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Comparative analysis of chirped, AMI and DPSK modulation techniques in IS-OWC system

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ABSTRACT

The work in this paper presents 64 Channel Inter-Satellite Optical Wireless Communication system using three Modulation methods. The advanced system has been achieved through Wavelength Division Multiplexing (WDM) by using optimized modulation methods like Chirped RZ, AMI and DPSK. The advanced system is composed and thus simulation is done at 10, 20 and 40 Gbps having range of 750 nm at different distances. The basic goal of the system is to provide good performance which has been achieved by high quality-factor and minimum BER. So eye diagrams have been presented at different bit rates. The comparative results show that at 10 and 20 Gbps, DPSK Modulation shows best performance. At 40 Gbps, AMI Modulation contains high Q-factor than Chirped and DPSK Modulation Techniques.

1. Introduction

An optical communication system comprise of transmitter part, transmission channel, and receiver part. There will be a merging of Wavelength-Division multiplexing (WDM) using OWC system which would result in providing excellent bit-rate, less bit-errors and high speed which can travel long distances. Free space optical communication is technology of optical transmission which is helpful for transmission of data and signals [1].One of the most important applications of FSO is IS-OWC. IS-OWC systems usually promote exchanging of information between two satellites. It has been helpful to carry an optical signal with the help of wireless links resulting in the combination of optical as well as wireless technology [3]. Optical wireless communication (OWC) contains certain merits such as it has the ability to operate at high bit rate, low loss, high bandwidth, the small size of the antenna and high efficiency of power. It has the ability to operate in several electromagnetic bands like ultraviolet communication (200–280 nm) and infrared wavelength (750–1560 nm) [6,10].

In a digital communication system, bit errors are the signal receiving bits that also contain a certain amount of disturbance, obstruction and interference. Thus bit rate is termed as the count of bits that is carried in certain amount of time [7]. Adopting inter-satellite with OWC system leads to the development in security and few bit errors [10].

The IS-OWC system has a number of benefits. First, no license is required in a communication link. The second benefit is the immunity and power to the RF interference or level of saturation [8]. An OWC system with 32-channels which operated at 10 Gbps adopted modulation techniques of Non-Return to Zero (NRZ) and Return to Zero (RZ) was described in [9].Thus OWC system with 64-channels which operated at 10, 20 and 40 Gbps adopted modulation techniques of carrier-suppressed

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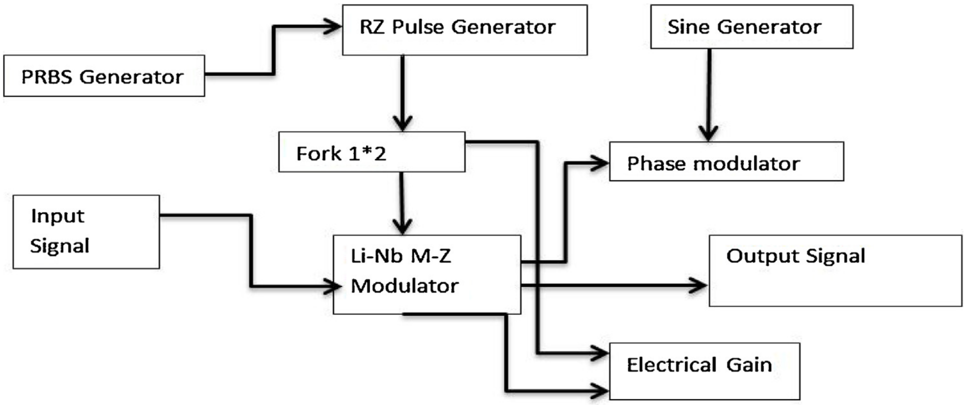
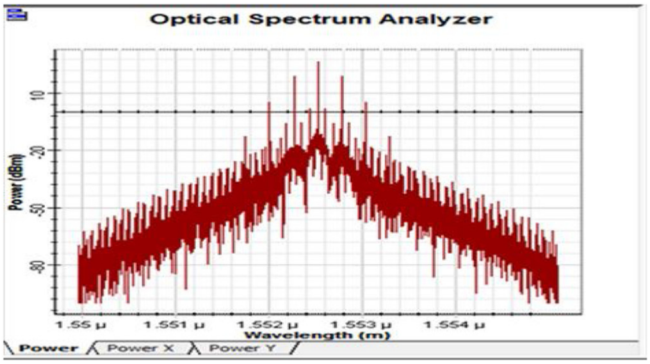


(a) Block Diagram of Chirped Modulation



(b) Optical Spectrum Analyzer at Chirped Modulation

Fig. 1. (a) Block Diagram of Chirped Modulation (b) Optical Spectrum Analyzer at Chirped Modulation.

Return to Zero (CSRZ), Duo-binary Return-to-zero (DRZ) and Modified Duo-binary Return to Zero (MDRZ) was described in [1].

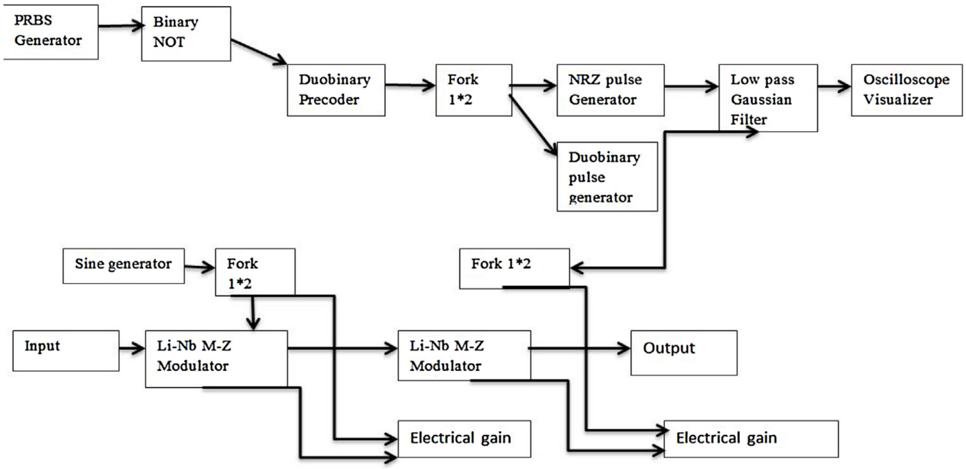
In this paper, IS-OWC system with excellent capacity having chirped and AMI modulation methods has been presented. Characterization of modulation methods and proposed system has been explained. Thus results have been taken and thus conclusion and future scope has been discussed to determine the efficiency of IS-OWC system.

2. Characterization of modulation methods and its simulation

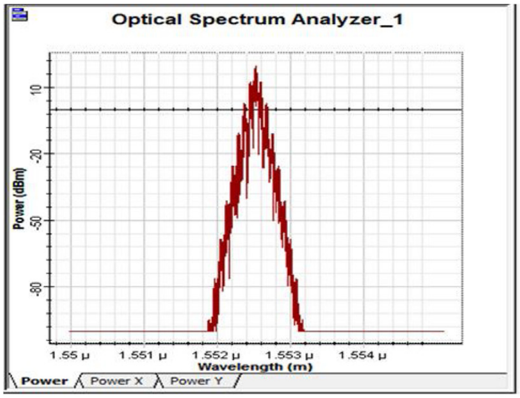
Fig. 1(a) illustrates the block diagram of Chirped modulation that is considered as the highly preferred modulation method. In this type of modulation, RZ optical signal which goes through LiNb Mach-Zehnder Modulator passes through phase modulator (PM). Chirped RZ, Chirped NRZ and Alternate Chirped NRZ are new modulation techniques that can be preferred in IS-OWC systems. The Extinction ratio is taken around 30 dB. Frequency is taken around 193.1 Thz and power is chosen around 30 dB. Chirped RZ is preferred as compared to other modulation techniques because of its high Q-factor and less BER. Chirped RZ have been quite useful in dispersion compensation and helps improvement in narrowband optical filtering. Non-linearity of optical fiber can be reduced by dispersion map [2]. The output of optical spectrum analyzer is shown in Fig. 1(b).

Fig. 2(a) shows the proposed block diagram of AMI Modulation format which is used to enhance transmission capacity of fiber and exhibit high SNR. AMI contains binary 0 for zero or neural voltage and binary 1 for alternate negative as well as positive voltages. AMI can be efficiently coordinated with WDM technology and it enhances the bandwidth of the optical system [3]. AMI is used in IS-OWC systems because it contains high encoding of data than NRZ and RZ modulation technique. In this type of modulation, NRZ pulse generator has been created by duobinary precoder and duobinary pulse generator. NRZ pulse generator drives to Low pass Gaussian filter and output of oscilloscope visualizer is measured. The sine generator takes the first Mach-Zehnder modulator and then connects it with another Mach-Zehnder Modulator. Fig. 2(b) shows the optical spectrum analyzer of AMI Modulation at 193.1 Thz.

Fig. 3(a) shows the proposed block diagram of DPSK Modulation format that requires the use of input bit sequence and its encoding. It has less complications in tracking, high tolerance to Doppler-shift and it performs at high data rates [4,5].



(a) Block Diagram of AMI Modulation



(b) Optical Spectrum Analyzer at AMI Modulation

Fig. 2. (a) Block Diagram of AMI Modulation (b) Optical Spectrum Analyzer at AMI Modulation.

It involves the use of Pseudo-random bit sequence generator which passes to duobinary precoder and NRZ pulse generator with the help of Fork 1*2. The CW laser contains the input signal which passes through Li-Nb Mach-Zehnder Modulator and thus sine generator helps another Li-Nb Mach-Zehnder Modulator to generate the output signal. This method is quite preferred in IS-OWC systems because it has little interference and less consumption of power. Fig. 3(b) shows the optical spectrum analyzer which shows the graph of power versus wavelength at frequency is taken at 193.1 Thz.

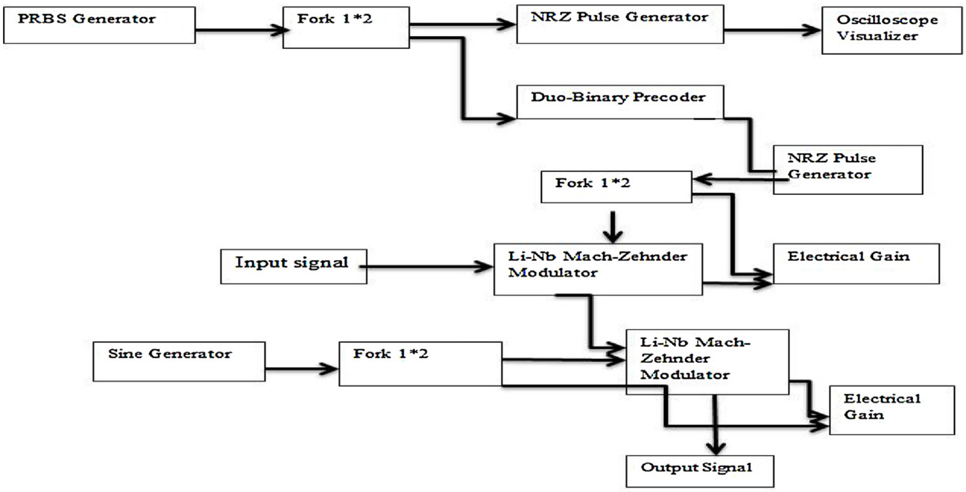
In free space optics, atmospheric channel is static which affects the characteristics of the optical beam. Thus turbulences in atmosphere and noise influence the phase and amplitude of transmission optical beam. When optical beams are transmitted via atmospheric channels, interference occurs between molecules and photons [12]. AMI line-codes can be easily produced through operations of delay subtract or duobinary precoder. The major factor that affects the beam propagation is atmospheric turbulence that is non-uniform motion present in the atmosphere. Thus IS-OWC system model can be represented by an equation:

$$P_r = P_T n_T n_R (\lambda/4\pi Z)^2 G_T L_T G_R L_R \tag{1}$$

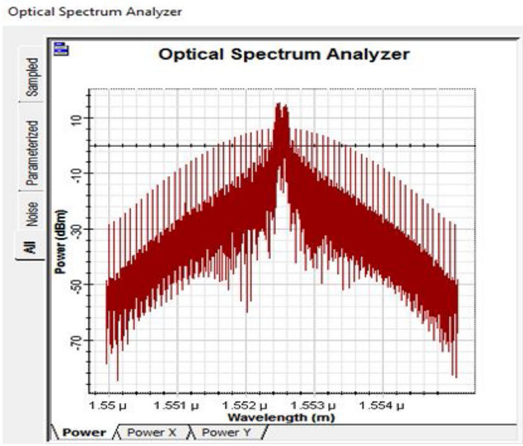
Where P_T is the optical power of the transmitter, n_T is efficiency of optical transmitter, n_R is the efficiency of optical receiver, λ is wavelength, Z is the distance taken between transmission side and receiver side, G_T and G_R are transmitter and receiver gain, L_T and L_R are transmission and reception pointing loss factor. Thus the losses in the signal propagation can be calculated as follows:

$$L_R = (\lambda/4\pi R)^2$$

where λ is wavelength in m and R is the distance between T_x and $R_{x.}$ To decrease the losses for the designed system, there is need to keep the value of R to be 250 km [3].



(a) Block Diagram of DPSK Modulation



(b) Optical Spectrum Analyzer at DPSK Modulation

Fig. 3. (a) Block Diagram of DPSK Modulation (b) Optical Spectrum Analyzer at DPSK Modulation.

Received power P_R usually contains transmitted power P_T which is described by an equation:

$$P_T = P_R \exp(-T_{od}) \tag{3}$$

Beam transmit power T can be described by an equation:

$$T = P_R/P_T = \exp(-T_{od}) = \exp(-\alpha(\lambda)L) \tag{4}$$

Where α is the attenuation taken in (1/m), T_{od} is the depth of optical beam and L is the length of transmission taken in m [11].

3. Advanced system

The designed system usually comprises of three sections: transmitter, channel of transmission and receiver. The transmitter section usually consists of 64 subsystems using WDM multiplexing. Thus modulation techniques like Chirped, AMI and DPSK has been used. Thus transmission channel usually consists of two EDFA optical amplifiers where each amplifier consists of OWC channels which are linked through Loop Control. At receiver side, it usually consists of APD photodiode which can better detect the signal and wavelength. APD passes through Low pass Bessel Filter. To calculate BER and Quality-Factor, Eye Diagram Analyzer and BER Analyzer has been preferred after 3R regenerator. The block diagram of 64 channel IS-OWC system is given in Fig. 4.

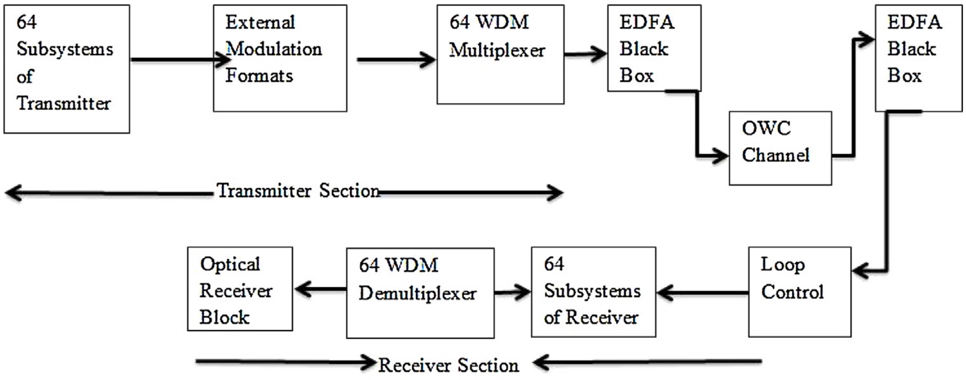


Fig. 4. Proposed Block Diagram of 64 channel IS-OWC system.

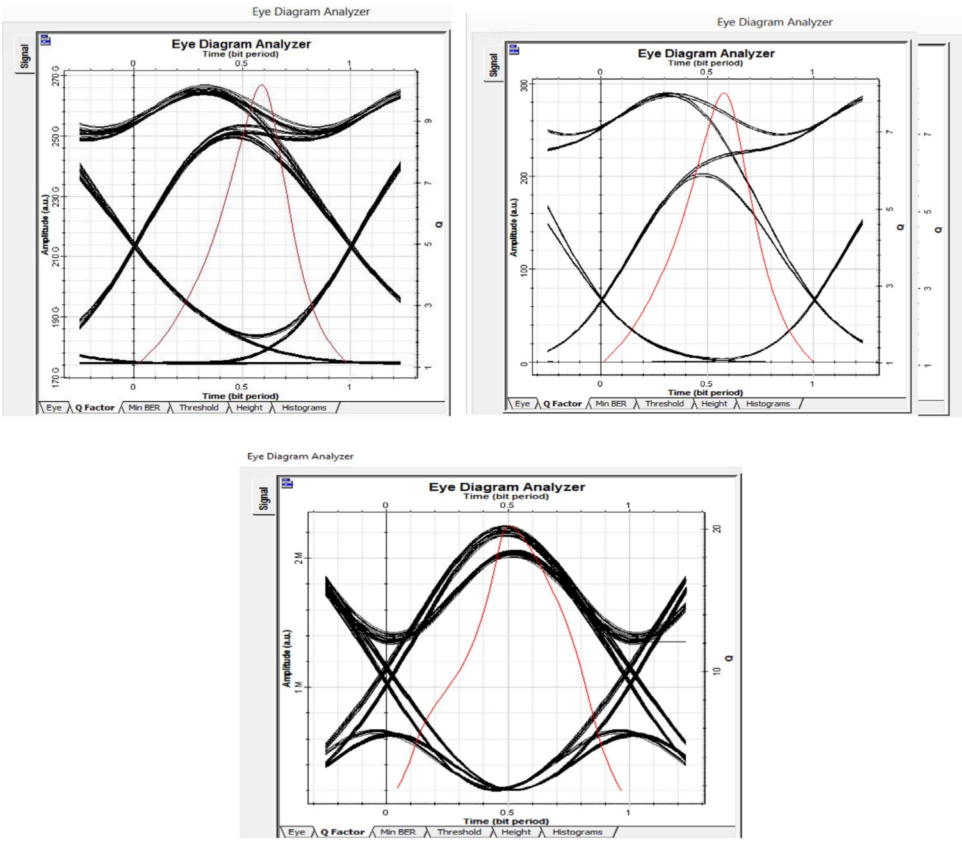


Fig. 5. Eye diagrams of (a) Chirped (b) AMI (c) DPSK Modulation at 10 Gbps.

Table 1
Shows the parameters for simulation in proposed system.

Parameters	Values taken
Channels/Bits	64
Bit rates	10, 20 and 40 Gbps
Input power	30 dB
EDFA Gain	30 dB
Length of Sequence	128 bits
Range	2500 km
No. of control loops	6
WDM Channel Spacing	50 GHz
Samples Per Bit	64
No. of Samples	8192

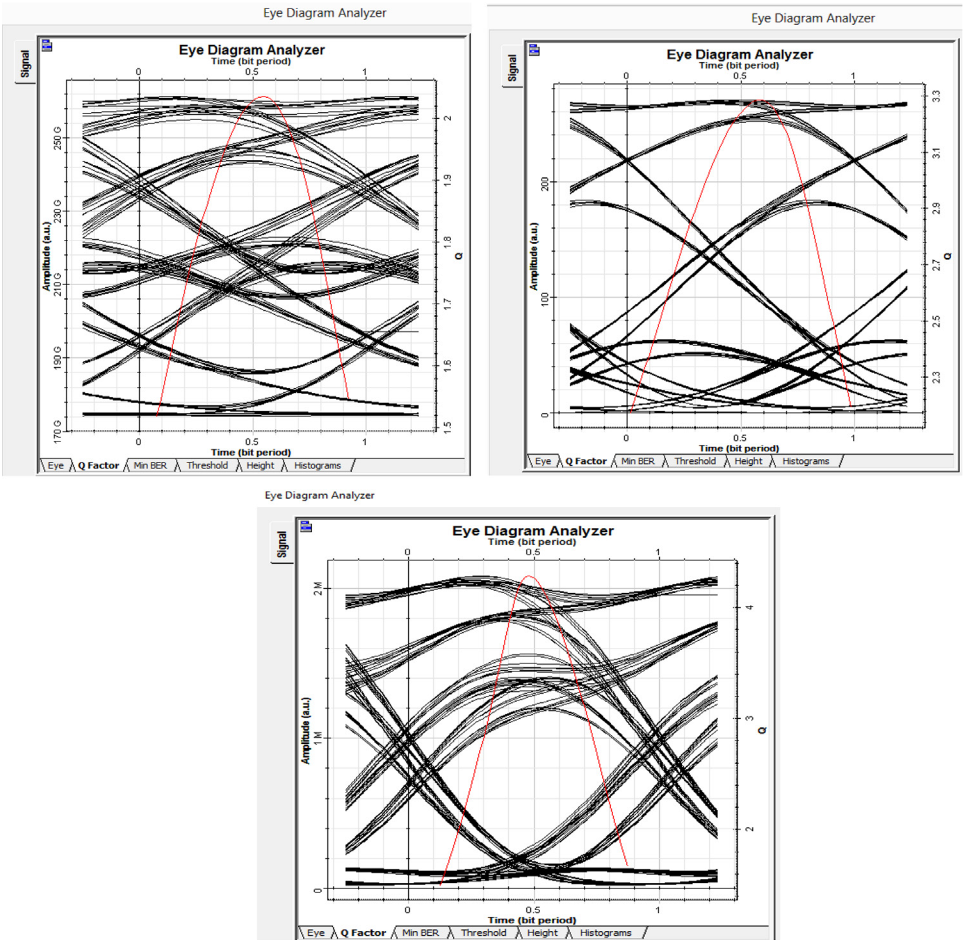


Fig. 6. Eye diagrams of (a) Chirped (b) AMI (c) DPSK Modulation at 20 Gbps.

The proposed system has been simulated using OWC channel over a distance of 2500 km and range of 750 nm. It has been taken at different bit rates of 10, 20 and 40 Gbps using three modulation methods like Chirped RZ, AMI and DPSK Modulation. Loop Control has been used to maintain the distance between transmitter and receiver (Table 1).

4. Results and discussion

The simulation has been done under the attenuation of 0.14 dB/km and visibility is taken around 25 km over 8192 samples. Fig. 5 shows the eye diagrams at bit rates of 10 Gbps using Chirped RZ, AMI and DPSK Modulation Format at distance of 2500 km. At 10 Gbps, maximum Quality Factor is achieved to be 10.09, 8.03 and 20.28. The minimum Bit–Error Rate is found to be $7.61*10^{-24}$, $7.88*10^{-16}$ and $2.1*10^{-91}$. The Quality factor is found to be maximum at DPSK Modulation and minimum at AMI modulation technique. The minimum BER is least at DPSK as Quality factor is inversely proportional to BER respectively.

At 20 Gbps, the simulation has been done for Chirped, AMI and DPSK modulation Techniques. Thus, maximum Quality Factor is found to be 2.03, 3.28 and 4.29 respectively. The minimum Bit-Error Rate has achieved to be 0.0207, 0.0005 and $1.7*10^{-6}$. Fig. 6 shows the eye diagrams at bit rates of 20 Gbps using Chirped RZ, AMI and DPSK Modulation Format at distance of 2500 km. Results proved that Quality factor is maximum and minimum BER is least in DPSK Modulation Technique for the designed system.

Finally, simulation has been done at 40 Gbps with huge capacity and high data rate using three modulation Techniques. Fig. 7 shows the eye diagrams at bit rates of 40 Gbps using Chirped RZ, AMI and DPSK Modulation Format at distance of 2500 km.

The maximum Quality Factor has found out to be 2.08, 4.08 and 3.41 at 40 Gbps. The minimum Bit-Error Rate is obtained out to be 0.0169, $6.08*10^{-5}$ and 0.00002 respectively. It has been noticed that AMI modulation shows best performance at 40 Gbps. AMI contains better Quality factor and less BER at the bit rates of 40 Gbps. Thus AMI technique can be quite useful in Inter-satellite to do integration with WDM systems. But DPSK shows best performance at 10 Gbps and 20 Gbps (Table 2).

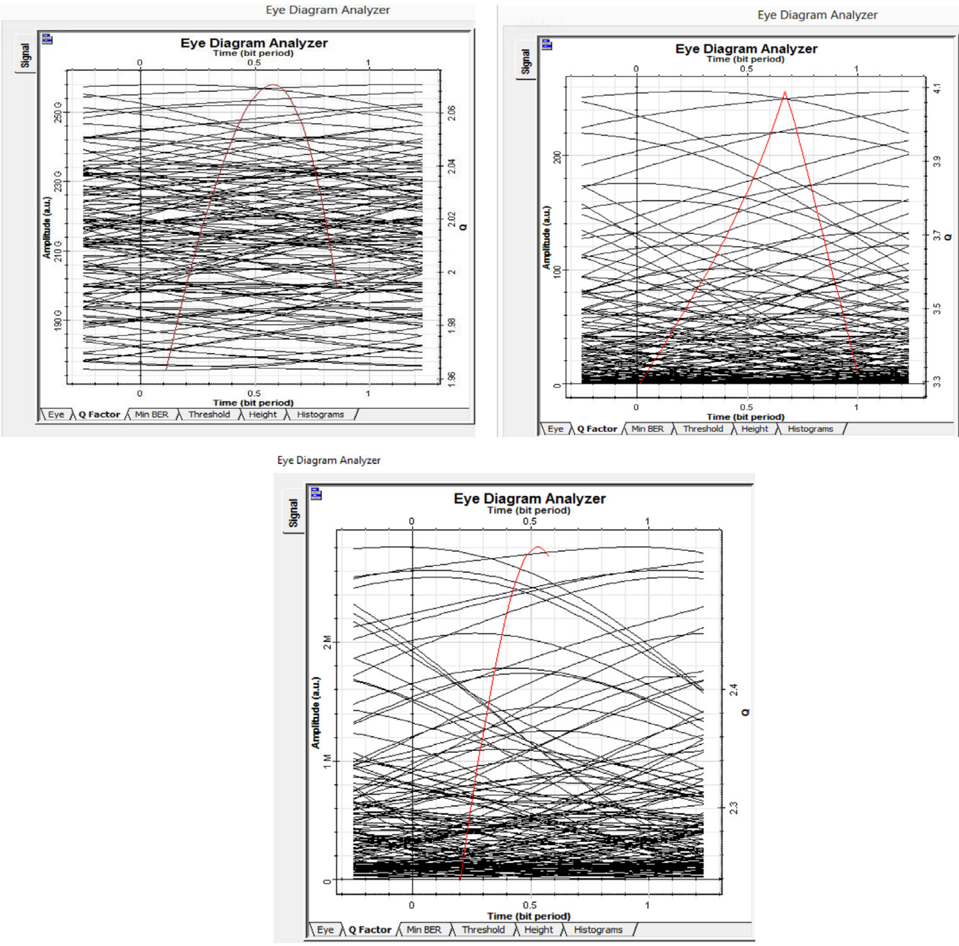


Fig. 7. Eye diagram of (a) Chirped (b) AMI (c) DPSK Modulation at 40 Gbps.

Table 2
Shows the comparison of the results at different bit rates of 10, 20 and 40 Gbps for three modulation techniques.

Bit rate(Gbps)	Analyzed Parameters	Chirped Modulation	AMI Modulation	DPSK Modulation
10	Q-Factor	10.927	8.03187	20.28
	BER	$7.61*10^{-24}$	$7.88*10^{-16}$	$2.1*10^{-91}$
20	Q-Factor	2.03272	3.28332	4.28
	BER	$2*10^{-2}$	$5*10^{-4}$	$1.7*10^{-6}$
40	Q-Factor	2.09	4.08136	3.41
	BER	0.0189	$5.98*10^{-5}$	0.00002

Now the comparison of these modulation techniques has been done by sweeping the distance from 500 to 2500 km unless we achieve the highest Q-Factor at different bit rates of 10, 20 and 40 Gbps. Fig. 8 shows the diagram of Maximum Q-factor versus distance for Chirped, AMI and DPSK Modulation Techniques. It has been observed that DPSK performs best at 10 and 20 Gbps for 2500 km. But at 40 Gbps, AMI shows better performance as compared to other modulation techniques for distance of 2500 km. The best results are obtained at 500 and 2500 km but 2500 km is preferred because of long distance transmission. It has also been clarified that good quality factor is achieved at any distance from 500 to 2500 km.

5. Conclusion

In Inter-Satellite Optical wireless communication, comparative simulation has been done between three modulation techniques at different bit rates of 10, 20 and 40 Gbps. The advanced system has been proposed taking around the distance of 2500 km and range of 750 nm. Results have proved that at 10 Gbps and 20 Gbps, DPSK Modulation has better Q-Factor and less BER than Chirped and AMI Modulation. At 40 Gbps, performance degrades as compared to 10 Gbps. AMI shows better

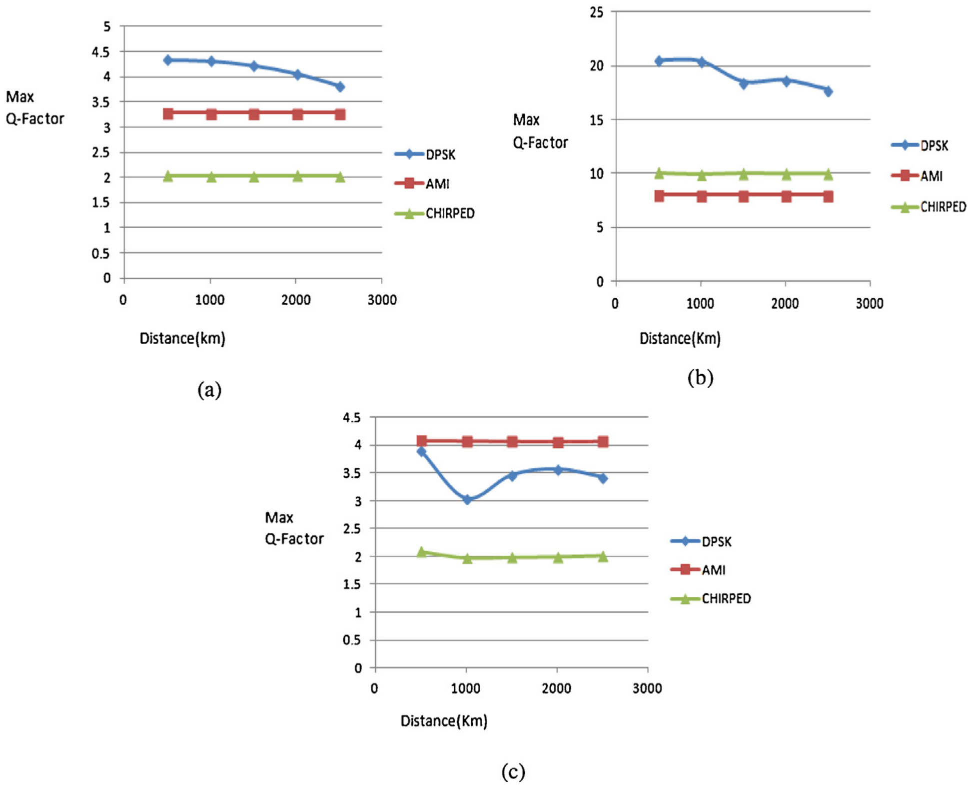


Fig. 8. Max Q-factor versus Distance for three modulation techniques at (a) 10 Gbps (b) 20 Gbps (c) 40 Gbps.

performance in comparison to DPSK and Chirped Modulation Techniques at 40 Gbps. Results also show that at 10 Gbps, we got best Q-Factor and minimum BER.

6. Future scope

As it is noticed that proposed IS-OWC system is efficient, still more future work can be done in order to increase efficiency and Q-factor of the system. Some modulation formats like DQPSK and OOK can also be used to design 64 channel IS-OWC systems. More coding techniques can also be designed to decrease power dissipation and BER of the Inter-Satellites.

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