Comparison of NRZ and RZ Modulation Formats using Dispersion Compensating Fiber

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***Abstract-* In Optical Wavelength division multiplexed (WDM) system in order to reduce dispersion various dispersion compensating techniques are used. Dispersion can also be controlled by selecting proper modulation format for the input data. In this paper we compare non-return-to-zero (NRZ) and return-to-zero (RZ) formats at different wavelength. These two modulation format are well-known cost-effective candidates for the optical communication. The overall system performance of WDM system is investigated by NRZ and RZ modulation respectively using DCF. In this work we have designed, 8-channel WDM (Wavelength Division Multiplexing) system using NRZ and RZ. System performance can be compared at different modulation format by varying wavelength of single mode fiber. Comparison of different wavelength i.e. 980nm and 1550nm and different modulation format NRZ and RZ using dispersion compensation fiber is analyzed in this paper. We found 1550nm in NRZ has better performance as compared to RZ in 1550nm and 980nm in NRZ has better Performance as compared to RZ in 980nm Wavelength. We use the dispersion compensation fiber along with single mode fiber for length of 105 km operating at data rate of 3Gb\s with 8-channel of WDM System. Q-factor and BER (equivalent to bit error ratio) is selected as the criterion for the comparison.**

***Keywords-* NRZ and RZ modulation format, WDM, Dispersion Compensating Fiber, BER, Q-factor.**

I. INTRODUCTION

The non-return-to-zero (NRZ) and return-to-zero (RZ) formats are two well-known cost-effective candidates for Optical communication. Generally, the RZ modulation may have better performance than NRZ due to a better match of the RZ pulses to the optical filter used at the receiver. On the other hand, the aforementioned noise and distortion impairments may suppress the RZ advantages [11]. Optical networks are having large number of advantages over the traditional wired networks like less losses, high data rates and large transmission distances. With the development of wavelength division multiplexing (WDM) the data transferring capacity of the optical fiber system has increased tremendously .WDM is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths of laser light. WDM systems not only enable a bidirectional communications over single strand of optical fiber but also increase capacity.[2] WDM system when the transmission distance is large than quality of the signal degrades after travelling certain distance depending on the channel spacing and characteristics of optical fiber cable. Degradation in the quality is basically due to dispersion. Further as the transmission bit rate increases the dispersion problem also increases. For higher bit rate WDM systems there is much need for dispersion management [10]. There are various techniques which are used for dispersion management like microchip compensation, mid span spectral inversion, optical phase conjugation, initial pre chip, different delay methods and dispersion compensating fibers. In this paper for dispersion management the use of dispersion compensating fibers is analyzed [9]. Dispersion compensating fibers have negative dispersion coefficient and when connected with standard single mode fiber having positive dispersion coefficient the overall dispersion is reduce. Dispersion is the main performance limiting factor in optical fiber communication. Dispersion is the main performance limiting factor in optical fiber communication. Dispersion greatly degrades the performance of optical fiber communication. Due to dispersion, broadens of optical pulse as they travel in single mode fiber. [3] As optical network supports huge bandwidth; WDM network splits this into a number of small bandwidths optical channels. It allows multiple data stream to be transferred along a same fibre at the same time. A WDM system uses a number of multiplexers at the transmitter end, which multiplexes more than one optical signal onto a single fibre and demultiplexers at the receiver to split them apart. Generally the transmitter consists of a laser and modulator. The light source generates an optical carrier signal at either fixed or a tuneable wavelength. The receiver consists of photodiode detector which converts an optical signal to electrical signal [7].

II. Effect of Fiber-Optic Dispersion on Optical Transmission

Dispersion is defined as because of the different frequency or mode of light pulse in fiber transmits at different rates, so that these frequency components or models receive the fiber terminals at different time. It can cause in tolerable amounts of distortions that ultimately lead to errors. In single-mode fiber performance is primarily limited by chromatic dispersion (also called group velocity dispersion), which occurs because the index of the glass varies slightly depending on the wavelength of the light, and light from real optical transmitters necessarily has nonzero spectral width (due to modulation) [4,8]. Polarization mode dispersion, another source of limitation, occurs because although the single-mode fiber can sustain only one transverse mode, it can carry this mode with two different polarizations, and slight imperfections or distortions in a fiber can alter the propagation velocities for the two polarizations. Mode birefringence Bm is defined as the follow Formula:

$$Bm = \left| \frac{Bx - By}{Ko} \right| = nx\text{-}ny \qquad (1)$$

nx, ny are the effective refractive of the two orthogonal polarizations. For a given Bm, its fast axis and slow axis components will be formed the phase difference after the light waves transmission L Km.

$$\varphi = Ko\ Bm = \frac{2\pi}{\lambda}(\mathbf{Nx - Ny})\mathbf{L} = (\boldsymbol{\beta}\mathbf{x} - \boldsymbol{\beta}\mathbf{y})\mathbf{L} \qquad (2)$$

If the Bm is a constant, through the light waves in transmission process the phase difference between its fast axis and slow axis will periodicity repetition. The power exchange also periodically. The length that it leads to a phase difference of 21t or power periodic exchange is called polarization beat length:

$$L_{B=}\ 2\pi/\lambda\ \ (N_{x-}N_y)\ L= (\beta_x\text{-}\beta_{y)})\ L \qquad (3)$$

If the incident light has two polarization components, due to refractive difference between the fast axis and slow axis, the transmit rate of two polarization components will be different. Because the randomness of fiber birefringence changes, the group velocity of different polarization direction is also random, this will result in the output pulse broadening. The influence of dispersion on system performance is also reflected in the optical fiber nonlinear effects. Dispersion increased the pulse shape distortion caused by the self-phase modulation dispersion (SPM); the other hand, dispersion in WDM systems can also increase the cross-phase modulation, four-wave mixing (FWM) and other nonlinear effects [5].

III. Dispersion Compensation Technology

In order to improve overall system performance and reduced as much as possible the transmission performance influenced by the dispersion, several dispersion compensation technologies are used. Amongst the various techniques are used for dispersion compensation and management could be broadly classified as: dispersion compensating fibers (DCF), chirped fiber Bragg gratings (FBG), and high-order mode (HOM) fiber. The idea of using dispersion compensation fiber for dispersion compensation was proposed as early as in 1980 but, until after the invention of optical amplifiers, DCF began to be widespread attention and study. As products of DCF are more mature, stable, not easily affected by temperature, wide bandwidth, DCF has become a most useful method of dispersion compensation [1]. In order to meet the growing demand of bandwidth for internet and other related communication applications, future long-haul systems are required to operate at bit-rate of 10 Gbit/s, 40 Gbit/s or even higher. In high capacity systems, dispersion compensation is critical. The transmission fibers in the existing network are the standard non-zero dispersion fibres (NZDF) with nominal value for dispersion equal to +17 ps / nm km . Although these fibers were deployed several decades ago, they are still preferred by system designers today because the high dispersion of the fiber is used efficiently to impair the non-linear manifestation of fibre in systems. However, the accumulation of dispersion in these fibres limits the transmission distance to approximately 60 to 300 km for 10 Gbit/s systems and 4 to 18 km for 40 Gbit/s systems if dispersion compensation is not employed. Hence dispersion compensation is required to increase the transmission distance in systems operating at high bit -rates. Furthermore, the DC device is required to have a sufficiently large bandwidth in order to achieve simultaneous compensation across all the channels. This implies that the DC device must be capable of dispersion slope compensation. Several dispersion and dispersion slope compensating devices have been demonstrated, including single-mode and higher-order-mode dispersion compensating fibres, fibre Bragg grating devices, Although many of these devices have great potential, including tune able dispersion, single mode dispersion compensating fibres (DCF) are still the only one that is widely deployed [6].

IV. SIMULATION SETUP

The simulation of WDM link using Dispersion compensation fiber has been done to study the performance of the system. Simulation model of transmitter and Receiver for optical fiber Communication is implemented on “OPTISYSTEM-7.0” software using 105 KM long Single mode fiber. To achieve high-capacity, high speed wavelength division- multiplexing (WDM) transmission, the embedded standard single-mode fiber (SMF) should be upgraded to compensate the dispersion. For this purpose, dispersion compensation scheme must be used periodically in the link. There are several different methods that can be used to compensate dispersion; in this work we have used dispersion compensating fiber (DCF). In this work we compare NRZ and RZ Modulation format at different wavelength i.e. 980nm and 1550nm. We have simulated 8-channel Wavelength division multiplexing system operated at data rate of 3Gb/s.. The simulation link for 8-channel dispersion compensating fiber (DCF) is shown in figure 1.

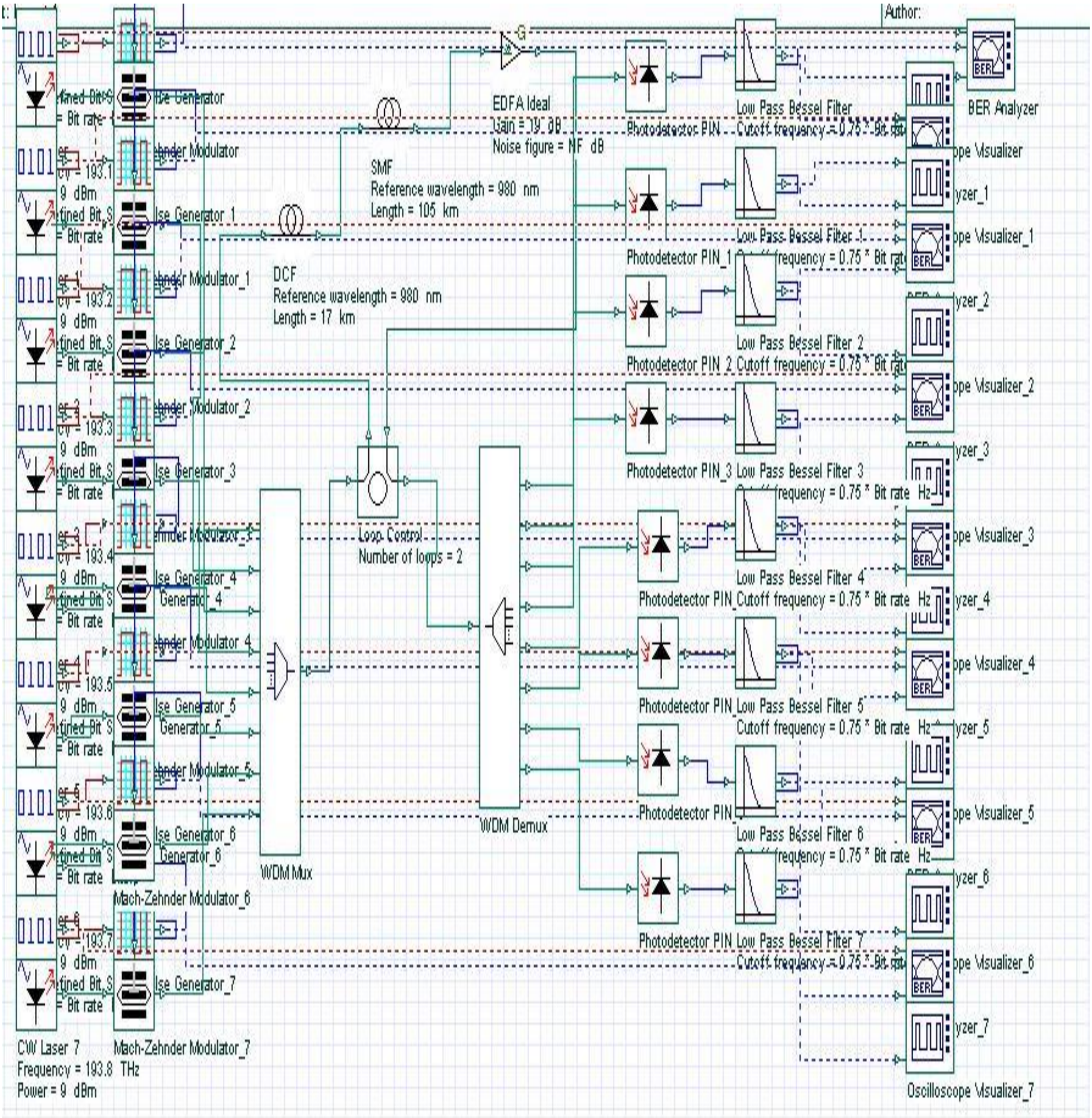


Figure 1: Simulation link for 8-channel Dispersion compensation fiber (DCF)

Figure 2 shows simulation setup for 8 channel WDM Optical communication at 3Gb\s.The simulation setup is composed of transmitter, fiber and receiver. The transmitter consist of user defined bit sequence generator data rate of 3Gb\s provide to Non return to zero(NRZ) that generates a electrical pulses to non return to zero coded signal and that signal provide to mach-Zehnder modulator is an intensity modulator based on an interferometric principle. CW laser is used to generate a continuous wave of optical signal and provide to mach-Zehnder modulator. We analysis the performance of WDM Link using Dispersion Compensation fiber at different modulation format and different wavelength. We design

WDM Mux and Demux using optisystem software. The parameters used in simulation link for NRZ and RZ are given in Table 1 shows the Parameter used in simulation link for 8-channel dispersion compensation fiber.

TABLE 1 : SIMULATION PARAMETER FOR 8-CHANNEL DCF

Parameters	**Values**
Wavelengths	980nm, 1550nm
No. of Channels	08
Modulation Scheme	NRZ and RZ
Data Rate	3Gb\s
Light Source (TX)	CW laser
Fiber	SMF
Receiver used (RX)	PIN
Fiber Length (SMF)	105Km
DCF Length	17Km
Power	9dBm
EDFA gain	19db
MZM Ratio	30db
Dispersion coefficient of SMF	16 ps/nm/km
Dispersion coefficient of DCF	-80 ps/nm/km

V. RESULT AND DISCUSSION

In this work we have design simulation link for WDM link using DCF at different wavelengths. We analyzed the performance of dispersion compensating fiber at different set of wavelengths i.e. 980nm and 1550nm and different modulation format. From comparison we found which wavelength and modulation format has better performance and Better bit error rate are analyzed. The design of 8-channel WDM link is shown in figure 1, using this link we can compare different wavelengths and different modulation format of single mode fiber. For the sake of simplicity of the work, we have shown the 2 best performance of channel out of 8 channels at different wavelengths. Firstly the results are obtained for NRZ at 980nm wavelength. We show two best performance channel out of 8-channel which channel has better performance is represent in this paper.

1) Performance of NRZ at 980nm Wavelength

The overall system performances when using NRZ modulation formats are compared for WDM channels. We show two best performance channels of NRZ out of 8-channels. In Figure 2 show Q-factor and BER of 1st channel As shown in eye diagram figure 2 at 980nm using Dispersion compensating fiber that provide Q-factor of 11.5794 and BER of 2.45884e-031.

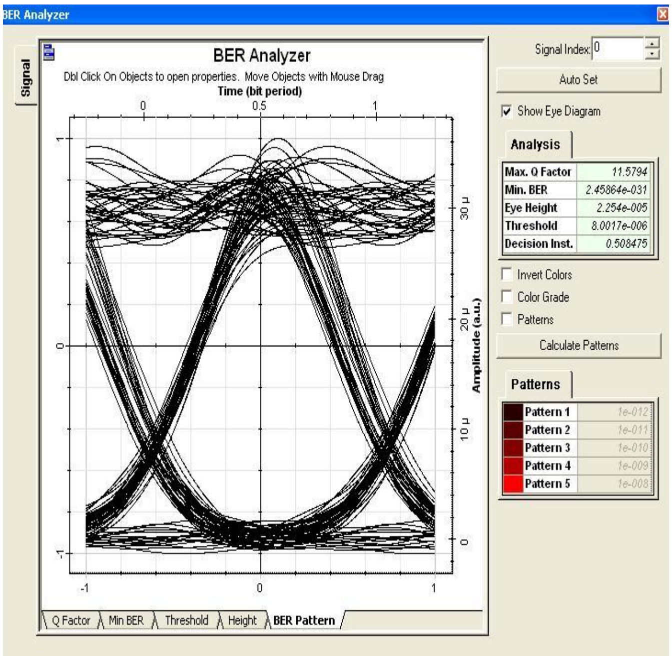
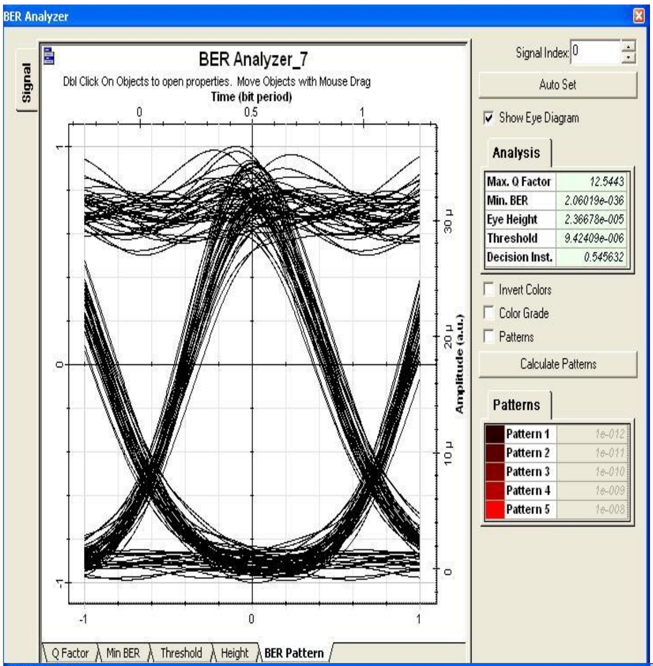


Figure 2: Eye diagram analysis for first channel of NRZ at 980nm

The Eye diagram for eighth channel at 980nm is shown in figure 3 As shown in figure of eighth channel at 980nm using DCF provide Q-factor of 12.5443 and min BER of 2.06019e-036.Compare with 1st channel of 980nm it has slightly better then first channel of 980nm in NRZ modulation format.


BER Analyzer
Signal
BER Analyzer_7
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Time (bit period)
Amplitude (a.u.)
Signal Index 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 12.5443
Min. BER 2.06019e-036
Eye Height 2.36678e-005
Threshold 9.42409e-006
Decision Inst. 0.545632
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
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Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008
Q Factor
Min BER
Threshold
Height
BER Pattern

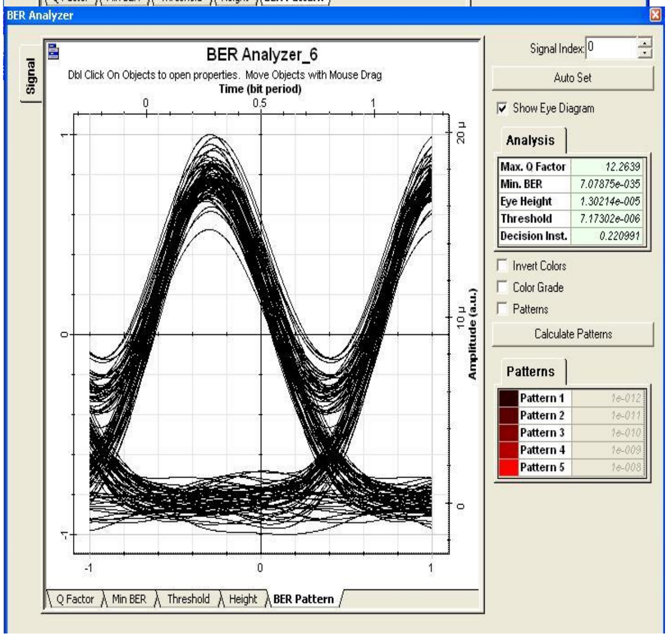
BER Analyzer
Signal
BER Analyzer_6
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Time (bit period)
Amplitude (a.u.)
Signal Index 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 12.2639
Min. BER 7.07875e-035
Eye Height 1.30214e-005
Threshold 7.17302e-006
Decision Inst. 0.220991
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-012
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008
Q Factor
Min BER
Threshold
Height
BER Pattern

Figure 3: Eye Diagram for 8th channel of NRZ at 980nm

2) Compare with RZ modulation format

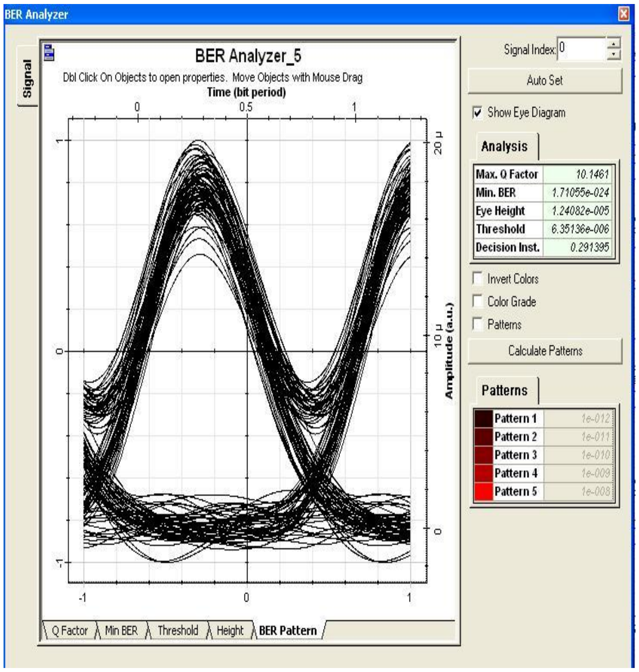

Figure 4: Eye Diagram for 6th channel of RZ at 980nm

Comparing the overall system performance under RZ modulation with respect to BER and Q-factor respectively. For the sake of simplicity we show two best performances of channels out of 8-channels. The eye diagram in figure 4 provides Q-factor and BER of 6th channel. Q-factor is 10.2428 and BER is $6.32*10^{-25}$.

Figure 5: Eye Diagram for 7th channel of RZ at 980nm

The Eye diagram for 7th channel at 980nm using RZ is shown in figure 5. As shown in figure of 7th channel at 980nm using DCF provide Q-factor of 12.5275 and min BER of 2.64085e-036.Compare with 6th channel of 980nm it has better then first channel of 980nm in NRZ modulation format.

TABLE 2:COMPARISON OF DIFFERENT MODULATION FORMAT OF 980nm LINK

Modulation Scheme	**Channels**	**Q-factor**	**BER**
NRZ	1st	11.5794	$2.4*10^{-31}$
NRZ	8th	12.5443	$2.0*10^{-36}$
RZ	6th	10.2428	$6.3*10^{-25}$
RZ	7th	12.5275	$2.6*10^{-35}$

As shown in table 2 Comparison of Different Modulation format of 980nm Link. This show NRZ Performance is slightly better then RZ modulation scheme, it has better Q-factor and BER as compared to RZ modulation.

3) Performance analysis of NRZ at 1550nm Wavelength

The simulation parameter for proposed DCF link are shown in Table1.we achieved better performance of optical link using dispersion compensating fiber (DCF).We have set the wavelength to 1550nm that produce Q-factor of second channel 15.7294 and min BER of 4.72717e-056 as shown in figure 6, out of 8-channel for different modulation scheme which channel has better performance is represent in this paper.

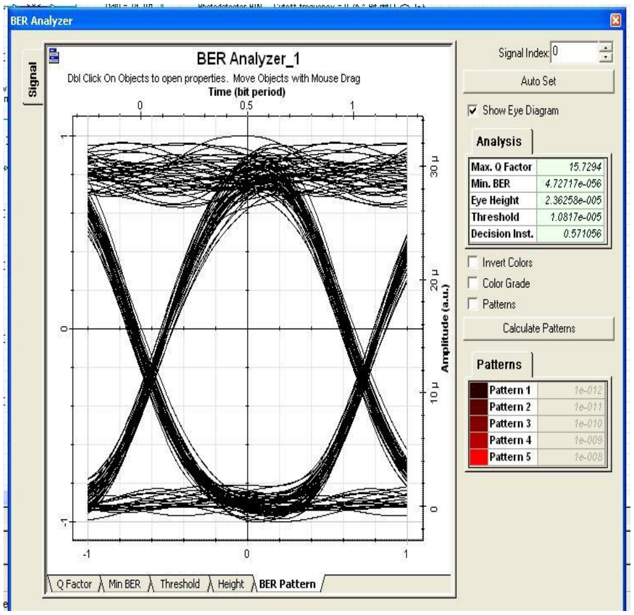

Figure 6: Eye Diagram for 2nd channel of NRZ at 1550nm

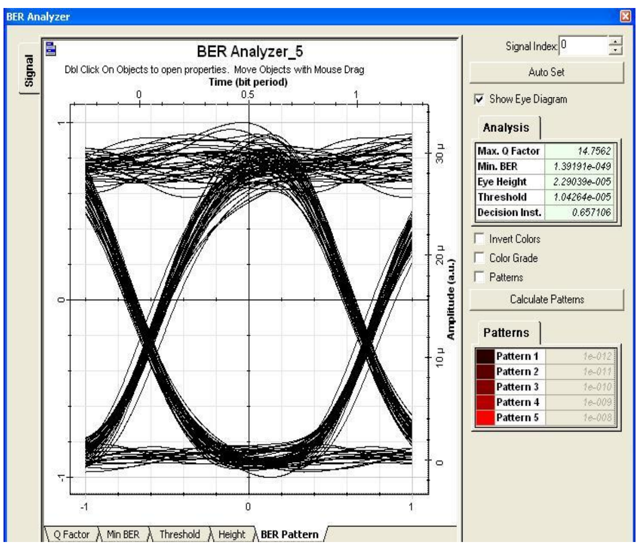

Figure 7: Eye Diagram for 6th channel of NRZ at 1550nm

Figure 6 shows that the time delays in the received bits are negligible and the signal distortion due to BER is tolerable. The eye diagram in figure 7 shows Performance of 6thChannel at 1550nm in non return to zero format. The result shows at 9dbm power provide Q-factor is 14.7562 and BER is 1.30191e-049. Performance of 6th channel is slightly less then 2ndchannel of 1550nm in NRZ modulation format. The overall system performances when using NRZ and RZ modulation formats are compared for typical WDM channels.

4) Compare with RZ modulation at 1550nm Wavelength

We have compare NRZ with RZ modulation at 1550nm wavelength. Comparing the system performance for RZ modulation with respect to BER and Q-factor respectively. For the sake of simplicity we show two best performances of channel out of 8-channels.The eye diagram in figure 8 shows performance of 2nd channel at 1550nm in RZ modulation.

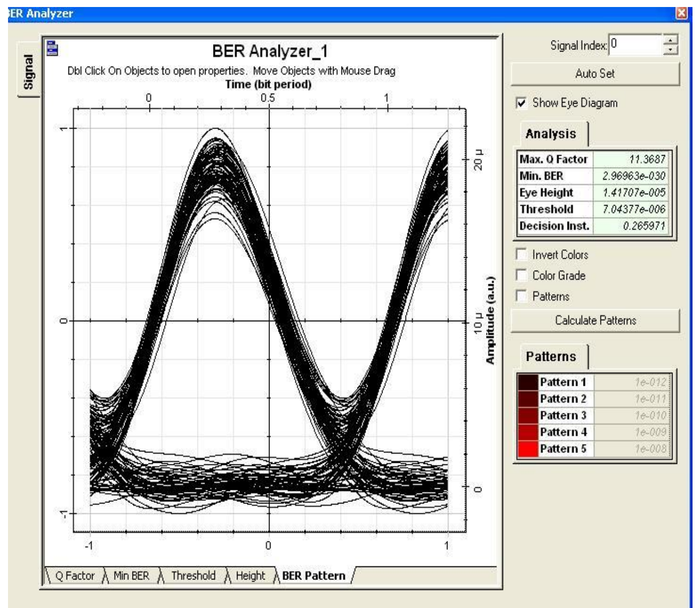

Figure 8: Eye Diagram for 2nd channel of RZ at 1550nm

Result show in figure 8 Provide Q-factor of 11.3687 and BER of 2.96963e-030 respectively. The acceptable Q-factor is 7 and BER is 10^{-9} respectively in optical communication. So achieved BER and Q-Factor is higher hen acceptable value. This show performance is stable and used for high bit rate. The eye diagram in figure 9 shows Performance of 4th Channel at 1550nm wavelength using Return to Zero (RZ) modulation format. This Provide Q-factor is 11.7176 and BER is 5.13724e-032. 4th Channel of RZ compare with 2nd channel, performance of 4th Channel is slightly better then 2nd Channel as shown in figure 9 and comparison of NRZ with RZ Modulation format at 1550nm wavelength is shown table 3.

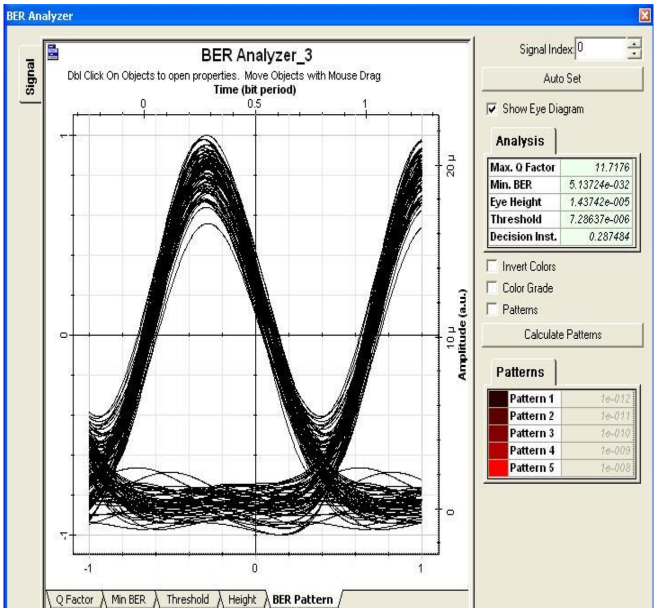

Figure 9: Eye Diagram for 4th channel of RZ at 1550nm

TABLE 3: COMPARISON OF DIFFERENT MODULATION FORMAT OF 1550nm LINK

Modulation Scheme	**Channels**	**Q-factor**	**BER**
NRZ	2nd	15.7294	4.72717e-056
NRZ	6th	14.7562	1.39191e-049
RZ	2nd	11.3687	2.96693e-030
RZ	4th	11.7176	5.13724e-032

Table 3 Shows Comparison of different modulation scheme at different channel we specify best performance of channels out of eight channels for each wavelength and compare them, as we can see from different eye diagram and comparison table, the 1550nm in NRZ has better Q-factor and min BER as compared to RZ modulation scheme. Performance of RZ also acceptable but on comparison of these two NRZ has better performance. The effect of dispersion compensation is very good and signal quality is high, eye opening is good in case of 1550nm.Through the whole system analysis found that the performance of WDM link at 1550nm wavelength is best in long distance high speed WDM Systems.

VI. CONCLUSION

In this paper comparison of NRZ and RZ modulation is investigated and compared at different wavelengths i.e. 980nm and 1550nm. We have simulated and analyzed the performance of 8-channel WDM network in NRZ and RZ Modulation format. To compensate Dispersion, we have used Dispersion Compensating Fiber. All the results have been compared and analyzed in terms of Q-factor, Bit error rate. The efficient performance of the link can be achieved by assuming threshold level of BER and Q-factor value which is dynamically set at 10^{-9} and 7 respectively. We select those channels which has best performance and that channel represent in this paper. At the end Simulation results shows that at the wavelength of 1550nm in NRZ has higher performance then RZ of 1550nm and 980nm wavelength. Performance of RZ in 980nm and 1550nm wavelength also has better performance but not comparison to NRZ modulation scheme. The result shows the NRZ in 980nm and 1550nm has higher performance as compared to RZ. We conclude that Q-Factor is 15.7294 and Min BER is 4.72717e-056 at 1550nm wavelength in NRZ modulation format.

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