ABHIYANTRIKI
An International Journal of Engineering & Technology
(A Peer Reviewed & Indexed Journal)
Vol. 4, No. 4 (April, 2017) http://www.aijet.in/ eISSN: 2394-627X

Compensation of Dispersion by using Dispersion Compensation Fiber (DCF)

Ranjita Rout
Assistant Professor
Deptt. of Electronics Engineering & Technology,
Gandhi Institute of Engineering & Technology,
Gunupur, Rayagada, India

Priyanka Mund*
B. Tech.
Department of ECE
Gandhi Institute of Engineering & Technology,
Gunupur, Rayagada, India

Krishna Kumari Pund
B. Tech.
Department of ECE
Gandhi Institute of Engineering & Technology, Gunupur, Rayagada, India

Abstract

Dispersion compensating fibers (DCF) are used to compensate the positive dispersion accumulated over the fiber length at 20 Gbits/sec. When different wavelengths of light pulses are launched into the optical fiber, these pulses travelled with different speeds due to the variation of refractive index with wavelength. The light pulses tend to get spread out in time domain after travelling some distance in fiber and this is continued throughout the fiber length. Three schemes of dispersion compensation (pre, post and symmetrical) with DCF are proposed in this paper by using OptiSystem 7.0 simulator. The results of three dispersion compensation schemes are compared in terms of Q-factor, BER, Eye height and Threshold value. Further, it has been observed that the system needs proper matching between EDFA gain and length of fiber for optimum performance. Motivation to this research is to compare all three compensation methods and it is found that the symmetrical compensation method is superior to pre- and post compensation methods. On comparing pre and post-compensation methods, it is found that the later is superior to the former. Thus by using these comparisons one can get a promising system to the symmetric high capacity access network with high spectral efficiency, cost effective, good flexibility.

Keywords: *Dispersion Compensation, DCF, Bit Error Rate (BER), Quality Factor.*

****Author for correspondence*** shikhamund09@gmail.com

1. Introduction

With the rapid growth of internet business needs, people urgently need more capacity and network systems. So the demand for the transmission capacity and bandwidth are becoming more and more challenging to the carriers and service suppliers. Under this situation optical fiber is becoming the most favorable delivering media and laying more and more important role in information industry, with its huge bandwidth and excellent transmission performance. When optical signals are transmitted over the optical links, different wavelength components of the signals will generally experience different propagation time due to the fact that the transport medium has different effective refractive indices for different wavelengths. In the recent years, with the rapid growth internet business needs, people urgently need more capacity and network systems. So the demand for the transmission capacity and bandwidth are becoming more and more challenging to the carriers and service suppliers. Therefore, it is necessary to investigate the transmission characteristics of optical fiber. The main goal of any communication system is to increase the transmission distance. Loss and dispersion are the major factors that affect the fiber optic communication system. In this paper, three dispersion compensation schemes (post-compensation, pre compensation and symmetrical/mix compensation) are analyzed to compensate dispersion in SMF. Simulation studies show that the symmetrical/mix compensation scheme is the best. It can greatly reduce the influences of the fiber nonlinearity and increase the transmission distance greatly.

2. Effects of Dispersion on Optical Communication Systems

Dispersion characterized optical fiber in terms of maximum transmission speed. When different wavelengths of light pulses are launched into the optical fiber, these pulses travelled with different speeds due to the variation of refractive index with wavelength. The light 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 broadening of pulse width is known as dispersion. Dispersion of transmitted optical signals causes the distortion for both digital and analog transmission through optical fiber. Each pulse broadens and overlaps with its neighbours eventually becoming indistinguishable at the receiver input. This effect is known as inter symbol interference (ISI).It reduces the effective bandwidth and at same time it increases the BER due to an increasing inter symbol interference.

3. Dispersion Compensation Techniques

In order to increase the system performance various dispersion compensation technologies are proposed. Among the various techniques proposed, the once that hold immediate promise for dispersion compensation are dispersion compensating fiber (DCF), chirped fiber bragg gratings (FBG), high order mode fiber (HOM). As the product of DCF are more mature, stable, not easily affected by temperature, wide band width, DCF has become among suitable method for dispersion compensation. As the components of DCF are more stable, not easily affected by temperature, wide bandwidth, DCF has become a most suitable method for dispersion compensation.

4. Dispersion Compensation with DCF

Dispersion compensating fiber has a high negative dispersion -70 to -90 ps/nm.km and used to compensate the positive dispersion of transmission fiber in C-band. According to the relative positions of DCF and single mode fiber the three dispersion compensation schemes pre-DCF, post-DCF and symmetrical/ mix-DCF are proposed. DCF-pre dispersion compensation is achieved by placing the DCF before the standard SMF. Post-DCF scheme achieve dispersion compensation by placing DCF after the standard SMF. Symmetrical/mix-DCF dispersion compensation scheme consists of both pre and post DCF dispersion compensation.

5. Simulation and Design Parameter Table

Table 1

SMF Parameters	Value
Reference wavelength	1550 nm
Length	150 km
Attenuation	0.25 db/km
Dispersion	17 ps/nm/km
Dispersion slope	0.08 ps/ /km
PMD coefficient	0.5 ps/km
Differential group delay	0.2 ps/km

Table 2

DCF Parameters	Value
Reference wavelength	1550 nm
Length	30 km
Attenuation	0.5 db/km
Dispersion	-80 ps/nm/km
Dispersion slope	0.08 ps/ /km

6. Simulation and Design Consideration

In these simulations, the transmitter section consists of data source, modulator driver (NRZ driver), laser source and Mach-Zehnder modulator (M-Z). Data source produces a pseudo random sequence of bits at data rate of 2.5 Gbits /sec. The output of the data source is given to modulator driver which produces a NRZ format pulse. The output of the laser source is CW type at frequency 193.1 THz and output power of 10 dBm. The Mach-Zehnder modulator has the excitement ratio of 30 db. The loop control system has one loop. Each span consists of 150 km of SMF and 30 km of DCF in order to fully compensate for the dispersion slope and accumulated dispersion in transmission fiber. The total length of the fiber channel is 180 km; however it is segmented into 1:5 i.e. 30 km of DCF and 150 km of SMF. Two EDFAs in front of transmission fiber (SMF) and DCF with gain 30 db, 15 db respectively and 4 db noise figure. At the receiver side the optical signal transformed into electrical signal by a PIN photodiode. Then the electrical signal is filtered by low pass Bessel filter.

7. Simulation Diagram

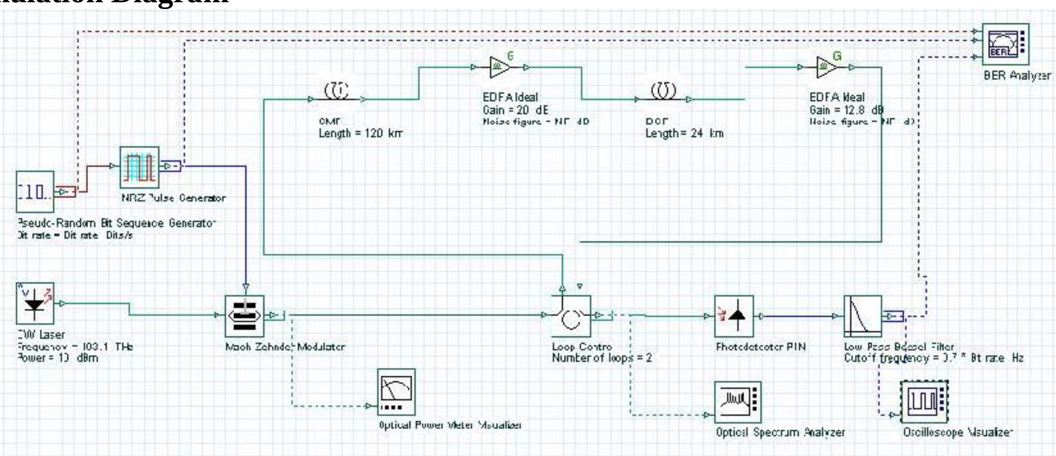

Figure a: Dispersion post compensation

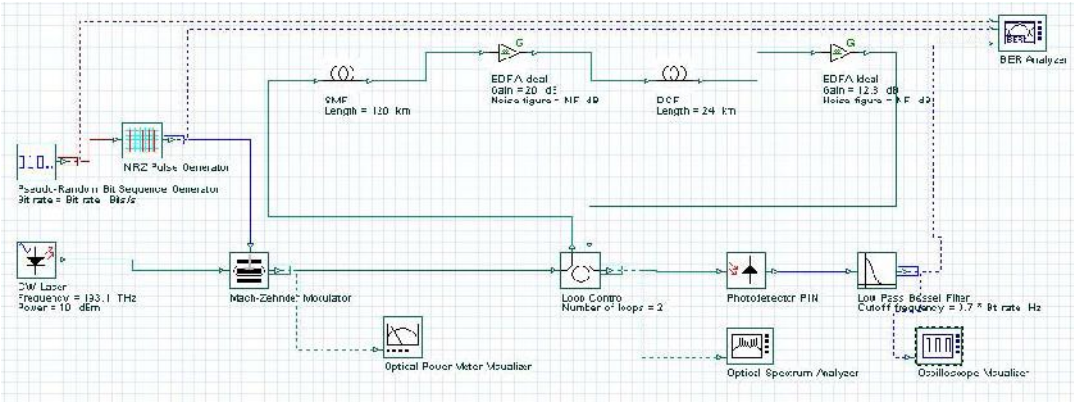

Figure b: Dispersion pre compensation

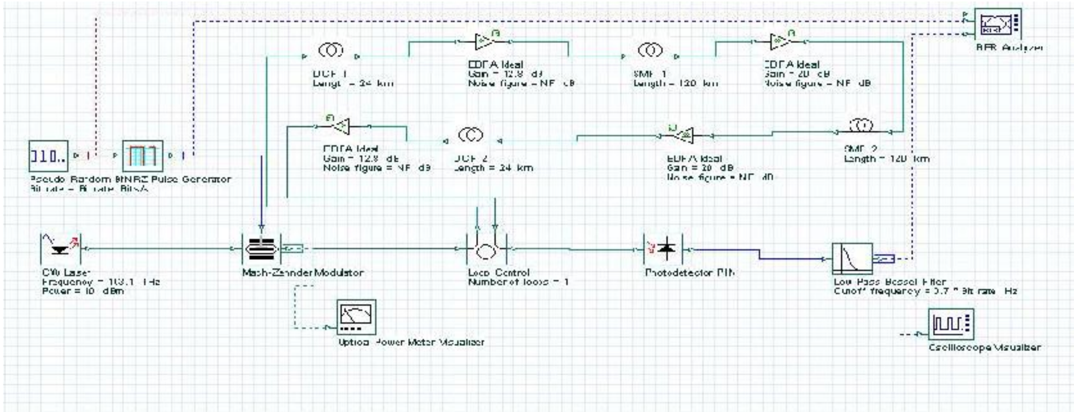

Figure c: Dispersion symmetrical compensation

Figure 1: Dispersion compensation techniques

8. Results and Analysis

The simulations are done in Optisystem 7.0 simulator. The eye diagrams for the three schemes are shown in figure 2.

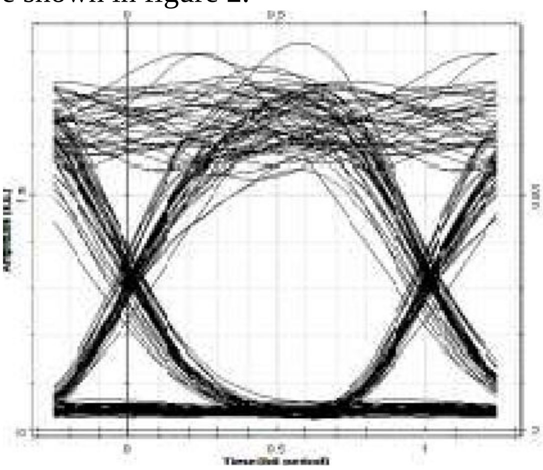

Figure (a) Post-compensation

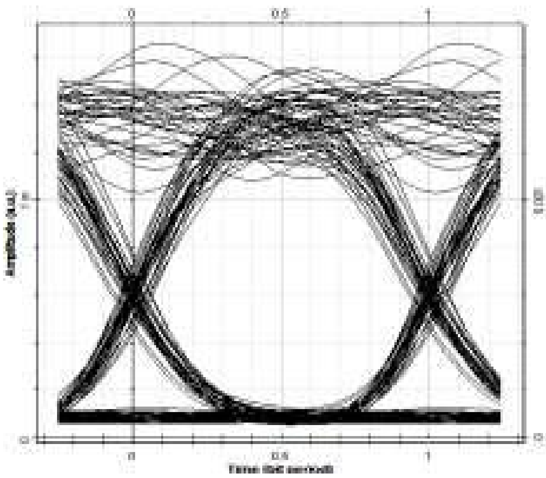

Figure (b) Pre compensation

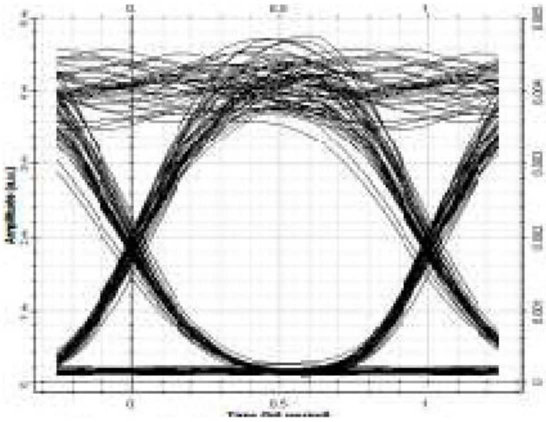

Figure (c) Symmetric compensation

9. Comparison of Three Dispersion Compensation Techniques

Table 3:

	Pre-compensation	Post-compensation	Symmetrical-compensation
Q-factor (dB)	5.22395	10.9964	21.5836
BER	8.00187e-008	1.86861e-028	1.14582e-103
Eye height	3.93313e-006	5.7598e-006	7.90557e-005
Threshold value	8.40115e-006	5.48348e-006	3.12374e-005

From the "Table 3" and eye diagrams, we can see that the symmetrical/mix compensation scheme is better than the pre-compensation and post –compensation schemes.

10. Conclusion

We have analyzed dispersion compensation with dispersion compensating fibers (DCF) at 20 Gbits/sec for 150 km of SMF and 30km of DCF. Three schemes of dispersion compensation (pre-, post-, and symmetrical/mix compensation) with DCF are proposed in this paper. After analysis, we find that the symmetrical/mix-dispersion compensation scheme is better than pre and post-compensation schemes. To obtain better signal at receiving end, we check for different combinations of SMF length, DCF length and EDFA gain.

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