Ultra-High Capacity DWDM System using Different Intensity Modulation Formats

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ABSTRACT:
In this paper, an ultra-high capacity 64-channel optical communication system using a single mode fiber is presented. The proposed system investigates the performance of optical network based on two methods of Duo-Binary modulation format at 10, 20 and 40 Gbps bit rates and distance of 1500 Km. Performance of the proposed under different modulation formats has been studied. The simulated results show that two methods are efficient. Also, the first method of Duo-Binary modulation format in ultra-high capacity optical network at 40 Gbps bit rate has better performance. It is proved that quality factor and bit error rate are function of fiber length.

KEYWORDS: Eye diagram, Duo-binary modulation, Single mode fiber, Bit error rate.

1. INTRODUCTION

The bandwidth and distance between transmitter and receiver are two factors in designing of long haul optical and fiber-optic networks. The technology of transmission over Single mode fiber (SMF) leads to reduction of network operation, high cost and complexity of system. To increase the capacity of optical communication systems, increase in data-rate per channel and channel spacing in Dense wavelength division multiplexing (DWDM) system is proposed [1-2]. The advance modulation formats for high bit-rate in modern application and network is presented in [1-2]. In [3], the performance of a DWDM system using Raman amplifier has been studied. Using optical filter in receiver block can reduce the Optical signal to noise ratio (OSNR). Transmission is one of the main block of DWDM system that is consist of SMF, Erbium-doped fiber amplifiers (EDFA) and Dispersion compensated fiber (DCF). Different compensation methods and hybrid optical amplifier have been introduced in [4-6], respectively. In [7], the modified duo-binary return to zero (MDRZ), Carrier-suppressed return to zero (CSRZ), and Duo-binary return to zero (DRZ) have been introduced. The operation of Chromatic dispersion (CD) on the system performance is a major factor of the pulse form degradation with single mode fiber. The nonlinear effects due to intensity of refractive index and stimulated scattering degrade the performance of optical fiber network [9]. To overcome these problems, several dispersion compensation techniques were introduced in [10]. In [11-12], a DWDM system based on optical wireless communication (OWC) and free space optical (FSO) is introduced, respectively. Semi-analytic models are derived based on non-linear effect as four wave mixing (FWM) in On-off keying (OOK) modulation formats [13].

In this paper an ultra-high capacity 64-channel DWDM system with intensity modulation such as two methods of duo-binary modulation at different bit rates for a coverage distance larger than 1500 km is designed and simulated. The transmission block of proposed system consists of SMF, EDFA and DCF. The performance of the optical network is evaluated in the final arrangement by Maximum quality factor and Bit error rate (BER) to optimize the parameters of transmission link. This paper is organized as follows: In the second part, we introduce the modulation techniques and proposed system. The simulation results and discussion are presented in the third part. In part fourth, parameters optimization of transmission link are presented and finally the paper is concluded at the part fifth.

2. MODULATION TECHNIQUES

Duo to improve the spectral efficiency, optical Duo-binary modulation has been attracted great attenuation, recently. This modulation is a form of intensity modulation that pulse intensity is transmitted based on the sum of any two adjacent bits. A duo-binary transmission combines optical carrier suppression and separation with optical duo-binary modulation to obtain high channel bit-rate, high-density DWDM network and very high spectral efficiency over a distance of 200 to 300 km [14-15]. The BER and *Q*-factor in optical communication system is related to each other [7-8] as:

$$BER = \frac{1}{Q\sqrt{2\pi}}\exp\left(\frac{-Q^2}{2}\right) \qquad (1)$$

The logical value of BER for optical communication is 10^{-9} to 10^{-15}. The Q-factor is given as:

$$Q = \frac{\left|\mu_1 - \mu_0\right|}{\left|\sigma_1 - \sigma_0\right|} \qquad (2)$$

Where μ_1, μ_0 are the average levels and σ_1, σ_0 are the deviation of mark (1) and space (0), respectively [8]. Fig. 1 show two methods of duo-binary modulations. Also, the optical spectrum of proposed modulations in comparison with Return to Zero (RZ) and Non Return to Zero (NRZ) modulations are shown in Fig. 2. As shown in Fig. 2, dispersion tolerance and optical bandwidth of proposed modulation formats are improved than conventional modulations.

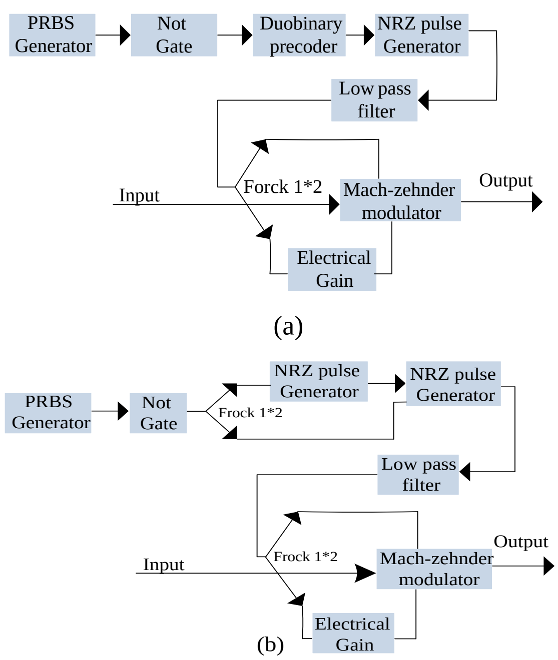


Fig. 1. Proposed Duo-binary modulation (a) first method; (b) Second method.

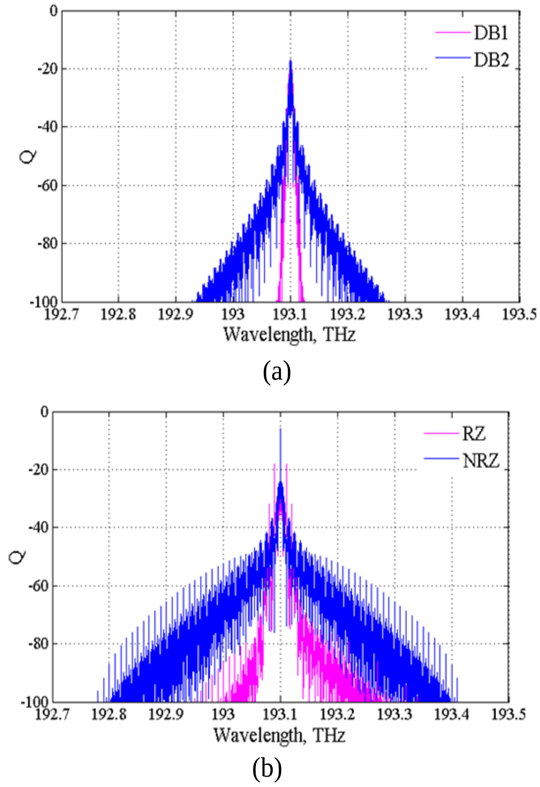


Fig. 2. (a) Optical Spectrum of the proposed modulation formats and (b) the conventional modulation formats.

3. SIMULATION RESULTS AND DISCUSSION

Fig. 3 shows the configuration of the proposed 64-channel DWDM link using post compensation technique. In proposed system a 64-chanel DWDM system has been modeled for distance of 1500 km in long haul optical transmission. The system consists of three main blocks of transmitter, transmission on fiber and receiver. The transmitter consist of a 64-DWDM transmitters, external modulation and optical multiplexer. We simulated proposed system by different bit-rates in the two methods of Duo-binary modulation that are used in transmitter block. The transmission block is modeled at a distance of 1500 km using loop control, SMF, dispersion conception fiber (DCF) and optical amplifiers. Loop control is used to increase the distance of the optical networks. Dispersion is an important issue in the optical fiber systems, which consists of material and waveguide dispersion. Dispersion limits the performance of SMF. To overcome this limitation, we used a fiber with revers dispersion that is known as DCF in our proposed system. Also, we used EDFA as optical amplifier in transmission block. The perfect optical amplifier has characteristics such as constant gain, low noise level and high output power. In EDFA, the gain bigger than of 30 dB and output power bigger than +17dB is obtained. The target parameters when selecting EFDA are low noise and flat gain [16]. The amplified spontaneous emission of optical amplifiers causes the noise in each stage of the optical power amplifier. As result, the optical signal to noise ratio (OSNR) degrades along the link. The OSNR is given as [17]:

$$OSNR(dB) = \frac{P_{out}}{N_{ASE}} = \frac{P_{out}}{(N.F.G-1)hf\Delta f} \quad (3)$$

Where NF is the noise figure, G is gain, hf is the photon energy and Δf is the optical measurement bandwidth. In the receiver part, we use optical receiver that consists of avalanche photodiode (APD) to detect signal and wavelength. Also, we can use PIN photodiode in receiver, but the APD has better performance than the PIN photodiode. The simulation parameters of the proposed systems are presented in Table I. Also, the characteristics of the fiber are given in Table II.

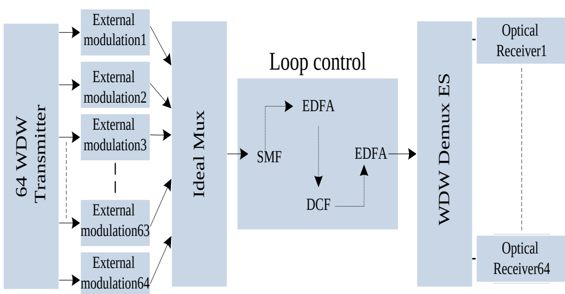


Fig. 3. Configuration of the proposed 64-channel DWDM link.

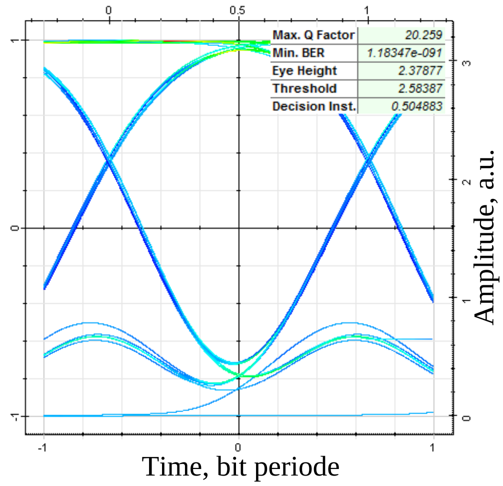
Table 1. The simulation parameters of the proposed system.

Parameters	Value
Bit rate	10, 20, 40 Gbps
Sequence length	32
Samples/bit	256
DWDM Channel Spacing	200 GHz
Capacity	64-Channel
Distance	1500 km
Input power	10 dB

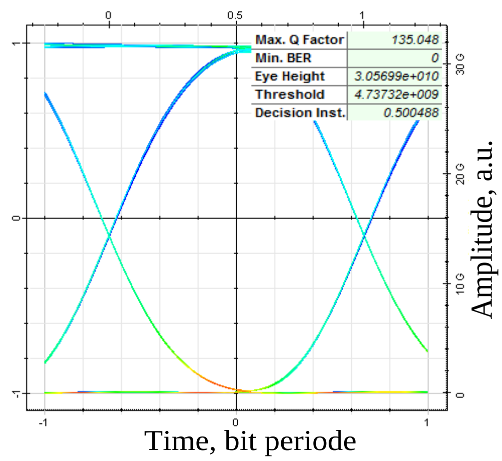
Table 2. Characteristics of the Fibers (SMF and DCF).

	Attenuation (dB/km)	Dispersion (ps/km-nm)	Dispersion slope (ps/km-nm^2)
SMF	0.2	17	0.075
DCF	0.5	-85	-0.3

Fig. 4(a) shows the eye diagram of the proposed system at 10 Gbps bit rate for 1500 km distance by using the first method of duo-binary modulation. As can be seen, the Maximum quality factor, Q 20.25 and bit error rate 1.18×10^{-91} has been obtained, which this result shows good performance for long distance transmission. Also, Fig. 4(b) demonstrates the eye diagram of 10 Gbps for the second method. The proposed method has the Maximum quality factor 135.04 and bit error rate 0.



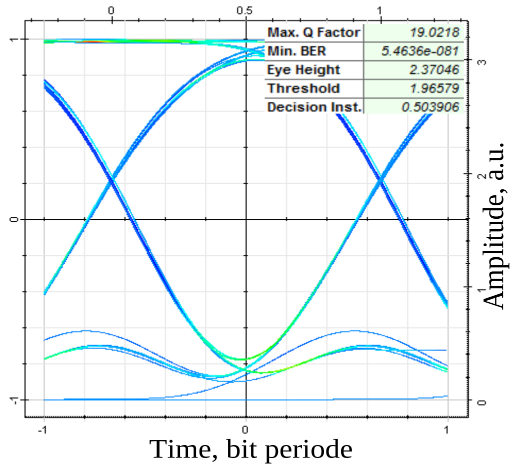
(a)



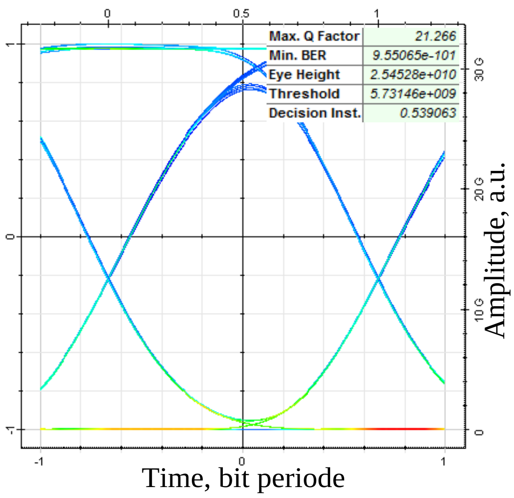
(b)

Fig. 4. (a) Eye diagram of the first method duo-binary modulation format (b) Eye diagram of the second method duo-binary B modulation forma. (at 10 Gbps).

Fig. 5 shows the eye diagram of proposed system for two methods of duo-binary modulation at 20 Gbps bit rate. When we increase the bit rate from 10 Gbps to 20 Gbps, the eye diagram shows that the value of Q decreases from 20.25 to 19.02 at the first method, and the bit error rate decreases from 1.18×10^{-91} to 5.46×10^{-81}. The results for second method at 20 Gbps are Maximum Q of 21.26 and bit error rate of 9.56×10^{-101}. Although, the maximum quality factor and BER have been changed than 10 Gbps bit rate. But, the performance of proposed system at 20 Gbps has good operation to design of communication system.



(a)

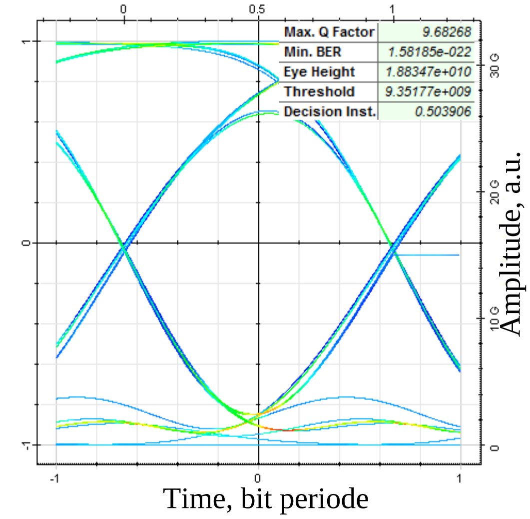


(b)

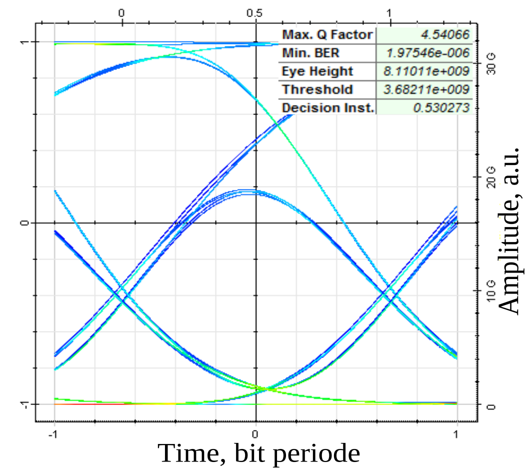
Fig. 5. (a) Eye diagram of the first method duo-binary modulation format (b) Eye diagram of the second method duo-binary modulation forma, (at 20 Gbps).

Finally, we simulated the proposed system at 40 Gbps to achieve the high capacity in optical network system. To reach this aim, we must loss other good trait such as Maximum Q and BER. Fig. 6, demonstrates the eye diagram for the two methods of duo-binary modulation at 40 Gbps. The first method has Maximum Q of 9.68 and bit error rate of 1.58×10^{-22}. Also the second method has Maximum Q of 4.54 and bit error rate of 1.97×10^{-6}.

The comparison based on the variation in the level of bit rate for two methods of modulation is shown in Table III. From Table III, it is obvious that, however second method has better performance at 10 and 20 Gbps, but it is not suitable for 40 Gbps bit rate. Hence, we offer first method of proposed modulation to design an ultra-high capacity DWDM communication system.



(a)



(b)

Fig. 6. (a) Eye diagram of the first method DB modulation format (b) Eye diagram of the second method DB modulation forma, at 40 Gbps.

Table 3. Comparison of the results of two methods for different bit rates.

Bit Rate (Gbps)	Analyzed Parameters	First method	Second method
10	Q-Factor	20.25	135
	BER	1.18×10^{-91}	0
20	Q-Factor	19.03	21.26
	BER	5.4×10^{-81}	9.87×10^{-101}
40	Q-Factor	9.68	4.54
	BER	1.58×10^{-22}	1.97×10^{-6}

Fig. 7 shows the Q factor versus time (bit period) for different modulations. As can be seen at 10 and 20 Gbps, proposed modulations and conventional modulations have good performance and BER for all modulations is less than 10^{-80}. But at 40 Gbps, first modulation has better performance to other modulations. So, for a DWDM system with ultra-high capacity, the first method is offered.

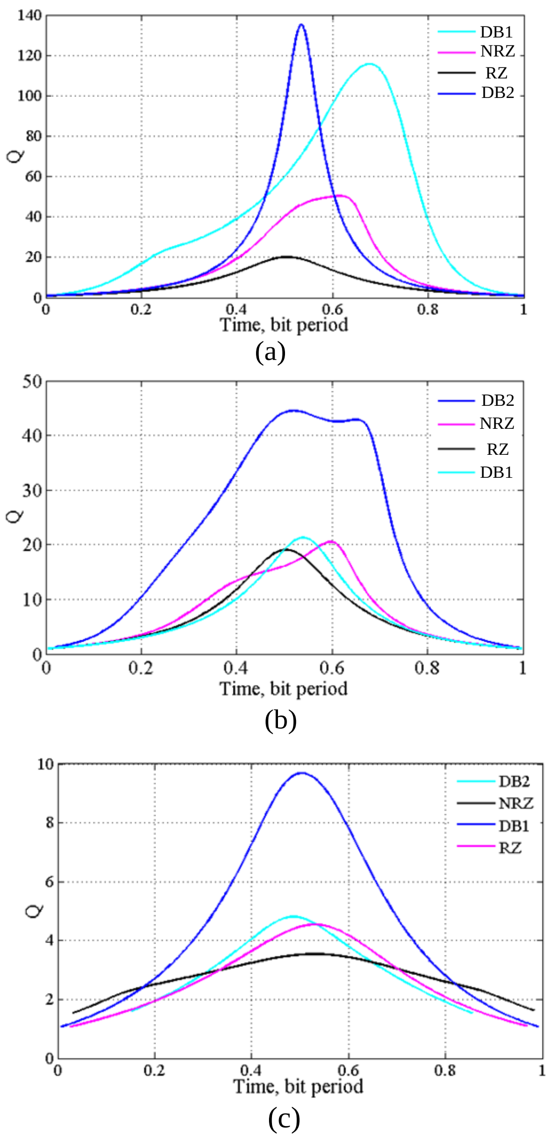


Fig. 7. Maximum quality factor versus time at (a) 10 Gbps bit rate (b) 20 Gbps rate (c) 40 Gbps bit rate**.**

4. OPTIMIZATION OF SMF AND DCF

In this section we try to optimize SMF and DCF length of transmission link to achieve the maximum *Q* factor. The lengths of SMF and DCF in proposed system are 50 and 10 Km, respectively. The equation between the length of SMF and DCF is obtained as [7]:

$$D_{SMF} L_{SMF} = D_{DCF} L_{DCF} \quad (4)$$

Also, we optimize the SMF and DCF length from 48 to 50Km and 8 to 10Km with 0.1 step, respectively. Fig. 8 shows the optimized length of SMF at 10, 20 and 40 Gbps bit rates for two methods of duo-binary modulation. Fig. 9 shows optimized length of DCF at 10, 20 and 40 Gbps bit rates for two methods of duo-binary modulation. The results of SMF and DCF optimization are shown in table IV.

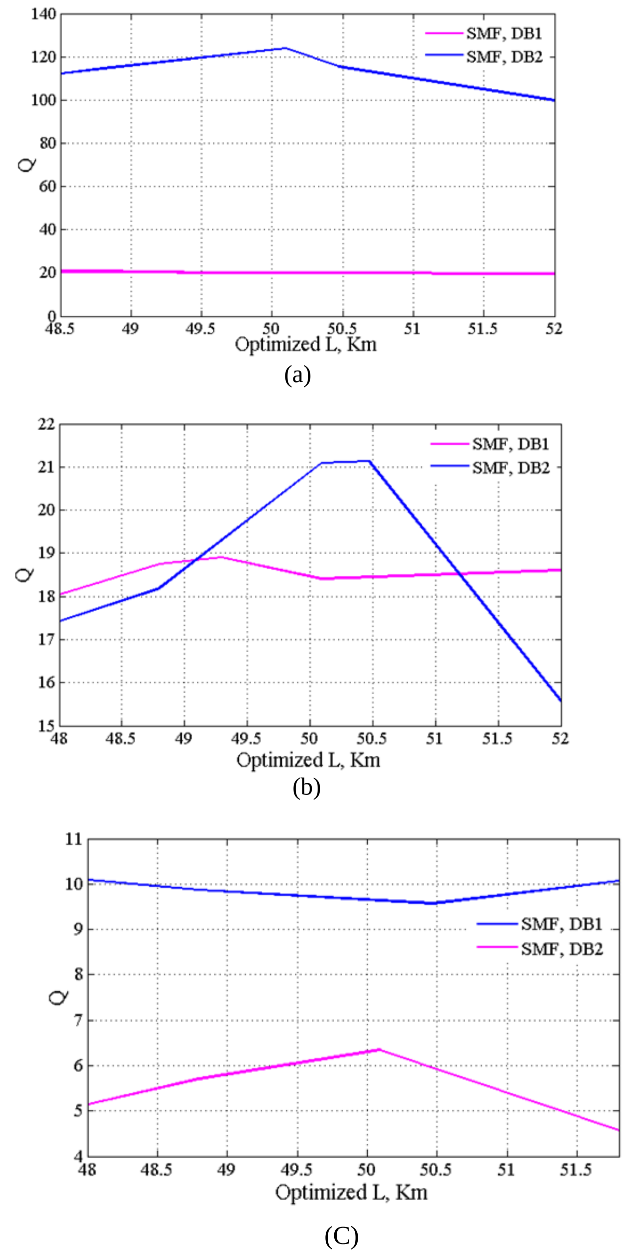


Fig. 8. (a) Maximum *Q*- Optimized L (SMF) at 10 Gbps (b) Maximum *Q*- Optimized L (SMF) at 20 Gbps (c) Maximum *Q*- Optimized L (SMF) at 40 Gbps.

Table 4. Results of optimization of SMF length for different bit rates.

Bit Rate (Gbps)	Optimized SMF length (Km)		Optimized DCF length (Km)	
10	First method	48.8	First method	10.47
	Second method	50.09	Second method	10.094
20	First method	49.29	First method	12
	Second method	50.47	Second method	10.094
40	First method	50.09	First method	12
	Second method	52	Second method	8.8

Results show that for proposed system with ultra-high capacity at 40 Gbps with second method, the optimized SMF and DCF is 52 Km and 8.8 Km, respectively.

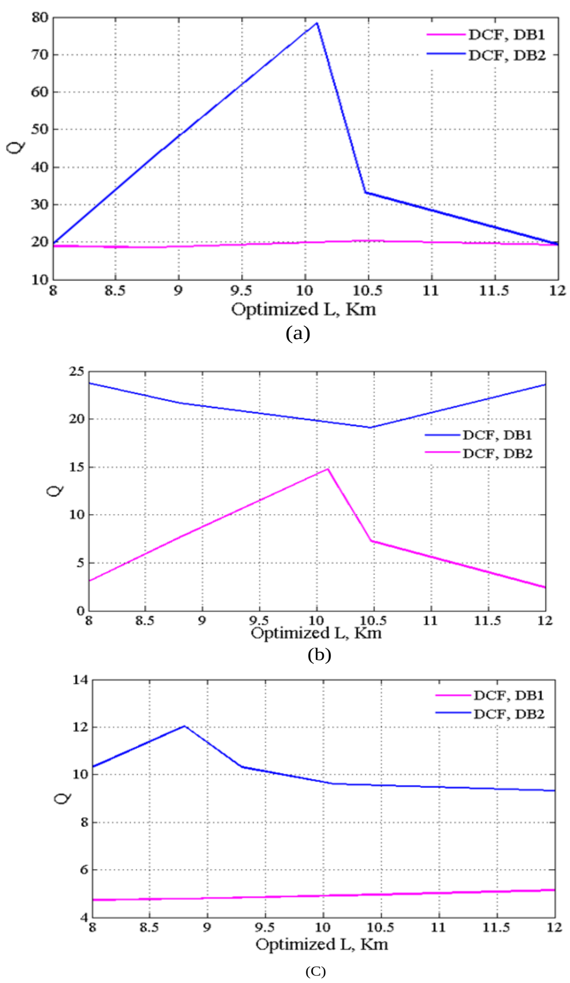


Fig. 9. (a) Maximum *Q*- Optimized L (DCF) at 10 Gbps (b) Maximum *Q*- Optimized L (DCF) at 20 Gbps (c) Maximum *Q*- Optimized L (DCF) at 40 Gbps.

5. CONCLUSION

In this paper, an ultra-high capacity long haul optical transmission system is presented. The proposed system is designed and simulated at different value of bit rates, 10, 20 and 40 Gbps by two methods of duo-binary modulations. The comparative analyses between proposed modulations with conventional modulations shows that all modulations have suitable performance for 10 and 20 Gbps and BER is less than 10^{-80}. But for 40 Gbps, the first method of duo-binary modulation has better performance. So it is more prevalent to use first method of duo-binary modulation at 40 Gbps bit rate to long haul optical transmission systems. Also, the transmission parameters is optimized to achieve the maximum quality factor. The proposed system is useful for computer networks and long haul optical communication systems.

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