International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 11, November-2014

Performance Analysis of 16 Channel WDM System via Dispersion Mitigation and Various Modulation Formats

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Abstract— **We analyze 100 Gbps ultra-high capacity WDM system for RZ, NRZ, CSRZ and Duobinary modulation formats using pre, post and symmetrical compensation. Using symmetrical compensation, optimized modulation format for 120 km has been demonstrated using OptiSystem software version 11 from Optiwave Systems Inc.**

Keywords*— *Return-to-zero (RZ), Non-return-to-zero (NRZ), Carrier suppressed return-to-zero (CSRZ), bit error rate (BER), dispersion compensating fiber (DCF)

I. INTRODUCTION

Optical network employing WDM is widely replacing the existing telecommunication infrastructure and probably is going to be the key technique for upcoming generation networks and future internet supporting variety of services that possess different requirements in terms of bandwidth, speed, reliability, and many more features. In today's scenario, with the growing demand for a large number of services like video on demand, use of internet, voice over IP, and live video has put extreme pressure for high bandwidth and data rate. Optical fiber satisfies the need of the hour by providing very large bandwidth [1] of approximately 32 THz and hence multiple channels can be transmitted through common fiber using concept of wavelength division multiplexing (WDM) but the performance is downgraded by dispersion and nonlinearities. Dispersion being main factor must be managed in order to avoid its deleterious effects. Dispersion is broadening of pulse in time domain due to the difference in group velocity of different modes. Dispersion compensation deploying alternate fiber segments of opposite dispersion values is a key technology that reduces total accumulated dispersion while suppressing most non-linear effects. In dispersion managed systems, the positive dispersion of single mode fiber (SMF) can be compensated by the large negative dispersion of DCF [2, 3] which must have low insertion loss and low nonlinearity.

In standard SMF, RZ and NRZ modulation formats are most commonly used and RZ performs better as compared to conventional NRZ systems [4]. But in case of WDM systems both RZ and NRZ are not suitable as NRZ is more adversely affected by nonlinearities, whereas RZ is more affected by dispersion [5]. The comparison of CSRZ and single SSB-RZ has shown that CSRZ is superior to RZ and SSB-RZ in terms of signal degradation due to Kerr nonlinearities and Chromatic dispersion in WDM as well as single channel 40 Gbps systems

[6] and also it is capable of providing high bit rate systems [8].

In this paper, we have simulated 16 Channel 100 Gbps WDM system having the central frequency of first channel at 190 THz with adjacent channel spacing of 200 GHz using RZ, NRZ, duobinary and CSRZ modulation formats. The input power of the WDM transmitter is taken as -3.99 dBm. The performance characterization of the system is evaluated using Optisystem™. Optical amplifier EDFA is inserted to compensate the fiber losses as amplified stimulated emission generated by the amplifiers helps to improve the optical signal to noise ratio (SNR). The four modulation formats have been compared numerically for different compensation schemes in terms of maximum Q-factor and minimum BER.

II. EQUATIONS

Pulse evolution along a fiber is governed by the nonlinear Schrodinger equation (1)

$$\frac{\partial A(z,t)}{\partial z} = -\frac{\alpha}{2}A(z,t) + i\frac{\beta_2}{2}\frac{\partial^2 A(z,t)}{\partial t^2} + \frac{\beta_3}{6}\frac{\partial^3 A(z,t)}{\partial t^3} - i\gamma\left|A(z,t)\right|^2 A(z,t) \quad (1)$$

Attenuation 1st order GVD 2nd order GVD Kerr nonlinearities

1st order group velocity dispersion is characterized by the dispersion parameter D [ps/(km.nm)] and 2nd order is characterized by the differential-dispersion parameter (dispersion slope) S [ps/(km.nm^2)]. Requirement for complete compensation of 1st order group velocity dispersion (GVD) at a single wavelength is given by

$$L_{SMF}.\ D_{SMF} = -L_{DCF}.\ D_{DCF} \quad (2)$$

where L and D are numerical values of length and dispersion respectively.

III. SYSTEM MODEL

Fig. 1 shows a schematic of simulation setup of a 16 channel WDM optical communication system at 100 Gbps. Fig. 2 delineates the designed 16 channel simulation model for symmetrical compensation scheme with adjacent channel spacing of 200 GHz over a transmission distance of 120 km with the central frequency of first channel as 190 THz and the performance of various channels is analyzed in terms of maximum Q-factor and minimum BER. The dispersion map consists of a 60 km long segment of single mode fiber with D_+ = 16 ps/(nm.km) followed by dispersion compensating fiber of 10 km length with opposite dispersion D_- = -85 ps/(nm.km). The attenuation of SMF and DCF is taken as 0.2 dB/km and 0.5 dB/km respectively. The EDFA gain is 30 dB and noise figure is 6 dB. The receiver module includes WDM demultiplexer having bandwidth of 80 GHz, receiver filters and BER analyzer.

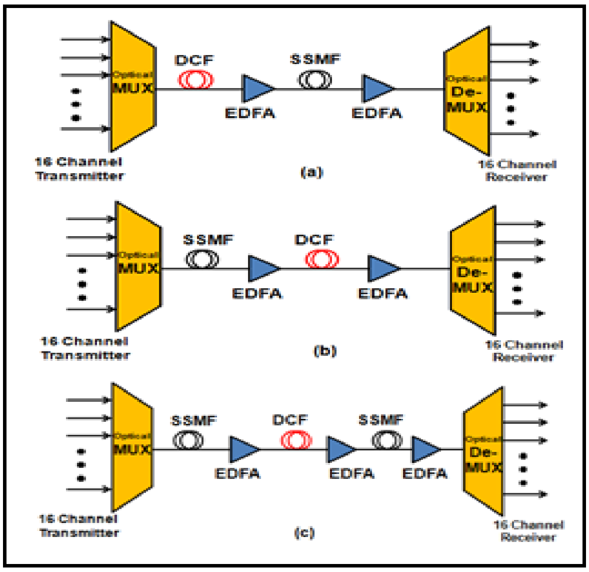


Fig. 1. Schematic diagram of (a) Pre (b) Post and (c) Symmetrical compensation

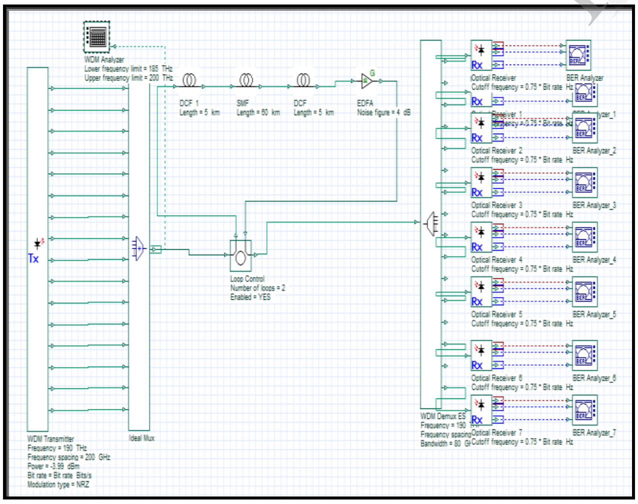
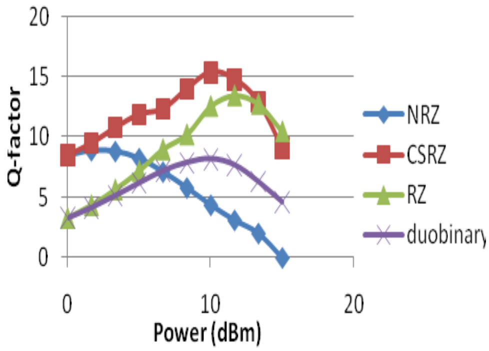


Fig. 2. Simulation model for symmetrical compensation

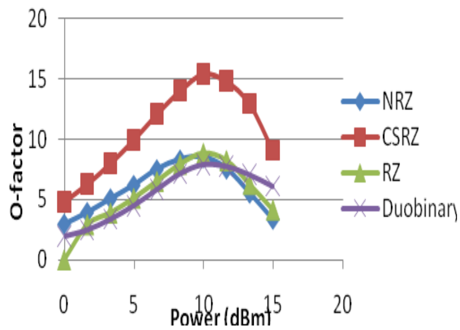
Fig. 3 demonstrates the graphical comparison of the four modulation formats for received Q-factor as a function of signal input power in different dispersion compensation schemes *i.e.* pre, post and symmetrical compensation. The comparison shows that the symmetrical compensation is best among these compensation schemes as it provides higher values of Q-factor at significant low input power for all modulation formats. Also the Q-factor value increases with increase in input power up to a certain limit (0-10 dBm) and then starts falling due to overlapping of wavelengths causing nonlinear effects like XPM and FWM caused by optical Kerr's effect.

IV. Results and Discussion

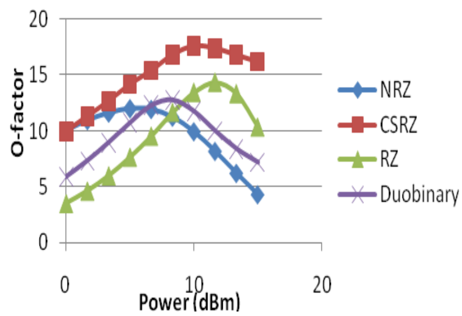
The CSRZ format with symmetrical compensation happens to be the most resilient against dispersion and nonlinearities providing the highest value of Q-factor of 13.26 and minimum BER of 1.5×10^{-40} in the simulation at input power of -3.99 dBm followed by RZ and NRZ.



(a) Pre compensation



(b) Post compensation



(c) Symmetrical compensation

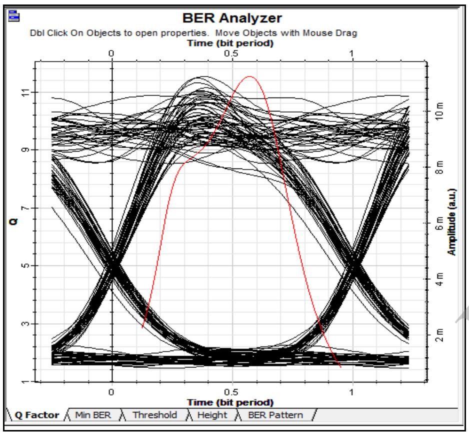
Fig. 3. Q-factor versus input power for different compensation schemes

Duobinary format shows the worst performance in all three compensation schemes due to strong impact of fiber nonlinearities, which is main limiting factor for maximum transmission length and achievable transmission quality. TableI. briefs the optimized values of Q-factor for different modulation formats in three different compensation schemes and minimum BER for symmetrical compensation.

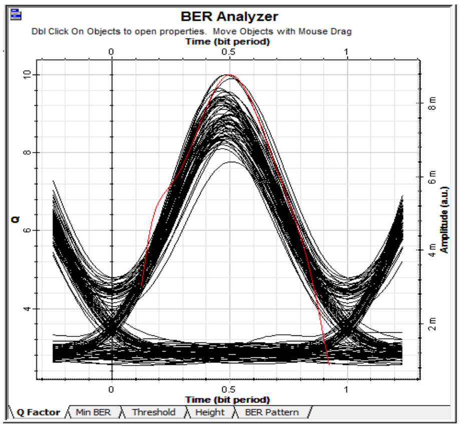
TABLE I. Q-FACTOR FOR VARIOUS COMPENSATION SCHEMES

Modulation format	Pre	Post	Symmetrical	
			Q-factor	*Min BER*
NRZ	4.691	6.519	7.953	1.37×10^{-19}
RZ	5.866	7.412	9.992	6.6×10^{-24}
Duobinary	3.714	5.627	6.061	0.00031
CSRZ	11.02	9.823	13.269	1.5×10^{-40}

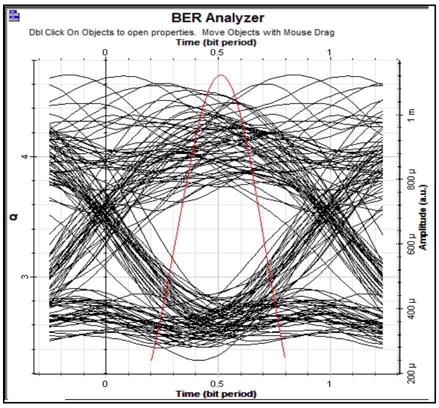
Fig. 4(a)-(d) shows the eye diagrams of the discussed modulation formats for channel 1 in symmetrical compensation scheme to provide values of Q-factor, minimum BER and percentage eye opening as the end channels i.e. 1st and 16th experience most dispersion and nonlinear effects [4]. The input power has also been optimized to select the minimum value of transmitter power to have maximum Q-factor and minimum BER by diminishing the effects of nonlinearities like FWM.



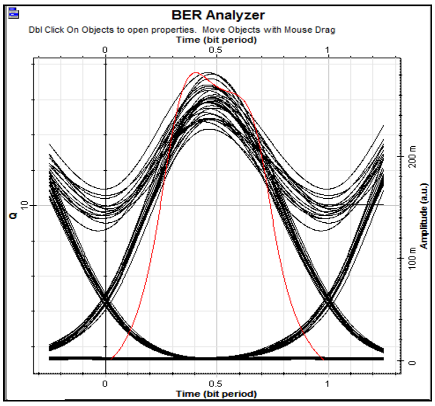
(a) NRZ



(b) RZ



(c) Duobinary



(d) CSRZ

Fig. 4 Eye diagrams of different modulation formats for symmetrical compensation

V. CONCLUSION

In this work, we have simulated 16 channel 100 Gbps WDM system over a transmission distance of 120 km using RZ, NRZ, duobinary and CSRZ modulation formats. The four modulation formats have been numerically compared for different dispersion compensation schemes i.e. pre, post and symmetrical compensation. The presented results show that symmetrical compensation has sufficient performance in terms of Q-factor over other schemes to obtain error free transmission over longer distance as dispersion is reduced to large extent. Superior performance of CSRZ has been observed with a Q-factor of 13.269 as it suppresses the optical carrier tone and due to its reduced spectral width compared to other conventional formats. Eye diagrams shows better value of threshold and height which ultimately results reduced jitter and improved synchronization in optical network.

ACKNOWLEDGMENT

The authors are indebted to Department of Electronics and Communication Engineering, SLIET Longowal, Punjab for providing OptiSystem (version 11) software and for making this work successful.

REFERENCES

[1] G. H. Patel, R. B. Patel and S. J. Patel, "Dispersion Compensation in 40Gb/s WDM Network Using Dispersion Compensating Fiber" Journal of Information, Knowledge and Research in Electronics and Communication Engineering, 02, 662-665 (2013).

[2] G.P. Agrawal, Nonlinear Fiber Optics, Academic Press, New York, 2001.

[3] G.P. Agrawal, Applications of Nonlinear Fiber Optics, Academic Press, New York, 2001.

[4] G. Bosco, A. Carena, V. Curri, R. Gaudino and P. Poggiolini, "On the use of NRZ, RZ, and CSRZ Modulation at 40 Gb/s with narrow DWDM channel spacing" J. Lightwave Technol. 20, 1694 - 1704 (2002).

[5] M. I. Hayee, and A.E. Willner, "NRZ Versus RZ in 10–40-Gb/s dispersion managed WDM transmission systems" IEEE Photonics Technol. Lett. 11, 991–993 (1999).

[6] T. Hoshida, O. Vassilieva, K. Yamada, S. Choudhary, R. Pecqueur and H. Kuwahara, "Optimal 40 Gb/s modulation formats for spectrally efficient long-haul DWDM systems" IEEE J. Lightwave Technol. 20, 1989 - 1996 (2002).

[7] D. Dahan and G. Eisenstein, "Numerical comparison between distributed and discrete amplification in a point-to-point 40-Gb/s 40-WDM-based transmission system with three different modulation formats" J. Lightwave Technol. 20, 379 - 388 (2002).

[8] Anu Sheetal, Ajay K. Sharma and R. S. Kaler, "Simulation of high capacity 40 Gb/s long haul DWDM system using different modulation formats and dispersion compensation schemes in the presence of Kerr's effect", Optik - International Journal for Light and Electron Optics,121, 739–749 (2010).