Dispersion Compensation in 16x40 Gb/s WDM system using DCF

Manpreet Kaur[1], Himali Sarangal[2]
[1] *M.Tech(student),Department of Electronics and Communication Engineering, GNDU RC Jalandhar, India*
[2] *Asst.Prof. Department of Electronics and Communication Engineering, GNDU RC Jalandhar, India*

Abstract— In wavelength division multiplexed (WDM) optical systems, the dispersion compensation is a key issue. A lot of research is going on for dispersion management in WDM optical systems. One way to compensate the dispersion is by using the dispersion compensating fibers. In this paper, the different dispersion compensation techniques using dispersion compensating fibers (DCFs) for 16x40Gbps WDM system has been analyzed and compared in terms of Q-factor, bit error rate (BER) and eye height. Optisystem is used for designing and simulation of the proposed WDM system. The simulation results obtained here demonstrate that the symmetrical-dispersion compensation technique is superior to the other techniques.

Keywords— *Dispersion compensation, WDM (wavelength division multiplexing), BER, Q-factor.*

I. INTRODUCTION

Wavelength division multiplexing (WDM) can significantly increase the information carrying capacity of optical networks. The capacity in WDM system can be further enhanced by increasing either the per channel data rates or the number of multiplexed channels. But, there are several factors that can degrade the performance of WDM optical networks, which are attenuation, chromatic dispersion, polarization mode dispersion and non-linear effects [1].

The losses due to attenuation in long distance transmission systems can be overcome by using the optical amplifiers (EDFA, SOA and Raman amplifier). EDFA (Er-doped fiber amplifier) is most commonly in optical transmission systems. It operates in 1550 nm wavelength window. [2], [3]. Fiber chromatic dispersion is the most severe limiting factor in long distance transmission system. So, dispersion management is very important in long distance WDM optical networks. To compensate dispersion in WDM system, various techniques are available, which are Fiber bragg gratins (FBG), Dispersion compensating fibers (DCFs), Optical phase conjugator (OPC), Electronic dispersion compensation (EDC) etc [4].

Considering all these dispersion management schemes, the dispersion compensating fibers (DCFs) has been used in this work to reduce the overall dispersion in the WDM optical network. Dispersion compensating fiber (DCF) can be connected in three configurations, pre-, post- and symmetrical/mix-compensation.

The paper [5] has investigated the 8 channel WDM system at 40 Gbps using dispersion compensating fibers (DCFs) over 50 km of single mode fiber (SMF) and 10 km of DCF with RZ super Gaussian pulse. The number of spans taken to be 4 i.e. the total length of the link is 240 km. In the investigation, the performance of pre-, post- and symmetrical-compensation techniques is compared for the different WDM systems.

The paper [6] has analyzed the 16 channel DWDM system with pre-, post- and symmetrical-compensation schemes using DCF with different modulation formats and at different bit rates 10, 20 and 40 Gbps. They have used the 50 km of SMF and 10 km of DCF. Paper [12] analyzed the 8x40Gbps WDM system for different dispersion compensation techniques.

In this paper, we have extended the work reported in [5] and [6]. We have investigated the 16x40 Gbps WDM system using DCF over the 100 km of SMF and 20 km of DCF. The number of spans taken to be 2 i.e. the total length of the link is 240 km.

The rest of the paper is organized as followed; in section II, The effects of dispersion are discussed. Section III discussed the Dispersion compensating fibers (DCFs). Simulation methodology is described in section IV. Section V presents the results and discussion and section VI concludes the Paper.

II. EFFECTS OF DISPERSION ON OPTICAL TRANSMISSION SYSTEM

Dispersion characterized the optical fiber in terms of maximum transmission speed. When different wavelengths of light pulses are launched in the single optical fiber, these pulses travel with different speeds due to the variation of refractive index with wavelength. The pulses tend to get spread out in time domain after travelling some distance in fiber and this is continued throughout the fiber length. This phenomenon of broading of pulse width is known as dispersion. Dispersion of transmitted optical signals causes the distortion for both digital and analog transmission through the optical fiber. Each light pulse spreads and overlaps with its neighboring pulses and becoming indistinguishable at the receiver end. This effect is known as inter symbol interference (ISI) [7].

Dispersion limits the information carrying capacity at high transmission speeds and distances. It reduced the effective bandwidth and increases the bit error rate (BER) due to ISI. In SMF, the performance is primarily limited by the chromatic dispersion (CD) and polarization mode dispersion (PMD). Chromatic dispersion occurs because the index of glass varies slightly depending upon the wavelength of light and PMD occurs because the SMF carry the two polarization modes and slight distortion of fiber can alter the propagation speeds of two polarization modes. This phenomenon is known as the birefringence [8]-[11].

III. DISPERSION COMPENSATING FIBERS (DCFS)

DCF is currently used as the standard solution for dispersion compensation in long-haul WDM optical links. The DCFs have very high negative dispersion -70 to -90 ps/nm/km while there is the positive dispersion in SMF, so by inserting the DCF the net dispersion is zero.

There are three dispersion compensation schemes based on DCF, which are:

i. Pre-compensation

ii. Post-compensation

iii. Symmetrical-compensation

In pre-compensation scheme, the DCF is placed before the SMF. In post-compensation, the DCF is placed after the SMF. In symmetrical/mix-compensation, both the above schemes are used to compensate the positive dispersion in SMF [12].

IV. SIMULATION METHODOLOGY

The 16 x 40 Gbps WDM system is designed and simulated using Optisystem simulator software. Three dispersion compensation schemes (pre-, post- and symmetrical) using DCF are investigated and compared. The parameters used in the simulations are shown in Table 1 and Table 2 presents the fiber parameters used in the simulations.

In the simulations, the transmitter section consists of data source, which produced the pseudo random sequence of bits at 40 Gbps. NRZ pulse generator converts the binary data into the electrical pulses that modulates the laser signal through the Mach-Zehnder modulator (M-Z). The transmitter section block diagram is as shown in “Fig. 1”.

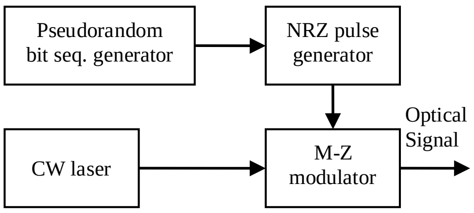


Fig.1: Transmitter section block diagram [12]

There are 16 laser sources generating optical signals of different wavelengths, the channel spacing of 100 GHz is used with 1 dbm output power.

The multiplexer combines the 16 input channels and transmit over the fiber optical channel. The transmission channel consists of SMF of length 100 km and DCF of length 20 km. The number of spans taken to be 2 in pre- and post-compensation schemes i.e. total length of the link is 240 km. In symmetrical-compensation scheme, 2DCFs of length 20 km each and 2SMFs of length 100 km each are used so that the total length of the link is same in all the schemes i.e. 240 km. Er-doped fiber amplifiers (EDFA) are used in the system to amplify the optical signals.

At the receiver side, 1:16 demultiplexer is used to splits the signal to 16 different channels. The output of the Demultiplexer is given to PIN photo detector and passes through the low pass Bessel filter and 3R regenerator. The receiver side block diagram is as shown in “Fig. 2”.

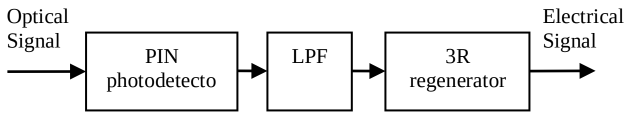


Fig.2:Receiver section [12]

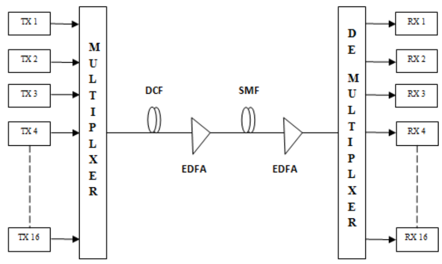
Table 1. Simulation parameters

Parameters	Value
Bit rate	40 Gbps
Sequence length	64
Samples per bit	256
Central frequency of first channel	192.3 THz
Channel spacing	100 GHz
Capacity	16x40 Gbps

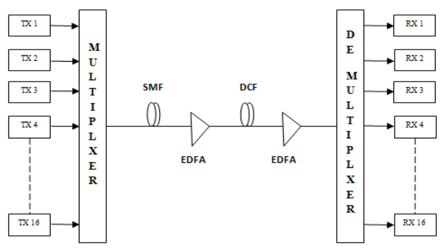
Table 2. Fiber parameters

	SMF	DCF
Length (km)	100	20
Attenuation (db/km)	0.2	0.6
Dispersion (ps/nm/km)	17	-80
Dispersion slop (ps/nm^2/km)	0.08	0.3
Differential group delay (ps/km)	0.5	0.5

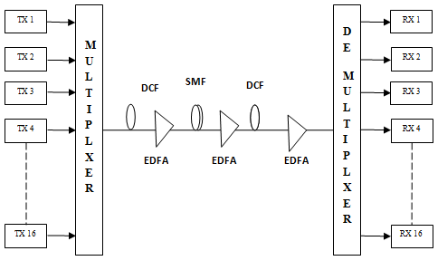
The block diagrams of simulation setups for the three schemes are shown in “Fig. 3”.



(a) Pre-compensation



(b) Post-compensation

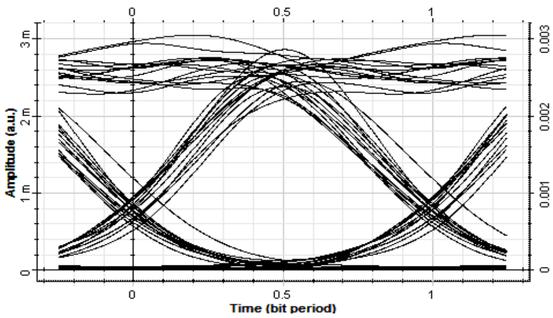


(c) Symmetrical-compensation

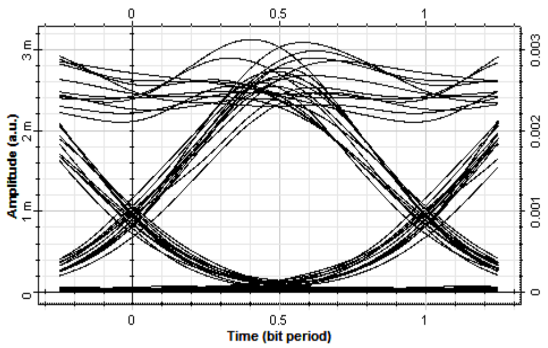
Fig.3: Block diagram of simulation setups of three schemes

V. RESULTS AND ANALYSIS

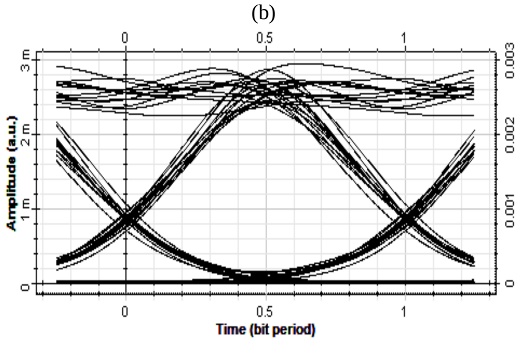
The different dispersion compensation techniques have been compared for 16x40 Gbps WDM system in terms of BER, Q-factor and eye height. To analyze the system, the eye diagrams at first channel for the three dispersion compensation schemes are shown in “Fig. 4”. The graphs for the parameters, BER, Q-factor and eye height at the 16 different frequencies for three schemes are shown in “Fig.5” and compared.



(a)

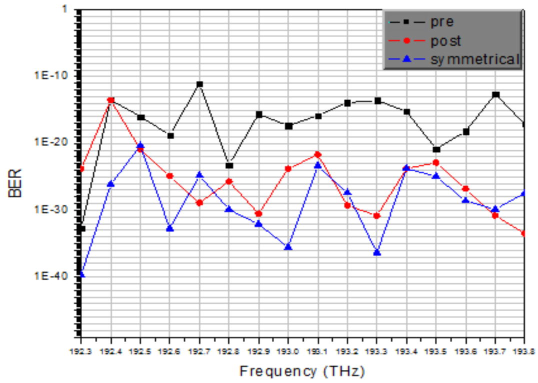


(b)

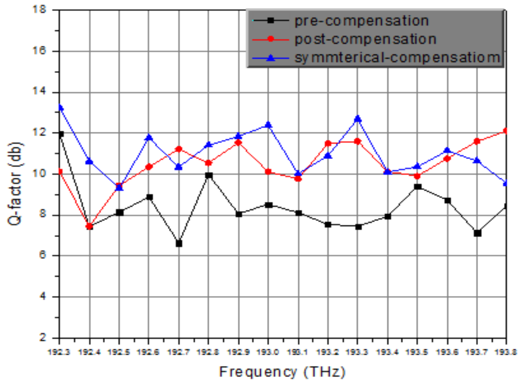


(c)

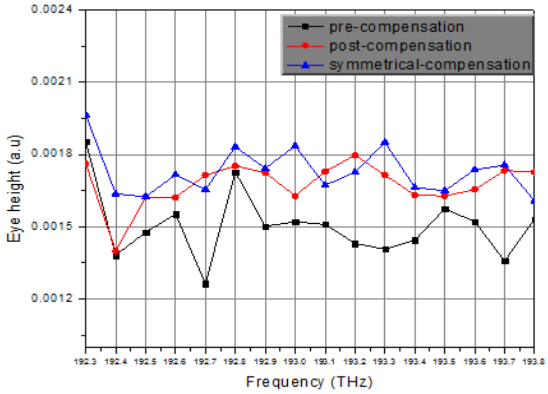
Fig.4: Eye diagrams of (a) pre-compensation (b) post-compensation and (c) symmetrical-compensation schemes



(a) BER for 16 users at different freq.



(b) Q-factor for 16 users at different freq.



(c) Eye height for 16 users at different freq.

Fig.5: Comparison of three compensation schemes

VI. CONCLUSION

One of the most severe impairments that limit the performance in long distance and high speed optical transmission systems is dispersion. In this investigation, the performance of pre, post and symmetrical-dispersion compensation techniques using DCF is compared for the 16x40 Gbps WDM System with channel spacing of 200GHz. The dispersion management is a key issue in long-haul WDM system at high bit rates. The simulation results revealed that the symmetrical-dispersion compensation technique performs better than the pre- and post-compensation techniques for 16x40 Gbps WDM system.

VII. ACKNOWLEDGMENT

The authors would like to acknowledge the GNDU for providing the Optisystem software.

VIII. REFERENCES

[1] J.-J. Yu, Kejian Guan, Bojun Yang, "The effects of channel separation, input power and cross-phase modulation on nonlinear WDM systems with dispersion compensation", Optics Communications 151 _1998. 222–228.

[2] R.S. Kaler, "Simulation of 16 x 10 Db/s WDM system based on optical amplifiers at different transmission distance and dispersion," Optik 123, 1654-1658, 2012.

[3] M.I. Hayee, A.E. Willner, Senior Member, "Pre and post-compensation of dispersion and linearities in 10-Gb/s WDM, IEEE Photon. Technology, Lett. 9 (9), 1997.

[4] R.J. Nuyts, Y.K. Park, P. Gallion, Dispersion equalization of a 10 Gb/s repeatered transmission system using dispersion compensating fibers, J. Lightwave Tech nol. 15 (1), 31–42, 1997.

[5] Gurinder Singh, Ameeta Seehra and Sukhbir Singh, "Investigations on order and width of RZ super Gaussian pulse in different WDM systems at 40 Gb/s using dispersion compensating fibers," Optik 125, 4270-4273, 2014.

[6] Jyoti Choudhary, Lalit Singh Garia and Rajendra Singh Shahi, "Comparative analysis of DWDM system using different modulation and dispersion compensation techniques at different bit rates," International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE), ISSN: 2278-1021, vol.3 Issue 5, 6512-6518, May 2014.

[7] Bo-Ning HU, Wang Jing, Wang Wei, Rui-Mei Zhao, Analysis on Dispersion Compensation with DCF based on Optisystem, 2nd International Conference on Industrial and Information Systems 2010, 40-43.

[8] S.Shen and A. M. Weiner, Complete Dispersion Compensation for 400-fs Pulse Transmission over 10-km Fiber Link Using Dispersion Compensating Fiber and Spectral Phase Equalizer, IEEE photonics technology letters, vol. 11, no. 7, July 1999, 827-829.

[9] Saurabh Kumar, Prof. A. K. Jaiswal, Er. Mukesh Kumar, Er. Rohini Saxena, Performance Analysis of Dispersion Compensation in Long Haul Optical Fiber with DCF, IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735, Volume 6, 2013, 19-23.

[10] R.S. Kaler, A.K. Sharma, T.S. Kamal, "Comparison of pre-, post- and symmetrical- dispersion compensation schemes for 10 Gb/s NRZ links using standard and dispersion compensated fibers," Optics. Communication, 209, 107–123, 2002.

[11] Manpreet Kaur, Himali Sarangal, "Analysis on Dispersion Compensation with Dispersion Compensating Fibers (DCF)," SSRG International Journal of Electronics and Communication Engineering (SSRG-IJECE), ISSN:2348-8549, Vol. 2, Issue 2, February 2015, 56-59.

[12] Manpreet Kaur, Himali Sarangal, " Performance comparison of Pre-, Post- and Symmetrical-Dispersion Compensation Techniques using DCF on 40Gbps WDM System," International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE), ISSN-2278-909 vol. 4, Issue 3, March 2015, 494-496.