Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 93 (2016) 647 – 654

Procedia Computer Science

6th International Conference On Advances In Computing & Communications, ICACC 2016, 6-8 September 2016, Cochin, India

Analysis of WDM System With Dispersion Compensation Schemes

Neheeda P[a,*], Pradeep M[a], Shaija P J[a]

[a]*Govt Model Engineering College, Thrikkakkara, Kochi, India - 682021*

Abstract

One of the major factors that limit the performance of a WDM system is dispersion. Use of Dispersion Compensating Fiber (DCF) is the most common method for dispersion compensation in WDM systems. In this work, the performance of a WDM system at 8Gbps employing different dispersion compensation schemes using DCF (pre compensation, post compensation and symmetrical compensation techniques) are analyzed in terms of BER and Q factor. Analysis of WDM system with NRZ and RZ modulation format is also done. It is found that a WDM system using RZ modulation format and employing symmetrical compensation scheme provides best performance.

Peer-review under responsibility of the Organizing Committee of ICACC 2016

Keywords: WDM system analysis; Dispersion compensation; DCF;NRZ format;RZ format

1. Introduction

The rapid growth in demand for high-capacity telecommunication links and efficient utilization of fiber bandwidth has resulted in an extraordinary increase in the use of Wavelength Division Multiplexing (WDM) in advanced lightwave networks. WDM is a method of transmitting data from different sources over the same fiber optic link at the same time whereby each data channel is carried on its own unique wavelength.

The optimal design and application of optical fiber are very important for the transmission quality of optical fiber transmission system. And the main goal of communication systems is to provide data transmission with high quality at a longer distance[1]. Loss and dispersion are the major factor that affect WDM network.

* Corresponding author.
*E-mail address:*neheeda@mec.ac.in

Peer-review under responsibility of the Organizing Committee of ICACC 2016
doi:10.1016/j.procs.2016.07.254

At high bit rate, the dispersion induced broadening of short pulses propagating in the fiber causes crosstalk between the adjacent time slots, leading to errors when the communication distance increases. The advent of erbium doped amplifiers (EDFAs) has increased the link distance as limited by fiber loss in optical communication systems. However, these amplifiers induce nonlinear effects, which limit the bit rate and the propagation distance in an optical fiber link. Signal degradation in WDM systems is due to combined effects of group velocity dispersion, Kerr nonlinearity and accumulation of amplified spontaneous emission due to periodic amplification. Therefore the management of dispersion and nonlinearities is of prime importance in WDM systems[2].

The most commonly employed techniques for dispersion compensation are Dispersion compensating fibers (DCF), Fiber Bragg Grating, Electronic dispersion compensation and Digital filters[3]. Because of simplicity and reliability, DCF is an important method for dispersion compensation and to upgrade the already installed links of single mode fiber.

In this paper, an analysis is done to evaluate the performance of WDM system with three DCF compensation schemes: pre compensation, post compensation and symmetrical compensation scheme at 8Gbps. Simulation studies show that symmetrical compensation scheme is the best. It can greatly reduce the influences of the fiber nonlinearity and increase the transmission distance greatly. A comparison of performance of the system with nonreturn-to-zero (NRZ) and return–to-zero (RZ) modulation format is also done.

2. DCF Dispersion Compensation Technology

Group velocity Dispersion (GVD) comprising of Material and Waveguide Dispersion resulting from slightly different group velocities associated with different spectral components of the signal is the major type of dispersion occurring in single mode fibers(SMF). Pulse propagation inside an optical fiber is governed by the nonlinear Schrodinger equation and is given by[4]

$$\frac{\partial A}{\partial z} + i\frac{\beta_2}{2}\frac{\partial^2 A}{\partial t^2} = -\frac{\alpha}{2}A + i\gamma\left|A\right|^2 A \tag{2.1}$$

where $\frac{\partial A}{\partial z}$ gives the rate of change of the wave envelop as a function of distance z, β_2 is the group velocity dispersion (GVD) parameter, α is the attenuation coefficient and γ is the nonlinear parameter. Dispersion, D, is related to GVD parameter by[4]

$$D = -\frac{2\pi c}{\lambda^2}\beta_2 \tag{2.2}$$

where λ is the signal wavelength and c is speed of light. The chromatic dispersion accumulated along the length of the fiber limits the transmission length. The limiting transmission distance, L, is given by[5]

$$L < \left(16\left|\beta_2\right|B^2\right)^{-1} \tag{2.3}$$

where B is the bitrate. Relatively large GVD of standard SMF thus limit the performance of communication system. The pulse propagation equation in linear case can be written as[4]:

$$\frac{\partial A}{\partial z} + i\frac{\beta_2}{2}\frac{\partial^2 A}{\partial t^2} - \frac{\beta_3}{6}\frac{\partial^3 A}{\partial t^3} = 0 \tag{2.4}$$

where A is the pulse envelope amplitude. The effect of third order dispersion are included by the term β_3. This term is usually ignored when $|\beta_2| > 0.1$ ps^2/km. With $\beta_3 = 0$, the solution of equation 2.4 is given by[4]

$$A(z,t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \tilde{A}(0,\omega)\exp(\frac{i}{2}\beta_2\omega^2 z - i\omega t)d\omega \tag{2.5}$$

where $\tilde{A}(0,\omega)$ is the Fourier transform of $A(0,t)$. Dispersion induced degradation of the optical signal is caused by the phase factor, $\exp(\frac{i}{2}\beta_2\omega^2 z)$, acquired by the signal during its propagation through the fiber[4]. Dispersion compensation schemes attempt to cancel this phase factor so that original signal can be restored.

Dispersion compensating fibers (DCF) are specially designed fibers with negative dispersion. Conventional DCFs have high negative dispersion in the range -70 to -90ps/nm-km. DCF is capable of compensating fiber GVD if average optical power is kept low enough that nonlinear effect inside the fiber is negligible. When optical pulse propagates through two fiber segments, the second of which is a DCF, then using equation 2.5 it will obtain[4]

$$A(L,t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \tilde{A}(0,\omega)\exp(\frac{i}{2}\omega^2(\beta_{21}L_1 + \beta_{22}L_2) - i\omega t)d\omega \tag{2.6}$$

where $L = L_1 + L_2$ and β_{2j} is the GVD parameter for the fiber segment of length L_j. If the DCF is chosen such that ω^2 term vanishes then pulse can recover its original shape. So the perfect condition for dispersion compensation using DCF is[4]

$$\beta_{21}L_1 + \beta_{22}L_2 = 0 \tag{2.7}$$

or

$$D_1L_1 + D_2L_2 = 0 \tag{2.8}$$

Since in case of standard SMFs, $D_1 > 0$, equation 2.8 shows that dispersion D_2 of DCF should be negative for dispersion compensation. Also length, L_2, of DCF should satisfy[4]

$$L_2 = -L_1(\frac{D_1}{D_2}) \tag{2.9}$$

To overcome residual dispersion in high speed systems, the dispersion slope, S_2, of DCF should satisfy[4]

$$S_2 = -S_1\frac{L_1}{L_2} = S_1\frac{D_2}{D_1} \tag{2.10}$$

where S_1 is the dispersion slope of SMF. According to the relative position of DCF and single mode fiber different compensation schemes: post compensation, pre compensation and symmetrical/mix compensation, are proposed. DCF pre compensation scheme achieve dispersion compensation by placing the DCF before a conventional single mode fiber i.e. after the optical transmitter. Post compensation scheme achieve dispersion compensation by placing the DCF after the single mode fiber. Symmetrical/mix compensation scheme consist of both pre-compensation and post compensation. In this paper, we compare these three dispersion compensation methods and evaluate the performance characteristics of the WDM system based on parameters like Quality factor (Q factor) and Bit Error Rate (BER).

3. Simulation Setup

A 4 channel WDM optical network was designed at 8Gbps using the Optisystem7.0 simulator software. The basic block diagram of the simulation setup is shown in Fig.3.1. The transmitter section consists of a data source, which produces a pseudo random sequence of bits at 8Gbps. Electrical pulse generator (NRZ or RZ according to the required modulation format) converts the binary data into electrical pulses that modulates the laser signal through the mach-zehnder modulator. There are 4 laser sources generating optical signals of different wavelengths and the channel spacing used is 200 GHz. The multiplexer combines the input channels and transmits over optical fiber channel consisting of SMF and DCF. At the receiver side, a 1:4 demultiplexer is used to split the signals to 4 different channels. The output of the demultiplexer is given to PIN photodetector and then passed through low pass electrical Bessel filter and BER Analyzer.

The relative position of SMF and DCF was chosen according to the compensation scheme. The number of spans is taken to be 2 in pre and post compensation schemes. In symmetrical compensation scheme only single span is used with 2 DCFs and 2 SMFs each are used, so that the total length of the link is same in all the three compensation schemes. EDFAs are used between the links in order to amplify the signals. To study the performance of the WDM system at various transmission distances, the length of SMF and DCF chosen are shown in Table.3.1. The parameters of SMF and DCF used for simulation are shown in Table.3.2.

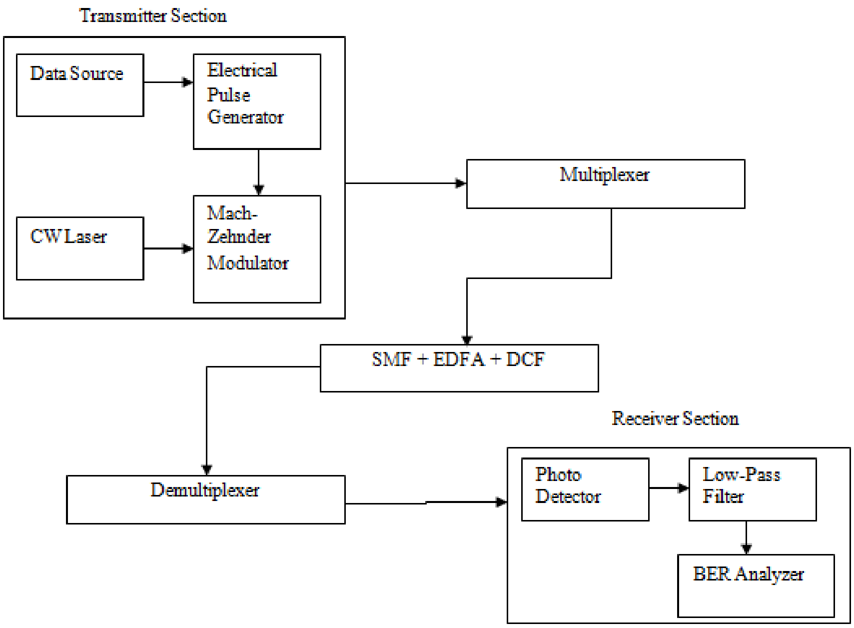

Fig .3.1 Basic block diagram of simulation setup

Table 3.1. Different cases of transmission distance

Length of SMF(*km*)	Length of DCF(*km*)
36	7.6
72	15
108	22.7
120	25.2
132	27.8

BER and Q-Factor are the parameters measured to evaluate the performance of the WDM system. Typical BER for optical fiber communication system ranges from[6] 10^{-9} to 10^{-12}. The acceptable value of BER for most communication systems is 10^{-9} or lower[4]. The BER improves as Q increases and becomes lower than 10^{-9} for Q > 6. If BER becomes greater than this value output signal become undetectable.

Table.3.2.Parameters of SMF and DCF

Parameter	SMF	DCF
Dispersion(ps/nm/km)	17	-80
Attenuation(dB/km)	0.2	0.6
Dispersion slope(ps/nm^{2}km)	0.075	-0.35
Effective area(μm^2)	80	22

4. Results And Discussion

The performance of the WDM system without placing DCF in the transmission link was analyzed. The BER obtained at different link lengths are plotted in Fig.4.1.

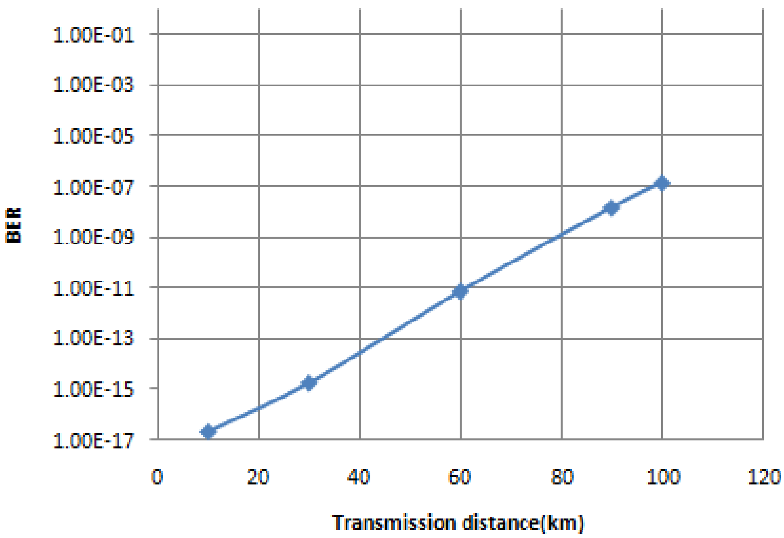

Fig.4.1.BER vs. transmission distance

From the plots it is clear that as the transmission distance increases, the BER increases. When the transmission distance approaches nearly 80km, the BER becomes greater than 10^{-9}. So in order to achieve a transmission distance above 80km with acceptable value of BER (BER < 10^{-9}) and Q factor (Q > 6) some dispersion compensation schemes are necessary.

To see the effect of pre, post and symmetrical compensation schemes using DCF on performance of WDM system, DCF was inserted to the link. The values of BER and Q factor obtained at different transmission distances corresponding to the cases in Table.3.1 with different compensation schemes are plotted in Fig.4.2 and Fig.4.3. In this case NRZ modulation format was used. The value of EDFA power is chosen to be 2dBm for all the cases.

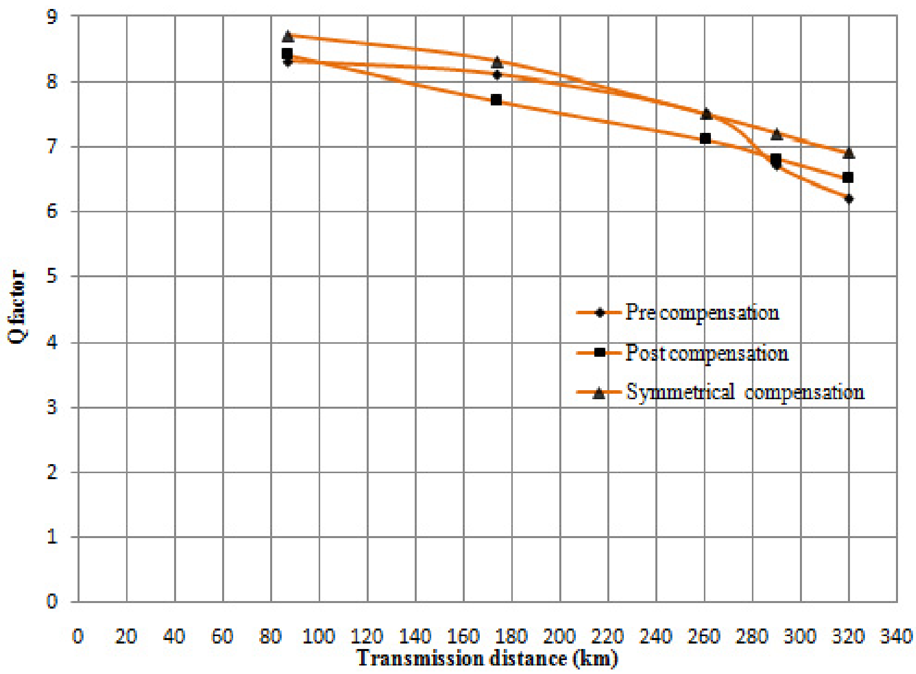

Fig.4.2.Q factor vs. Transmission distance with different compensation schemes

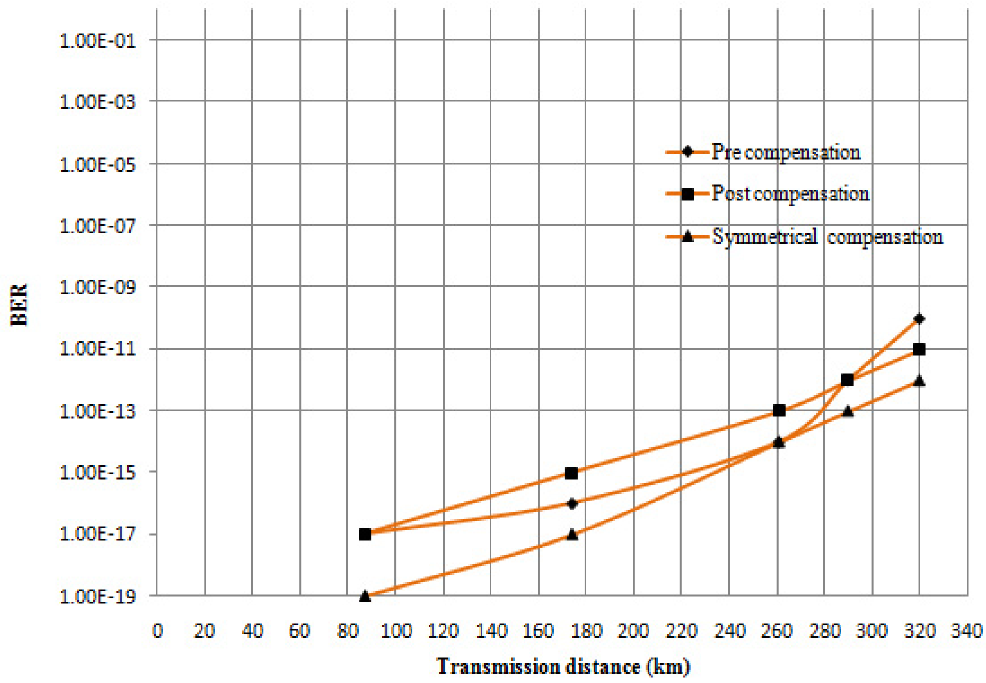

Fig.4.3.BER factor vs. Transmission distance with different compensation schemes

When compared with Fig. 4.1, it is seen that a better performance of WDM system is achieved when dispersion compensation is introduced and a higher transmission distance can be obtained with a better value of Q factor and BER. From the Fig.4.3 it is also clear that symmetrical compensation provides better performance with a low value of BER. Even at a transmission distance of 320km,a BER of 10^{-12} is obtained using symmetrical compensation. So a transmission distance above this can be obtained using this scheme. But in case of post and pre compensation the variation of Q factor and BER with distance is high. So further increase in link length is not possible. Comparing post and pre compensation it can be seen from the figure that former performs the best at longer distance.

To see the performance of the above WDM system when RZ modulation format is used, in the simulation setup NRZ pulse generator was replaced with RZ pulse generator. The values of Q Factor and BER obtained using RZ modulation format with different compensation schemes is plotted in Fig.4.4 and Fig.4.5.

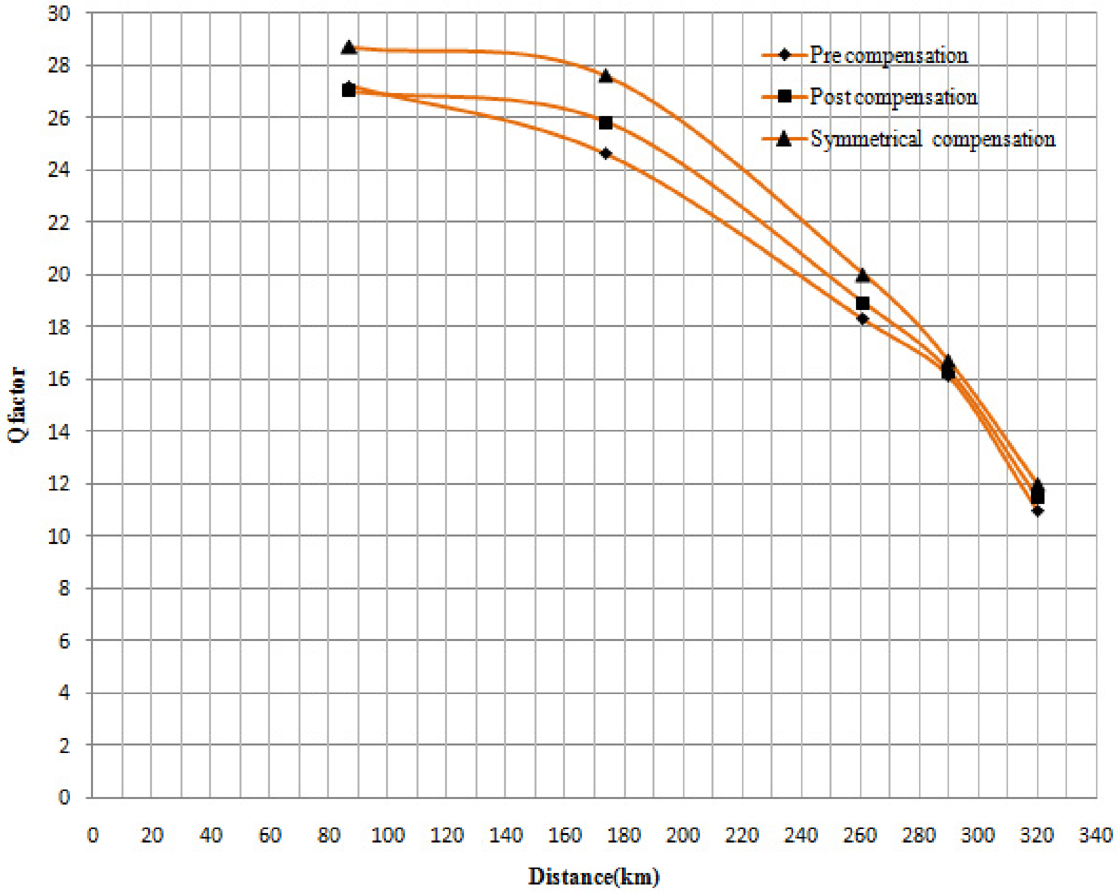

Fig.4.4 .Q factor vs. Transmission distance with RZ modulation format.

It is clear from the figures that system with RZ modulation format performs better with all the compensation schemes. But the variation in Q factor and BER with distance is higher when compared with system using NRZ modulation format. In this case also performance of the WDM system with symmetrical compensation scheme is the best.

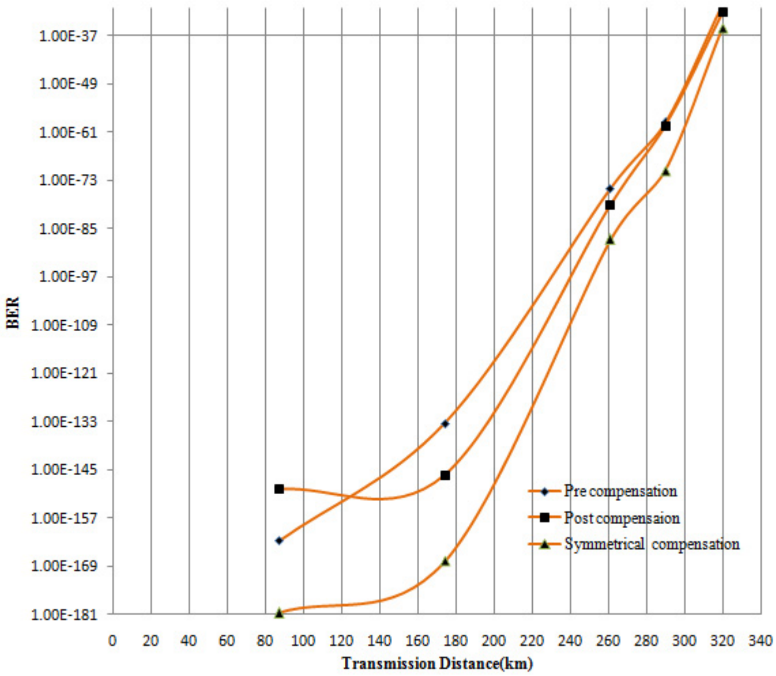

Fig.4.5 .BER factor vs. Transmission distance with RZ modulation format.

5. CONCLUSION

The work has emphasized on analysis of WDM system with dispersion compensation techniques using DCF at 8Gbps. The performance of the system is evaluated using the parameters, BER and Q factor, with pre, post and symmetrical compensation techniques using DCF at various link lengths. Best performance of the WDM system is obtained with symmetrical compensation. And a transmission distance of above 320km can be obtained using symmetrical compensation with acceptable value of BER and Q factor. It is also seen that the performance of the WDM system is further enhanced when RZ modulation format is used. When comparing pre and post compensation techniques, later shows best performance. It can be concluded that at 8Gbps a WDM system using RZ modulation format and symmetrical compensation technique shows better performance.

References

1. Hu,Bo-ning, et al. Analysis on Dispersion Compensation with DCF based on Optisystem. *Industrial and Information Systems (IIS), 2010 2nd International Conference on*.Vol. 2.IEEE; 2010.

2. R.S Kaler, Ajay K Sharma, T.S Kamal, Comparison of pre-, post- and symmetrical dispersion compensation schemes for 10Gb/s NRZ links using standard and dispersion compensated fibers. *Optics Communications* 209 (2002) 107–123.

3. N.K.Kahlon, G.Kaur. Various Dispersion Compensation Techniques for Optical System: A Survey.*Open Journal Of Communications And Software*, Volume 1, Number 1; May 2014..

4. Govind P. Agrawal,*Fiber-Optic Communications Systems*, 3rd ed. John Wiley & Sons, Inc., 2002, pp.155-266.

5. Bhupeshwaran Mani, Sivasubramanian. Design of Symmetric dispersion compensated, long haul, Single and Multichannel Optical Lightwave Systems in Telecommunications: Theory, Background and Simulation Model-A Study. *IOSR Journal of Electronics and Communication Engineering, Volume 7, Issue 4 (Sep. - Oct. 2013), PP 69-82*

6. Gerd Keiser, *Optical Fiber Communications*, 4thed.Tata McGraw Hill Education Private Limited,2008, pp.255-412.