A Design & Comparative Analysis Of 320 Gb/s DWDM Optical Network With CSRZ, DRZ & MDRZ Modulation Formats

Gaurang H Patel, Prof. Rohit B Patel, Prof.Sweta J Patel

Abstract: ***This paper demonstrate design of 320 Gb/s Dense wavelength division multiplexing optical network with optimized modulation format. In this paper, system is simulated with 8-channels with data rate of 40 Gb/s. The system is simulated using different modulation formats and different dispersion compensation techniques like pre, post and symmetrical compensation. The optimized modulation format offer very high dispersion tolerance so due to this, it make possible to achieve longer distance communication. Among the different dispersion compensation techniques, symmetrical compensation with MDRZ modulation format shows best performance in terms of highest Q-Factor and minimum BER.***

Keywords: ***BER, Dispersion Compensating Fiber, DWDM Network, Modulation Formats, Q-Factor.***

I. INTRODUCTION

In today's scenario demand for high bandwidth and high data rate is there because of growth in different technology like video on demand, use of internet, voice over IP, streaming video. Optical fiber fulfill this demand because it offer very large bandwidth so multiple channels can be transmitted through the common fiber using concept of wavelength division multiplexing technique. DWDM technique offers high spectral efficiency but performance is limited due to the problem of dispersion and fiber nonlinearities. So these problem must be minimized to achieve better performance. Dispersion compensation is achieved using different techniques like dispersion compensating fiber, fiber bragg grating, optical phase conjugation and electrical equalizer. Among all these technique, dispersion compensation fiber is proposed for compensation of dispersion. In conventional optical fiber communication, return-to-zero and non-return to zero modulation formats are used. But NRZ and RZ are not efficient for DWDM network. So different modulation formats like carrier suppressed return to zero(CSRZ) and modified duo-binary return to zero formats are proposed.

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Bo-ning HU1, Wang Jing1, Wang Wei2 and Rui-mei Zhao1 analyzed Fibres-optic dispersion and its effect on optical transmission system. In this paper, three schemes (pre, post and symmetrical dispersion compensation) of dispersion compensation with DCF are proposed. Symmetrical-compensation gives best result among all of these three [1].

M. I. Hayee and A. E. Willner describe the group velocity dispersion (GVD) and nonlinear effects, such as self- and cross-phase modulation (SPM/XPM) and four-wave mixing (FWM) in wavelength-division-multiplexed (WDM) systems at 10 Gb/s that degrade the performance of the system. In this paper, 10-Gb/s WDM systems that use pre-compensation, Post-compensation or dual-compensation of each channel to minimize dispersion and nonlinear effects is explained [2].

Anu Sheetal, AjayK.Sharma and R.S.Kaler describes the simulative analysis of 40 Gb/s long haul DWDM system with ultra high capacity has been carried out for carrier-suppressed return-to-zero (CSRZ), duo binary return-to-zero (DRZ) and modified duo binary return-to-zero (MDRZ) modulation formats. The DWDM system has been analyzed for the pre, post and symmetrical dispersion compensation schemes in order to find the optimum modulation format for a high bit rate optical transmission system [3].

Rajani, Raju Pal, Vishal Sharma investigate pre, post and symmetrical-dispersion compensation methods for 10/15Gb/s using different modulation formats like NRZ, RZ and RZ Super gaussian using standard and dispersion compensated fibers through computer simulations to optimize high data rate optical transmission. It is recommended to use symmetric- and post-DCF schemes for all the simulated optical pulses rather than using pre-DCF scheme at high transmission rate in dispersion compensated optical communication system in conjunction with laser line width of 100 MHz [4].

R.S. Kaler, Ajay K.Sharma and T.S. Kamala investigate pre-, post- and symmetrical-dispersion compensation methods for 10 Gb/s non-return to zero (NRZ) links using standard and dispersion compensated fibers through computer simulations to optimize high data rate optical transmission. The influence of EDFA power and increase in length of each type of fiber has been studied to evaluate the performance of optical communication systems [5].

II. DISPERSION COMPENSATION USING DISPERSION COMPENSATING FIBER.

In optical network, optical fiber offers very large bandwidth but it suffers from one problem of dispersion. Dispersion is nothing but it is broadening of the pulse in time domain due to the difference in the group velocity of different modes. It has two effects, 1) it reduces the energy contain in the pulse and 2) it results in spreading of pulse so it interfere with adjacent pulse so it creates inter symbol interference effect. There are mainly three types of dispersion. 1) Modal dispersion 2) Group velocity dispersion or chromatic dispersion and 3) Polarization mode dispersion. Modal dispersion is mainly occurred in multimode fiber because of the difference in group velocity of different modes. Chromatic dispersion is due to the material and waveguide property of the fiber. Polarization mode dispersion is due to the different polarization states of the mode travel with different group velocity.

This dispersion problem degrades the system performance. So this dispersion effect should be minimized using different techniques to improve system performance. In this paper, to minimize dispersion effect, dispersion compensation fiber technique is proposed. Dispersion compensating fibers have negative dispersion of -80 to -90 ps/nm.km and used to compensate the positive dispersion of the single mode fiber. In optical WDM network, performance degradation is due to the chromatic dispersion, fiber nonlinearity, and accumulation of amplified spontaneous emission noise due to periodic amplification. Due to the nonlinear propagation of signal in optical fiber, system performance mainly decided by the power levels at the input of different types of fibers and also on the position of the DCF . There are basically three dispersion compensation schemes like pre, post and symmetrical compensation depending on the position of DCF in the system whether the DCF is placed before the SMF, after the SMF or symmetrically across the SMF.A DCF must have low insertion loss, low optical nonlinearity and also it must offers large negative dispersion coefficient to minimize the size of a DCF. By placing one DCF with negative dispersion after a SMF with positive dispersion, the net dispersion should be zero.

$$D_{SMF} \times L_{SMF} = -D_{DCF} \times L_{DCF}$$

Where D_{SMF} and L_{SMF} are the dispersion and length of single mode fiber and D_{DCF} and L_{DCF} are the dispersion and length of dispersion compensating fiber.

Compensation is done by three different methods depending on the position of the DCF:

(i) Pre-Compensation
(ii) Post Compensation
(iii) Symmetrical Compensation

Pre-Compensation: In this Compensation scheme, the dispersion compensating fiber of negative dispersion is placed before the standard fiber to compensate positive dispersion of the standard fiber.

Post-Compensation: In this Compensation scheme, the dispersion compensating fiber of negative dispersion is placed after the standard fiber to compensate positive dispersion of the standard fiber.

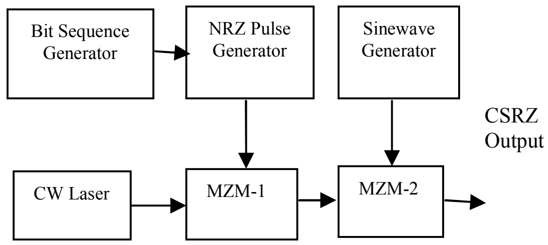
Symmetrical-Compensation: In this Compensation scheme, the dispersion compensating fiber of negative dispersion is placed before and after the standard fiber to compensate positive dispersion of the standard fiber.

III. DIFFERENT MODULATION FORMATS.

In this paper, three different modulation formats like carrier suppressed return to zero(CSRZ), duo binary return to zero(DRZ) and modified duo binary return to zero(MDRZ) are proposed. The different modulation formats and their simulation set-up is explained as below.

1) Carrier suppressed return to zero(CSRZ)

Fig. 1(a) shows the schematic diagram for the generation of the CSRZ modulation format. In this ,the NRZ signal is given to MZM and then given to the phase modulator. The phase modulator is driven by a sine wave generator at the frequency half of the bit rate and phase shift of pi between any two adjacent bits is introduced. Because of this, the central peak at the carrier frequency is suppressed. It performs better in the presence of the combined effect of self phase modulation and chromatic dispersion. Fig. 1(b) shows the optical spectrum of CSRZ format.



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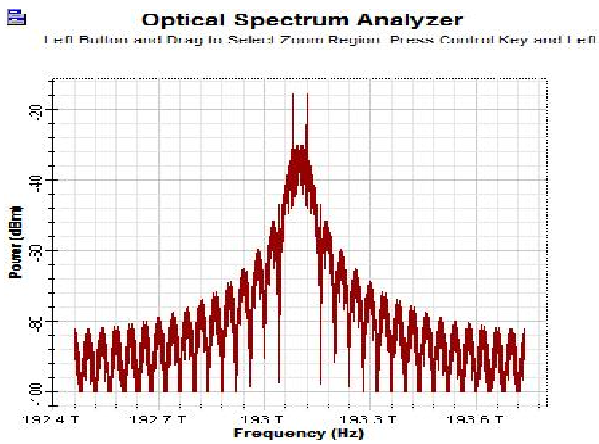

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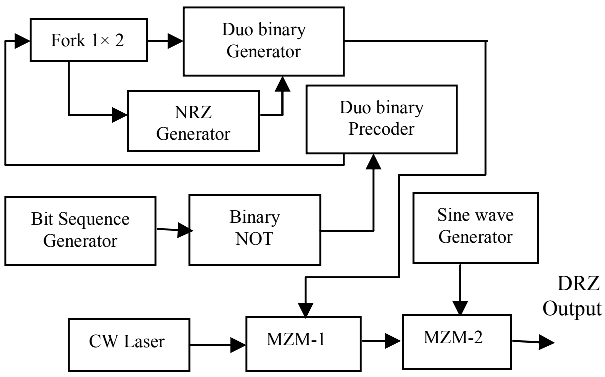
Fig 1: (a) schematic of CSRZ modulation format. (b) optical spectrum of CSRZ format.

2) Duo-binary return to zero(DRZ)

Fig. 2(a) shows the schematic for the generation of the DRZ modulation format. In this first NRZ duo-binary signal is generated by making the use of a duo-binary pre-coder, NRZ generator and a duo-binary pulse generator. The generator drives the first MZM and then connected with the second MZM. The second MZM is driven by a sine wave generator with the frequency of 40 GHz and phase of -90. DRZ has bandwidth half of the NRZ format. Fig. 2(b) shows the optical spectrum of DRZ format.

3) Modified duo binary return to zero(MDRZ)

Fig. 3(a) shows the schematic for the generation of the MDRZ modulation format. In this, first NRZ duo-binary signal is generated that drives the first MZM and then connecting this modulator with a second modulator that is driven by a sine wave generator with the frequency of 40 GHz and phase -95. Fig. 3(b) shows the optical spectrum of MDRZ signal.



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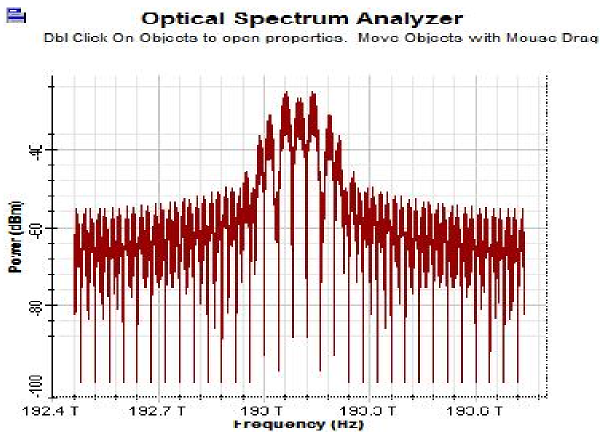

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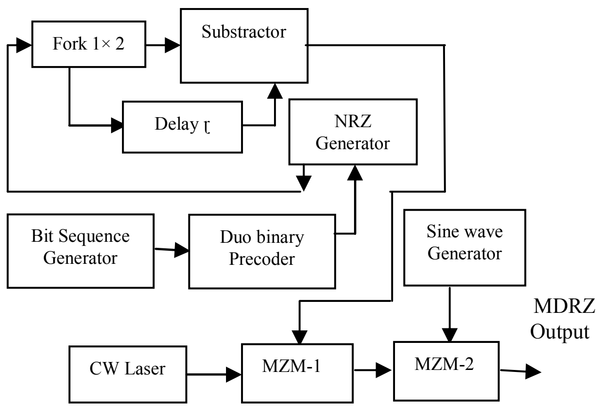
Fig 2: (a) schematic of DRZ modulation format. (b) optical spectrum of DRZ format.

IV. SIMULATION SETUP

In DWDM network, to achieve high capacity and high speed data transmission with higher accuracy, the dispersion and other non-linearity must be compensated. For this purpose, some dispersion compensation scheme must be used periodically in the link. There are several different methods that can be used to compensate for dispersion, including dispersion compensating fiber (DCF),fiber Bragg gratings, optical phase conjugation and electrical dispersion compensation. we have simulated one Dense Wavelength division multiplexing topology supporting four user and operated at data rate of 8×40 Gb/s=320 Gbps. In this topology, to compensate dispersion, dispersion compensation fiber (DCF) technology is used. We have simulated three DCF compensation scheme, pre-compensation, post compensation and symmetrical compensation scheme at 320 GB/s with different modulation formats. Among these entire three schemes Symmetrical compensation scheme can greatly reduce the dispersion effects, this program is better than the pre compensation and post compensation program. The above techniques are compared in terms of Q-factor and Bit error rate.Fig.4 shows Block diagram of simulation setup of a 8 channel DWDM optical network at 320 GB/s. The simulation parameters and fiber parameters used in the system model are given in Table 1.



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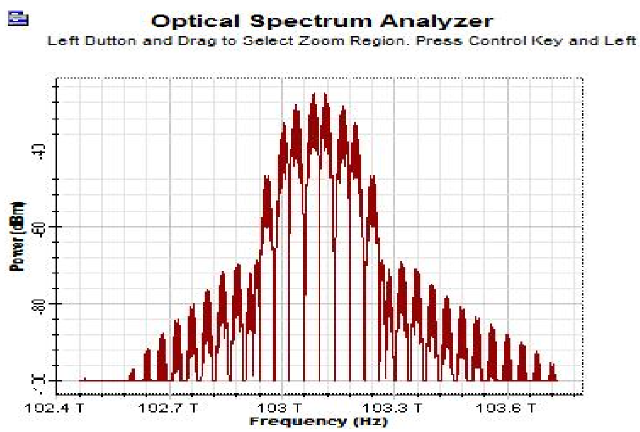
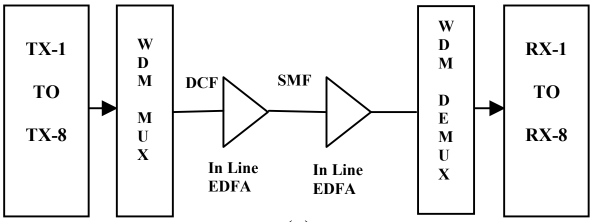


(b)

Fig 3: (a) schematic of MDRZ modulation format. (b) optical spectrum of MDRZ format.

The simulation setup is composed of transmitter, fiber and receiver. The WDM transmitter consists of a CW laser source for each channel, data modulators and the optical multiplexer. To the output port of the CW laser a data modulator has been connected. Optical signals from 8 data modulators are fed to the 8 input ports of an optical multiplexer. Here different modulators are used like carrier suppressed return to zero, duo binary return to zero and modified duo binary return to zero.



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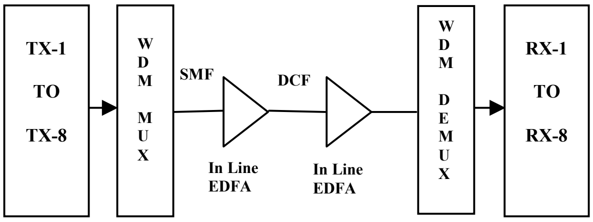

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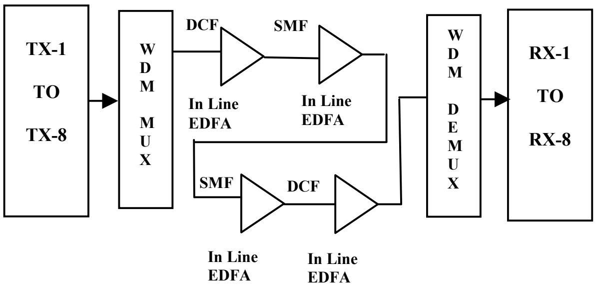


(c)

Fig 4: Block Diagram of Simulation Setup: (a) Pre compensation scheme (b) Post compensation scheme (c) Symmetrical compensation scheme.

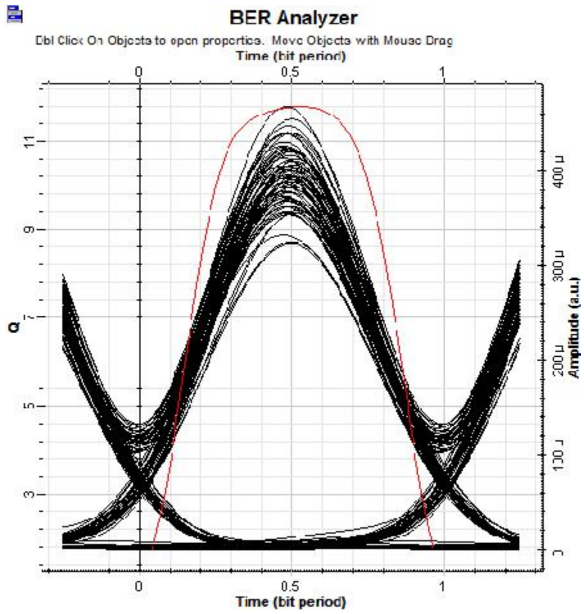
The transmission channel at 320 GB/s is designed by using the fiber parameters of DCF and SMF in such a way that the dispersion is compensated exactly. The gain of the erbium doped fiber amplifier (EDFA) placed after each fiber is such that it compensates the losses of the preceding fiber. The noise figure of the amplifiers is constant and set to 4 dB. The signal is then launched over 10 spans of standard single mode fiber (SMF) of 50 km each. DWDM system has been simulated for three different dispersion compensation schemes i.e. pre-compensation, post-compensation and symmetrical-compensation. In pre-compensation scheme, as shown in Fig 4(a), to compensate the dispersion, DCF fiber of 10 km is used before the SMF fiber of 50km length. Also, two in-line-EDFA with gain of 5 and 10 dB have been used in the link. The post-compensation scheme has been shown in Fig 4(b) where DCF fiber of 10km is used after the SMF fiber of 50km length to compensate the dispersion. In symmetrical compensation scheme, as shown in Fig 4(c), two DCF fibers of 5 km are used before and after of the two SMF fibers of 25 km length each. Here four in-line-EDFA have been used in the link. In the receiver the signal is demultiplexed, detected by PIN detector, passed through the filter. The filtered electrical signal is given to the 3R Regenerator. 3R Regenerator output is connected directly to the BER analyser which is used as a visualize to generate graphs and results such as eye diagram, BER, Q value, eye opening etc. The parameters used in simulation are given in Table I.

Table I. Parameters used in simulation

Parameter	Value
Bit-Rate	320 Gbps
Length of SMF	50 Km
Length of DCF	10Km
No. of spans	10
Dispersion coefficient of SMF	17 ps/nm/km
Dispersion coefficient of DCF	-85 ps/nm/km
Gain of Inline EDFA placed after DCF	5 db
Gain of Inline EDFA placed after SMF	10 db
Attenuation factor of SMF	0.2 db/km
Attenuation factor of DCF	0.5 db/km

V. SIMULATION RESULTS

We have simulated one DWDM network at 320 Gb/s with channel spacing of 100 GHz and the transmission distance is 500 km. we have made the comparative analysis of the system by employing different dispersion compensation schemes like pre-compensation, post-compensation and symmetric compensation and also using different modulation formats. The system performance is also analysed in terms of received maximum Q value and Minimum Bit error rate. The Eye diagram of the symmetrical compensation scheme with different modulation format is shown in figure below.



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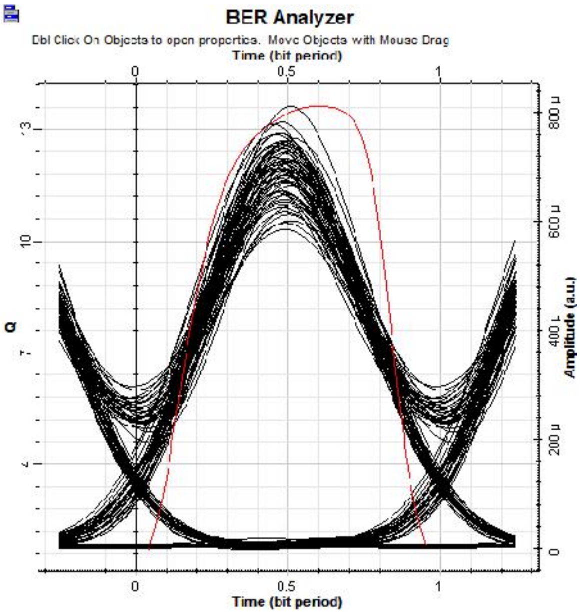

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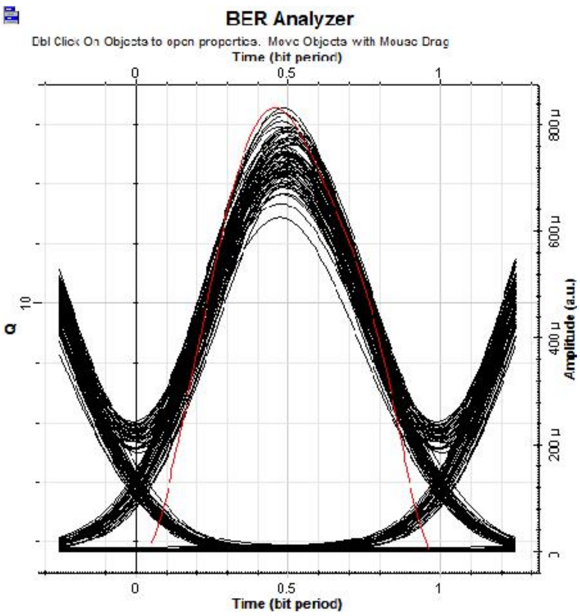
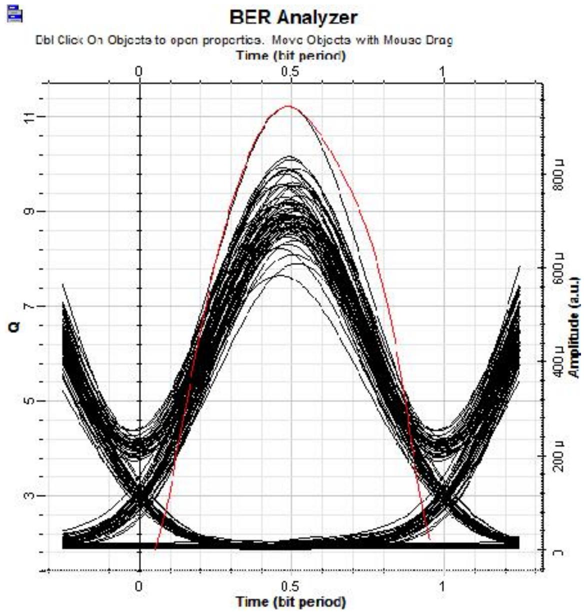


(c)

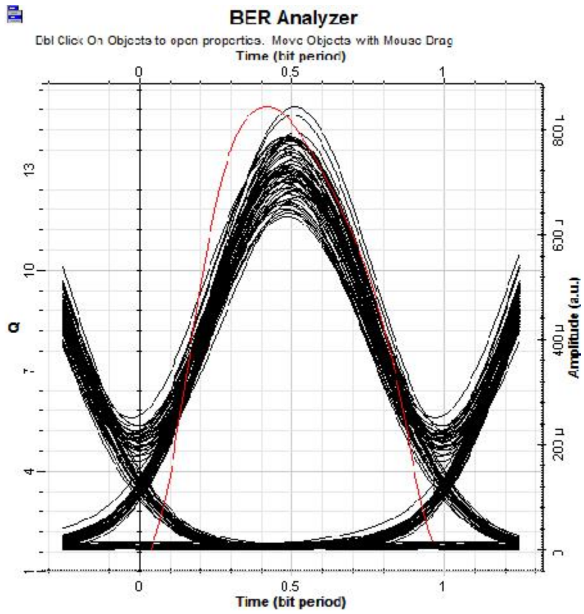
Fig 4. Eye Diagram of Symmetrical compensation scheme: (a) CSRZ format (b) DRZ format (c) MDRZ format.

As shown in Fig. 4, Symmetrical compensation scheme with MDRZ modulation format gives highest Q-factor and minimum BER. The performance comparison of the different modulation formats with symmetrical compensation is shown in Table II.

We have also simulated pre compensation, post compensation and symmetric compensation with MDRZ modulation format and made the comparative analysis. The eye diagram of the above three dispersion compensation scheme with MDRZ modulation is shown in figure below.



(a)



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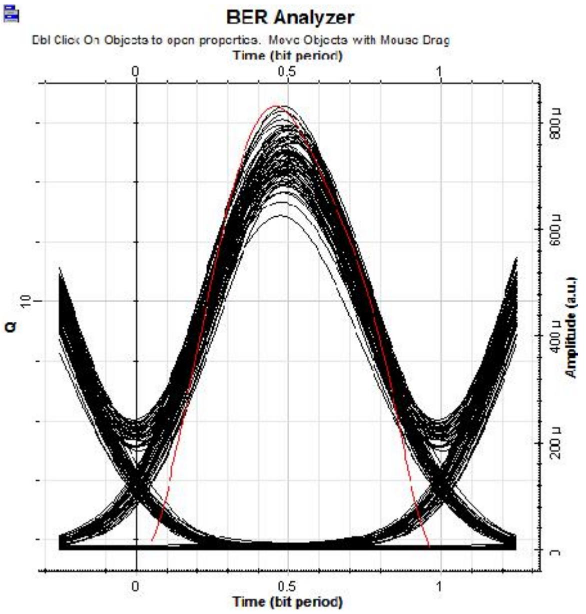
As shown in Fig. 5, Symmetrical compensation scheme with MDRZ modulation format gives highest Q-factor and minimum BER. The performance comparison of the different dispersion compensation schemes with MDRZ format is shown in Table III .



(c)

Fig 5: Eye Diagram of MDRZ format at 500 km : (a) pre compensation (b) post compensation (c)symmetrical compensation.

Table II. Comparison of different modulation formats.

Modulation	Q-factor	BER
CSRZ	11.7867	1.47×10^-032
DRZ	13.6264	9.23×10^-043
MDRZ	16.5425	5.70×10^-062

Table III. Comparison of different dispersion compensation schemes.

Dispersion Compensation Scheme	Q-factor	BER
Pre	11.2407	7.62×10^-030
Post	14.8844	1.27×10^-050
Symmetrical	16.5425	5.70×10^-062

VI. CONCLUSION

In this paper, we have simulated one DWDM network at 320 Gb/s with channel spacing of 100 GHz up to distance of 500 km. We have made the comparative analysis of the different dispersion compensation schemes like pre, post and symmetrical with different modulation formats. From this comparative analysis, we have concluded that symmetrical dispersion compensation with MDRZ modulation format gives best performance than other compensation scheme and modulation formats. So it is preferable to use MDRZ modulation at transmitter side and symmetrical dispersion compensation scheme in the channel while designing the optical communication system.

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