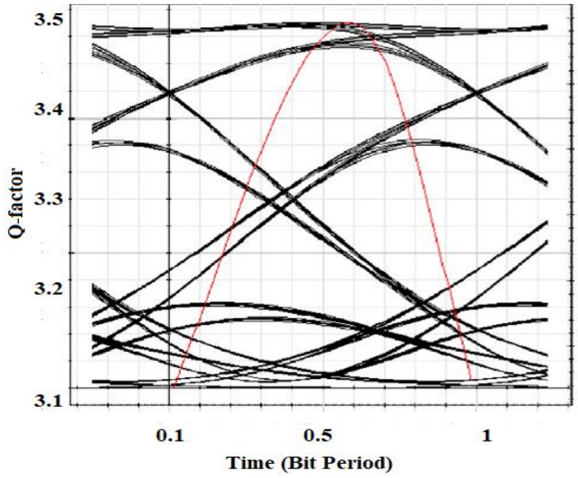


(d)

Figure 8 Representation of Eye diagram of the proposed system and conventional system at 2500 km link distance for 10 Gbps in case of (a) chirped (b) AMI (c) DPSK (d) Hybrid WDM-TDM-DPSK



(a)



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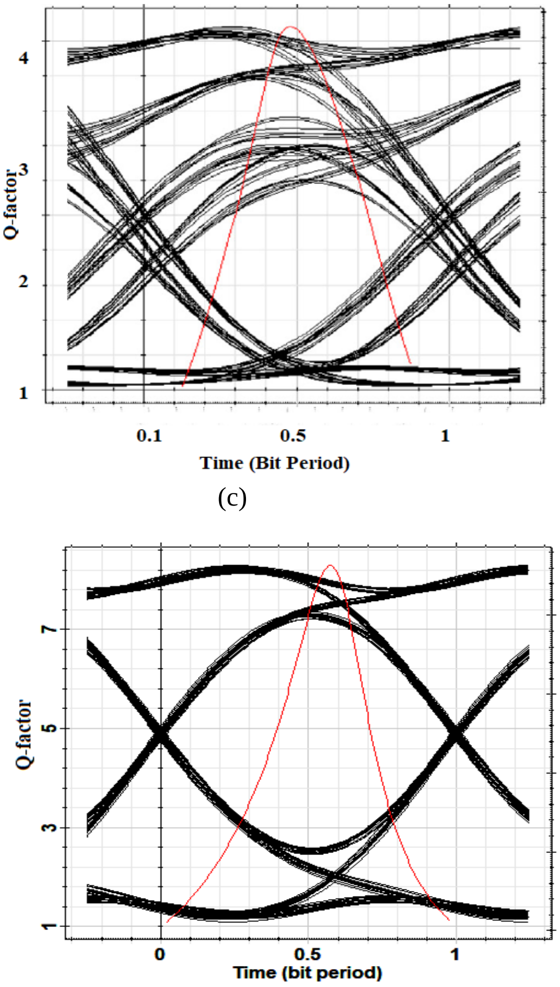


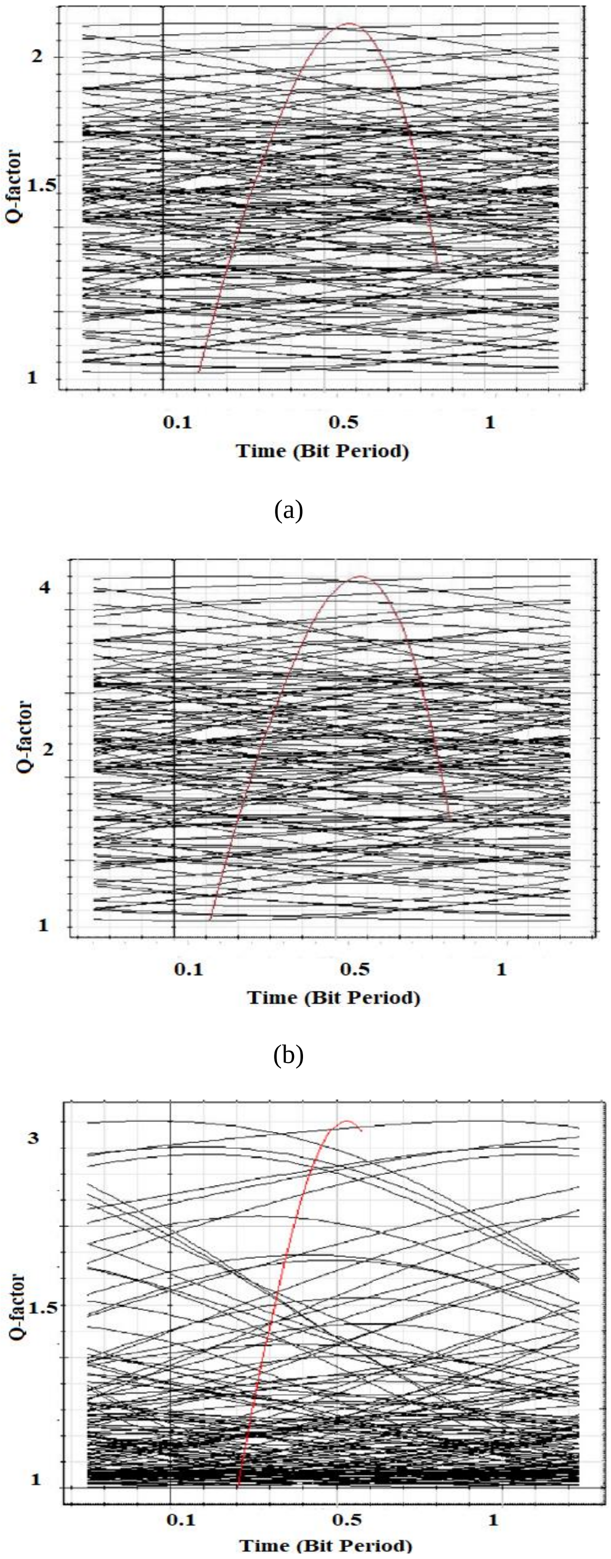
(c)

(d)

Figure 9 Representation of Eye diagram of the proposed system and conventional system at 2500 km link distance for 20 Gbps in case of (a) chirped (b) AMI (c) DPSK (d) Hybrid WDM-TDM-DPSK

Figure 9 (a) (b) (c) (d) represents the Eye of modulations such as chirped, AMI, DPSK and hybrid WDM-TDM-DPSK at 20 Gbps for the link length of 2500 km respectively. Figure 9 (d) shows maximum Eye opening and this is for hybrid WDM-TDM-DPSK. At 20 Gbps, alternate mark inversion has least opening.

Eye diagrams of chirped, AMI, DPSK and hybrid WDM-TDM-DPSK are shown in Figure 10 (a) (b) (c) (d) at 40 Gbps for 2500 km respectively. It is perceived that broad eye opening is seen in Figure 10 (d) and this is for hybrid WDM-TDM-DPSK which means this is best system in proposed work.



(a)

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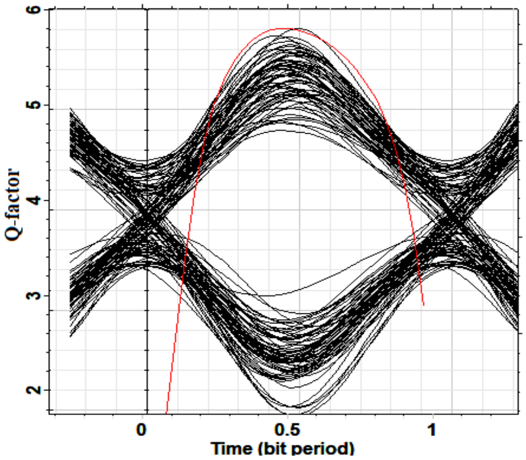

(d)

Figure 10 Representation of Eye diagram of the proposed system and conventional system at 2500 km link distance for 40 Gbps in case of (a) chirped (b) AMI (c) DPSK (d) Hybrid WDM-TDM-DPSK

IV. CONCLUSION

In this work, an ultra-dense 64 channel hybrid wavelength and time division multiplexing based inter-satellite wireless optical system is proposed by incorporating differential phase shift keying modulation. Hybrid multiplexing is incorporated in the proposed system in order to reduce the interference of adjacent WDM channels. Lower earth orbit-based satellite signal transmissions studied till the distance of 2500 km. Moreover, comparison of proposed system is accomplished with conventional signal multiplexing reliant 64 channel WDM-IsOWC system which employed modulation such as chirped, DPSK and Alternate mark inversion (AMI). Proposed system and single multiplexing-based system are analyzed at 10 Gbps, 20 Gbps and 40 Gbps bit rate at diverse link lengths such as 500 km to 2500 km in terms of Q factor. Results revealed that proposed system has greater capacity and exhibits best performance al ever distance as compared to WDM-IsOWC system modulations. Hybrid WDM-TDM-DPSK work for 2500 km within acceptable range of Q factor at 10 Gbps, 20 Gbps, 40 Gbps, and on the other hand WDM-IsOWC system works for only 10 Gbps till 2500 km within acceptable Q value.

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