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Comparative analysis of DWDM system using different modulation and dispersion compensation techniques at different bit rates

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Abstract: Dense wavelength division multiplexing (DWDM) is a fiber optic technology that can transmit multiple information streams simultaneously over the single fiber. In this paper we are doing comparative analysis of 16 channels Dense wavelength division multiplexing (DWDM) system using different modulation formats (NRZ, Carrier suppressed return-to-zero, Duobinary return-to-zero and Modified duobinary return-to-zero) and compensation schemes (Pre, Post and Mix compensation) at different bit rates (10Gbps, 20Gbps and 40Gbps) with standard and dispersion compensated fiber on the basis of Q-factor, eye-diagram and bit error rate for fixed gain EDFA and length both type of fiber. On the basis of comparison we found that mix compensation is superior to pre and post compensation schemes and gives better results even at high bit rate (40Gbps) with Modified duobinary return-to-zero (MDRZ) modulation format.

Keywords: DWDM, NRZ, CSRZ, DRZ, MDRZ, Quality factor

I. INTRODUCTION

At present, the major issue in networking industry is exponential increase in user demand for bandwidth. Fiber exhaust has evolved as a big problem for the network providers. Dense wavelength division multiplexing has become a key component of the communication infrastructure. For DWDM systems, if data rate is > 10Gbps/ channel harmful effect of dispersion and nonlinearity affects the performance of system. These effects must be managed to achieve the transmission over long distances by dispersion management techniques in which alternating fiber of opposite dispersion value is utilizes. This technique is best to keep accumulated dispersion value low and subdue the nonlinear effects.

In dispersion- managed systems utilizing single- mode fiber (SMF) and dispersion compensating fiber (DCF), the positive dispersion of single- mode fiber can be compensated by the large negative dispersion of dispersion compensating fiber (DCF) [1][2]. By using advanced modulation formats along with dispersion compensation schemes performance and tolerance of system can be increased. Advanced Modulation formats are very important to improve the spectral efficiency as bit rate of system gets higher. Like modified duobinary return- to-zero modulation format is faithful for long distance transmission over 1450km [3]. In this paper we are doing comparative analysis of 16 channels dense wavelength division multiplexing (DWDM) system using different modulation formats (NRZ, CSRZ, Duobinary return-to-zero and Modified duobinary return-to-zero) and compensation schemes (Pre, Post and Mix compensation) at different bit rates (10Gbps, 20Gbps, 40Gbps) with standard and dispersion compensated fiber on the basis of Q-factor, eye-diagram and bit error rate for fixed gain EDFA and length both type of fiber.

For transmission in DWDM systems, several other modulation formats like carrier-suppressed return-to-zero (CSRZ) [4][5][6][7], and duobinary modulation [8][9] have been proposed.

In section II , we are described differnts modulation formats of transmitter. In section III, described the methodology and simulation parameters and fiber parameters we are using. Section IV is result and discussion in which we are doing comparative study of DWDM optical communication system with different modulation formats and dispersion compensation schemes at different bit rates. In the end section V, conclusions are made.

II. MODULATION FORMATS

A. NRZ Format

Fig.1 (a) shows the schematic of NRZ transmitter. It is a type of amplitude –shift-keying. Traditionally, NRZ modulation format has been widely used format.

B. CS-RZ (Carrier suppressed return-to-zero) Format

Fig.1 (b) shows the schematic of CS-RZ transmitter. It has narrow optical spectrum then the conventional RZ format and high tolerance to group velocity dispersion (GVP) and mixed effect of self phase modulation (SPM) [5].

C. DRZ (Duobinary return-to-zero) Format

Fig.1(c) shows the schematic of DRZ transmitter. Because of their optical modulation bandwidth DRZ format is very attractive. It can be compressed to the data bit rate B that is half- bandwidth of NRZ format 2B [9].

D. MDRZ (Modified Duobinary return-to-zero) Format

Fig.1 (d) shows the schematic of MDRZ transmitter. The generation of MDRZ and DRZ is identical except the

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delay-and-add circuit is replaced by delay-and-subtract circuit.

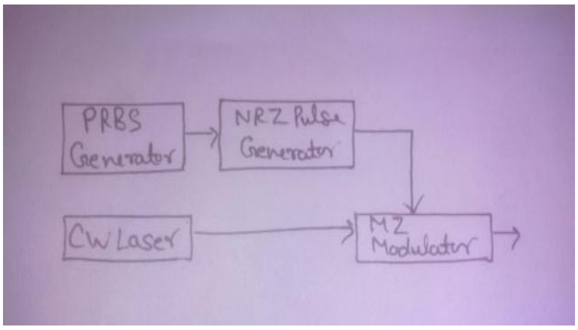

Fig.1 (a)

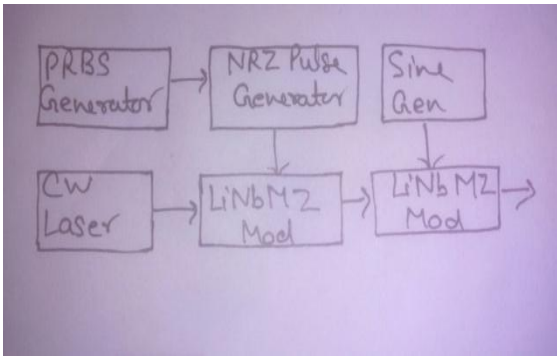

Fig.1 (b)

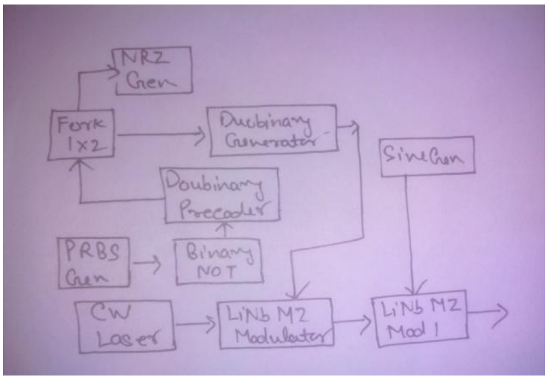

Fig.1 (c)

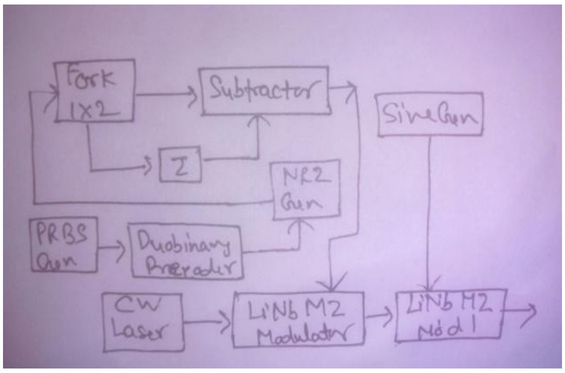

Fig.1 (d)

Fig.1 Schematic of transmitter (a) NRZ format, (b) CS-RZ format, (c) DRZ format, (d) MDRZ format

III. METHODOLOGY

We are using Optisystem 12 for simulation and designing. It is an innovative, powerful and rapidly evolving software design tool. It enables users to test, plan and simulate almost all type of optical link.

Below Fig.2 shows the schematic of simulation setups of 16 channel DWDM system which is consist of transmitter, fiber and receiver. Transmitter has CW laser array with 16 output ports which has equally spaced emission frequency range from 191.5- 194.5 THz, data modulator and the optical multiplexer. Data modulators are connected to each ouput port of CW laser array then signals from data modulator is fed to 16 input ports optical multiplexer having bandwidth 30GHz. EDFA (Erbium doped fiber amplifier) is placed after every fiber to compensate the losses of the fiber with constant noise figure. DWDM system is analyzed for three compensation schemes (Pre compensation, Post compensation and Mix compensation). Fig.2 (a) shows, pre compensation scheme in which DCF is placed before the SMF to compensate the dispersion and nonlinearities and two inline EDFA are also used. Fig.2 (b) shows, post compensation scheme DCF fiber is placed after SMF to compensate the dispersion and nonlinearities and two inline EDFA are used. Fig.2(c) shows the mix compensation scheme. Here DCF is placed between two SMF and also three inline EDFA has been used. Receiver of the system consists of demultiplexer, PIN detector and low pass Bessel filter. Signals are demultiplexed by the optical demultiplexer has 16 output ports and detected by the PIN detector. PIN photodiode has responsivity [A/W] is 1 and dark current is 0.1 nA.

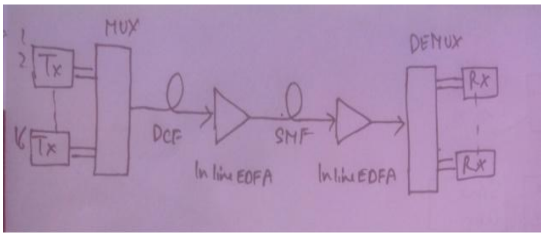

Fig.2 (a)

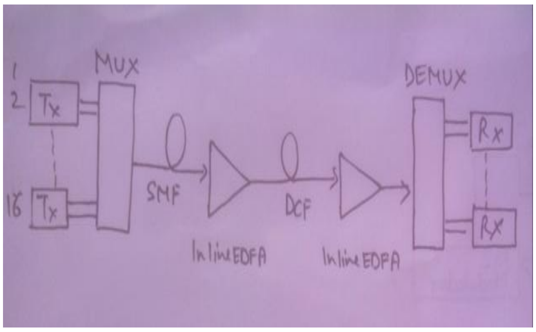

Fig.2 (b)

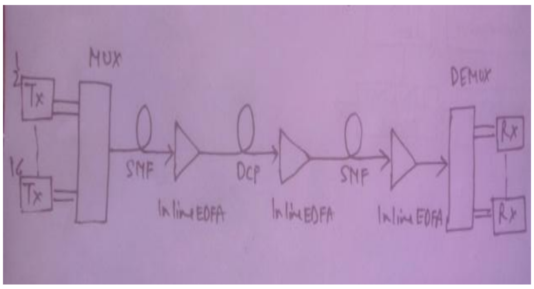

Fig.2 (c)

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Fig.2 Schematic of simulation setups: (a) Pre-compensation scheme, (b) Post-compensation scheme, (c) Mix compensation scheme

A. Simulation parameters

Table 1 shows the simulation parameters and Table 2 shows the fiber parameters used in the DWDM system.

Table 1. Simulation parameters

Bit rate	10Gbps, 20Gbps and 40Gbps
Sequence length	64
Samples per bit	256
Bandwidth	30 GHz
Central frequency of 1^{st} channel	191.5 THz
Capacity	16x10Gbps,16x20Gbps and 16x40Gbps

Table 2. Fiber parameters

	SMF	DCF
Length (Km)	50	10
Attenuation(dB/Km)	0.2	0.5
Dispersion (ps/nm/Km)	16.75	16.75
Dispersion slop(ps/Km-nm^2)	0.075	0.075
Differential group delay (ps/km)	0.2	0.2
Effective area (μm^2)	70	22

IV. RESULTS AND DISCUSSION

Below figures shows the simulated results of 16 channels of DWDM optical communication system. This system is analysed for three different compensation schemes which are pre compensation, post compensation and mix compensation at different bit rates.

In this paper we are doing comparative analysis of 16 channels Dense wavelength division multiplexing (DWDM) system using different modulation formats (NRZ, Carrier suppressed return-to-zero, Duobinary return-to-zero and Modified duobinary return-to-zero) and compensation schemes (Pre, Post and Mix compensation) at different bit rates (10Gbps, 20Gbps, 40Gbps) with standard and dispersion compensated fiber on the basis of Q-factor, eye-diagram and bit error rate for fixed gain EDFA and length both type of fiber.

On the basis of simulate result we can say advanced modulation formats plays very important role. As we increases bit rate, quality factor start to decreases and bit error rate increases. At high speed advanced modulation formats and dispersion compensation scheme gives better results. We can see mix compensation technique gives better results than others and at high speed 40 Gbps with modified duobinary return-to-zero gives better results with highest Q- factor 10.3499 and low bit error rate (BER) than other post and pre compensation scheme. We can see at low bit rate 10Gbps every modulation format gives good result with all compensation scheme. But CSRZ (carrier-suppressed return-to-zero) modulation format with mix compensation scheme gives better result than others compensation scheme. It has highest Q factor 46.8353 with zero bit error rate (BER) and maximum eye opening.

Now we increases bit rate from 10 Gbps to 20 Gbps. We can see at 20 Gbps bit rate, mix compensation technique with modified duobinary return-to-zero gives better results than other dispersion compensation scheme and modulation format. It has highest Q factor 31.2613 with low bit error rate (BER).

Fig.3 shows the Q-factor and BER of pre- dispersion compensation scheme at 10Gb/s using different- different modulation formats: (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ

Fig.4 shows Q-factor and BER of post- dispersion compensation scheme at 10Gb/s using modulation formats: (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ

Fig.5 shows Q-factor and BER of mix-dispersion compensation scheme at 10Gb/s using modulation formats: (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ

Fig.6 shows Q-factor and BER of pre-dispersion compensation scheme at 20Gb/s using modulation formats: (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ

Fig.7 shows Q-factor and BER of post- dispersion compensation scheme at 20Gb/s using modulation formats: (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ

Fig.8 shows Q-factor and BER of mix dispersion-compensation scheme at 20Gb/s using modulation formats: (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ

Fig.9 shows Q-factor and BER of pre dispersion-compensation scheme at 40Gb/s using modulation formats: (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ

Fig.10 shows Q-factor and BER of post dispersion-compensation scheme at 40Gb/s using modulation formats: (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ

Fig.11 shows Q-factor and BER of mix dispersion-compensation scheme at 40Gb/s using modulation formats: (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ

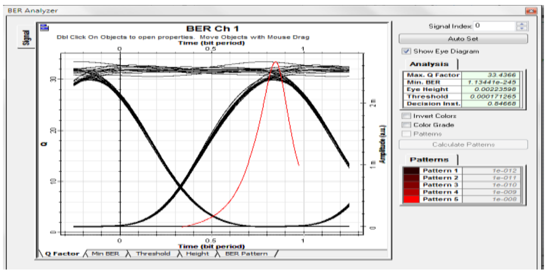

Fig. 3(a)

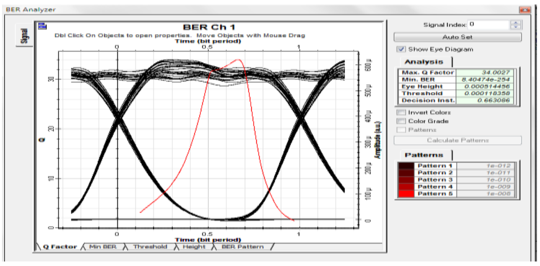

Fig. 3(b)

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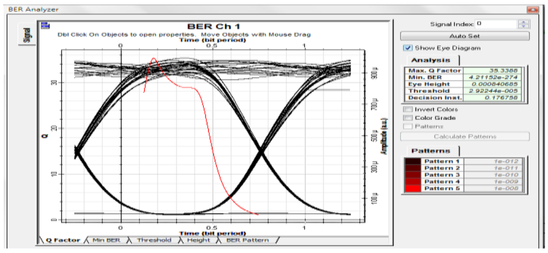


Fig. 3(c)

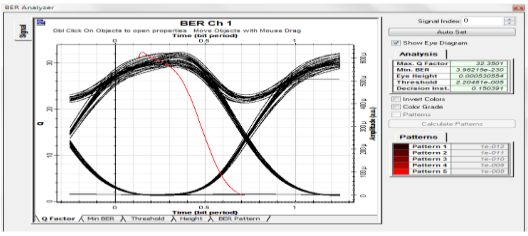
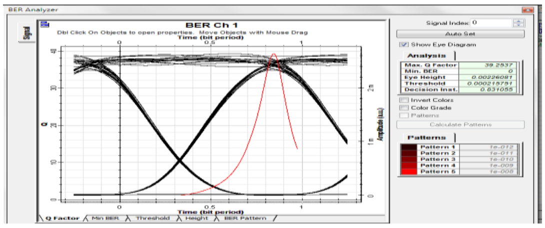


Fig. 3(d)

Fig. 3 Q-factor and BER of pre-compensation scheme at 10Gb/s using format (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ



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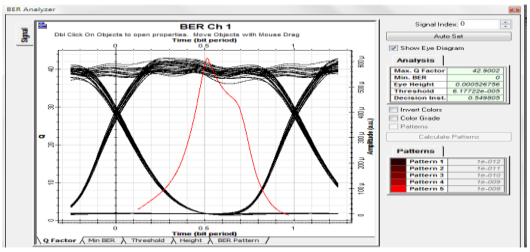


Fig. 4(b)

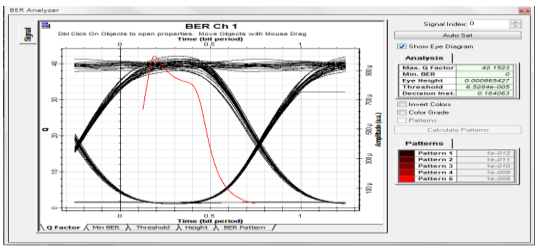


Fig. 4(c)

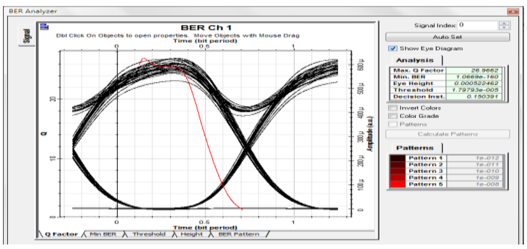
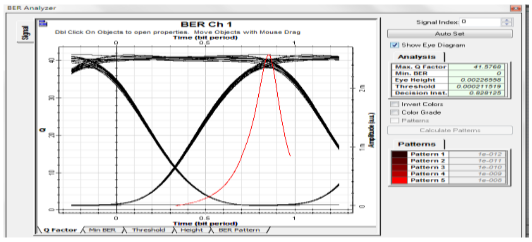


Fig. 4(d)

Fig. 4 Q-factor and BER of post-compensation scheme at 10Gb/s using format (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ



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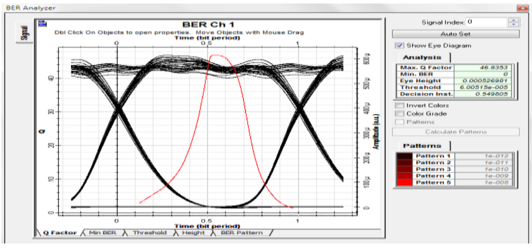


Fig. 5(b)

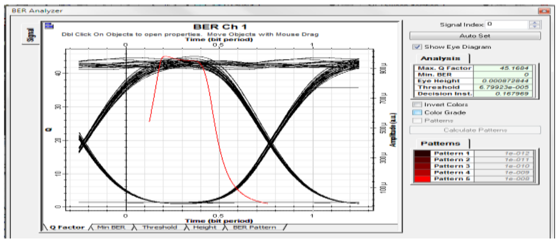


Fig. 5(c)

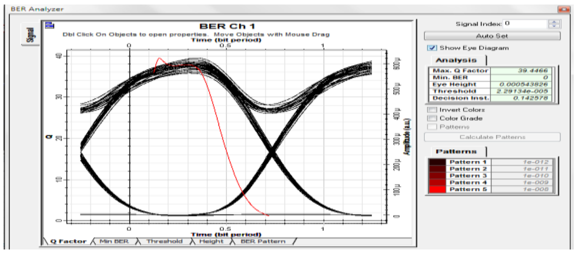
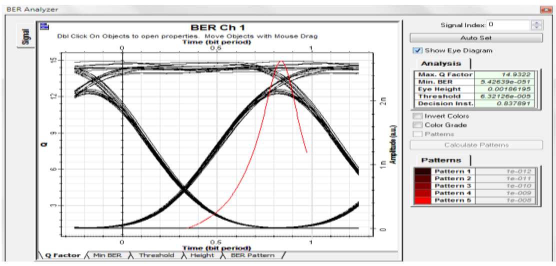


Fig. 5(d)

Fig. 5 Q-factor and BER of mix-compensation scheme at 10Gb/s using format (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ



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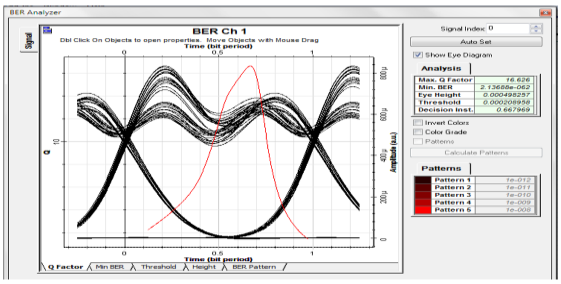

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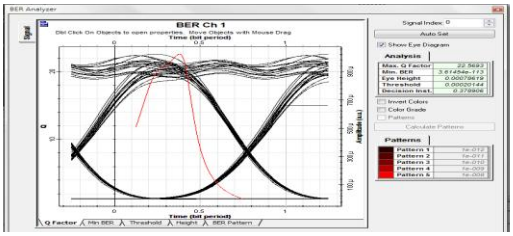

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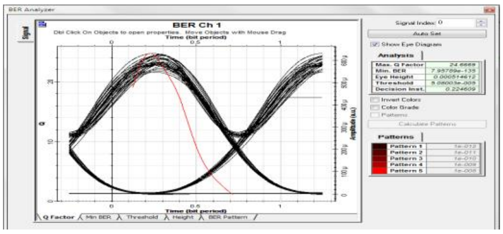
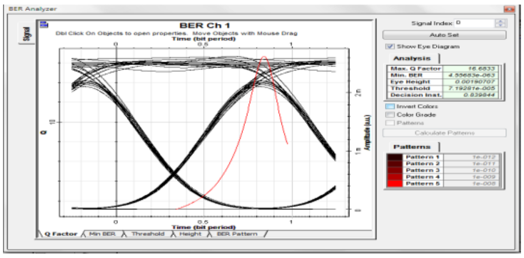


Fig. 6(d)

Fig. 6 Q-factor and BER of pre-compensation scheme at 20Gb/s using format (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ



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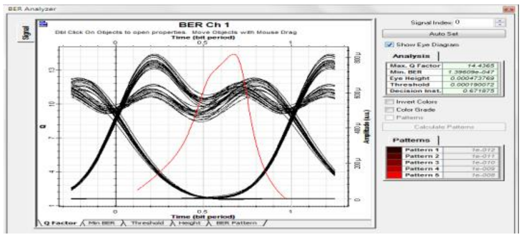

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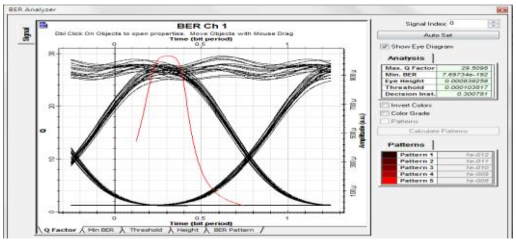

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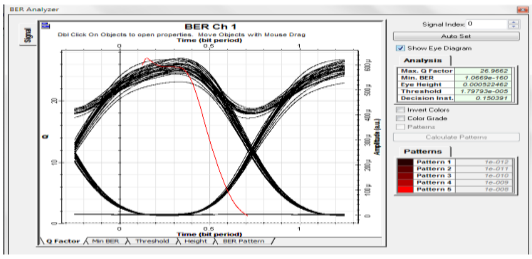
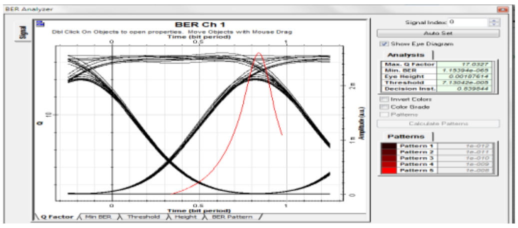


Fig. 7(d)

Fig. 7 Q-factor and BER of post-compensation scheme at 20Gb/s using format (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ



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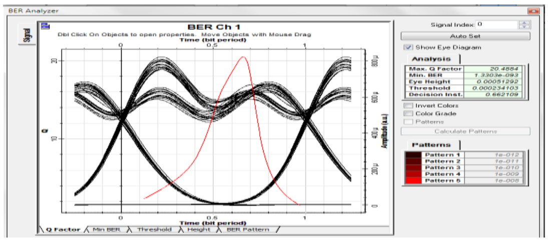

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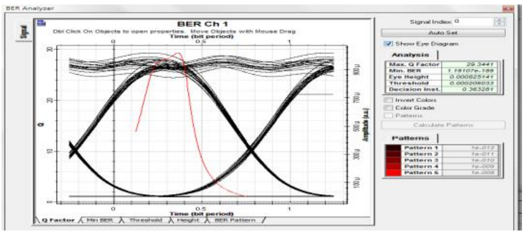

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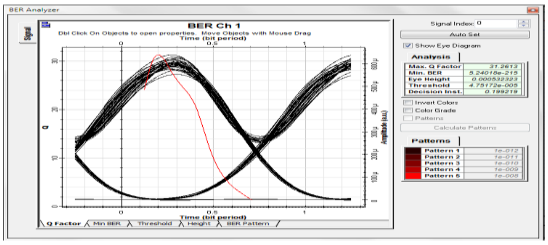
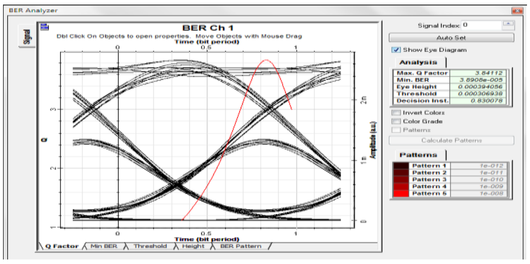


Fig. 8(d)

Fig. 8 Q-factor and BER of mix-compensation scheme at 20Gb/s using format (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ



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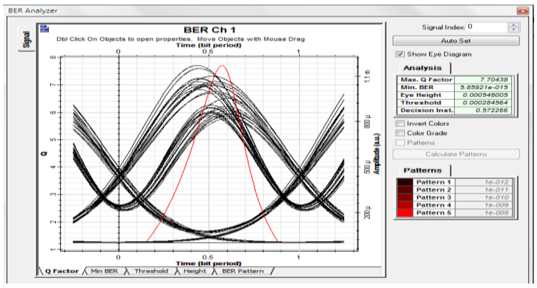

Fig. 9(b)

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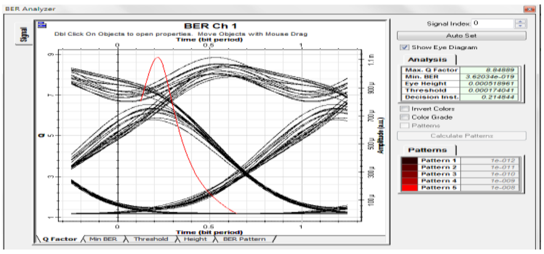

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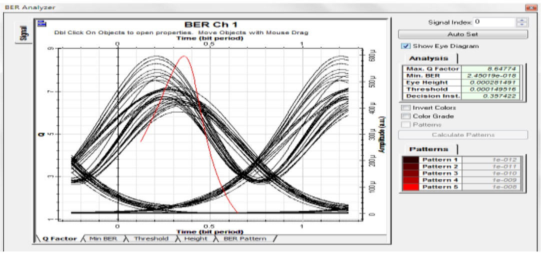
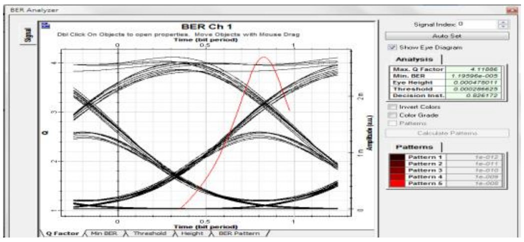


Fig. 9(d)

Fig. 9 Q-factor and BER of pre-compensation scheme at 40Gb/s using format (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ



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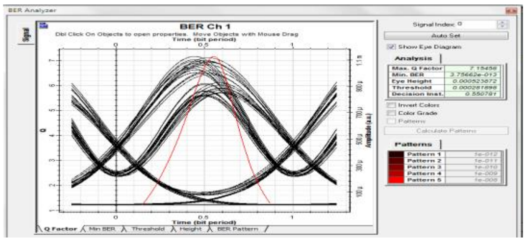

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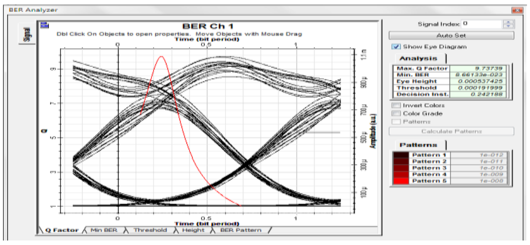

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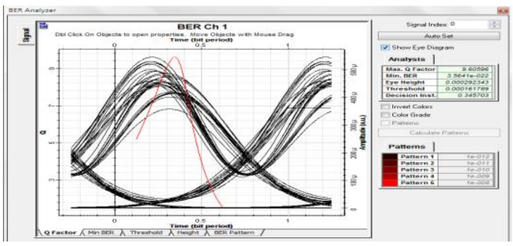
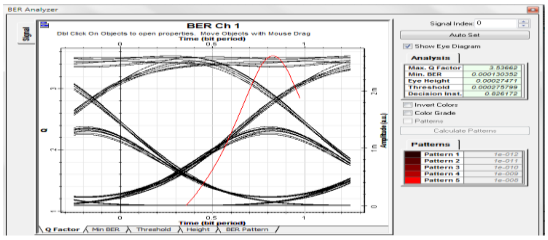


Fig. 10(d)

Fig. 10 Q-factor and BER of post-compensation scheme at 40Gb/s using format (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ



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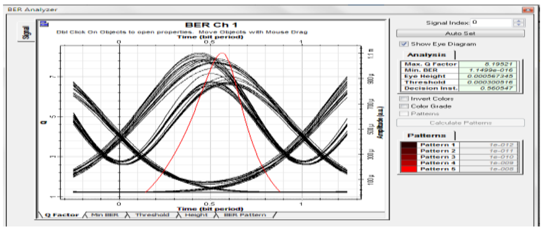

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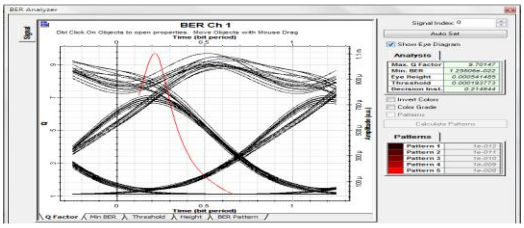

Fig. 11(c)

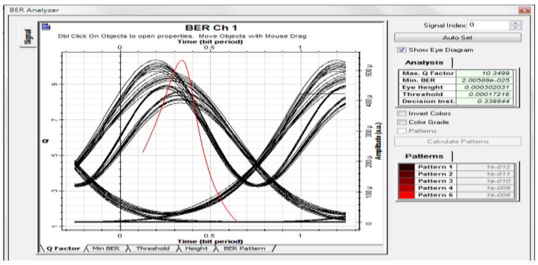

Fig. 11(d)

Fig. 11 Q-factor and BER of mix-compensation scheme at 40Gb/s using format (a) NRZ, (b) CSRZ, (c) DRZ, (d) MDRZ

V. CONCLUSION

In this paper we have analysed 16 channels DWDM optical communication system for different dispersion compensation schemes pre, post and mix dispersion compensation scheme using DCF using different modulation system NRZ, CS-RZ, DRZ and MDRZ at different bit rates 10Gbps, 20Gbps and 40 Gbps. We observed that at high bit rate MDRZ format gives better performance than others. We found that mix- dispersion compensation scheme shows better performance as compare to other schemes on the basis of Q factor, bit error rate (BER) and eye opening.

In the we can say that MDRZ modulation format is faithful for long distance communication using mix-dispersion compensation scheme.

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