

# Dispersion Compensation with Dispersion Compensating Fibers (DCF)

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**Abstract:** In this paper, dispersion compensating fibers (DCF) are used to compensate the positive dispersion accumulated over the length of the fiber at 10Gbits/sec and 250 km of optical fiber with 50 km of DCF. Three schemes (Pre-compensation, post-compensation and symmetrical-compensation) of dispersion compensation with DCF are proposed. The simulated transmission system has been analyzed on the basis of different parameters by using OptiSystem 7.0 simulator. The results of three dispersion compensation methods are compared in terms of four parameters, which are Q-factor, BER, Eye height and threshold value, investigated at the receiver end. Further, it has been observed that the system needs proper matching between EDFA gain and the length of the fiber for the optimum performance.

**Keywords:** Dispersion compensation, Dispersion compensating fiber (DCF), BER, Q-factor, Eye height.

## I. INTRODUCTION

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. Under this situation, optical fiber is becoming the most favourable delivering media and laying more and more important role in information industry, with its huge bandwidth and excellent transmission performance. 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. The EDFA (Erbium doped fiber amplifier) is the gigantic change that happened in the optical fiber communication systems; the loss is no longer major factor to restrict the fiber optic transmission. Since EDFA works in 1550 nm wave band, the average Single Mode Fiber (SMF) dispersion value in this wave band is very big, about 15-20ps / (nm.km-1). So, it is easy to see that the dispersion become the major factor that restricts the long distance fiber optic system. [1]

In this paper, three DCF compensation schemes (post-compensation, pre-compensation and symmetrical/mix compensation) are analyzed to compensate dispersion in SMF. Simulation studies show that post compensation scheme is the best. It can greatly reduce the influences of the fiber nonlinearity and increase the transmission distance greatly.

The rest of the paper is organized as followed. In section II, The causes and effects of dispersion on optical transmission system are presented. In section III, The present dispersion compensation technologies. In section

IV, DCF dispersion compensation technique is presented. Section V presents the transmission system simulation with OptiSystem 7.0 and different parameters are analyzed and compared. Section VI concludes the paper.

## II. EFFECTS OF DISPERSION ON OPTICAL COMMUNICATION SYSTEM

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 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. The pulse width gradually increases and the peak power of pulse reduces. Dispersion of the transmitted optical signal causes the distortion for both digital and analog transmission along optical fibers. Each pulse broadens and overlaps with its neighbours eventually becoming indistinguishable at the receiver input. This effect is known as inter symbol interference. [2]

Dispersion limits the information capacity at high transmission speeds. Dispersion reduces the effective bandwidth and at same time it increases the BER due to an increasing inter symbol interference. In order to remove the spreading of optical pulses, dispersion compensation is required. 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. Polarization mode dispersion is another source of limitation which 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. This phenomenon is called birefringence. [3], [4]

### III. DISPERSION COMPENSATION TECHNOLOGIES

In order to improve overall system performance and reduced as much as possible the transmission performance influenced by the dispersion, several dispersion compensation technologies were proposed. Amongst the various techniques proposed in the literature, the ones that appear to hold immediate promise 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 in 1980 but, until after the invention of optical amplifiers, DCF began to be widespread attention and study. As the products of DCF are more mature, stable, not easily affected by temperature, wide bandwidth, DCF has become a most suitable method of dispersion compensation.

There is positive second-order and third-order dispersion value in SMF, while the DCF dispersion value is negative. So by inserting a DCF, the average dispersion is close to zero. [5]

### IV. DISPERSION COMPENSATION WITH DCF

The use of dispersion compensating fibers is an efficient way to upgrade installed links of standard single mode fiber (SMF). Conventional dispersion compensating fibers have a high negative dispersion -70 to -90 ps/nm.km and can be used to compensate the positive dispersion of transmission fiber in C-band.

According to the relative position of DCF and single mode fiber, post-compensation, pre-compensation and symmetrical/mix compensation, is proposed. DCF pre-compensation scheme achieve dispersion compensation by placing the DCF before a conventional single mode fiber or after the optical transmitter. Post-compensation scheme achieve dispersion compensation by placing the DCF after the single mode fiber. Symmetrical/mix compensation scheme is consist of both pre-compensation and post-compensation. [6]

### V. METHODOLOGY

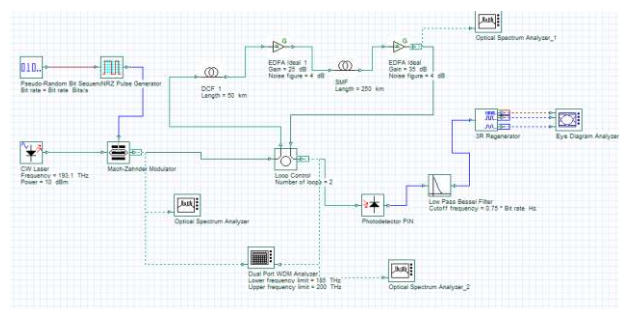
We used the Optisystem 7.0 for simulation and designing. It is an innovative, rapid developing and powerful software design tool. It enables the users to test and simulate almost all kinds of optical fiber links.

The Simulation of three dispersion compensation schemes is shown in Fig.1. We use the parameters in Table 1 for the simulation of dispersion compensation systems. In these simulations, the transmitter section consists of data source, modulator driver (NRZ driver), laser source and Mach-Zehnder modulator. Data source produces a pseudo-random sequence of bits at a rate of 10Gbit/s. The output of data source is given to modulator driver which produces NRZ format pulse with duty cycle of 0.5. The output of

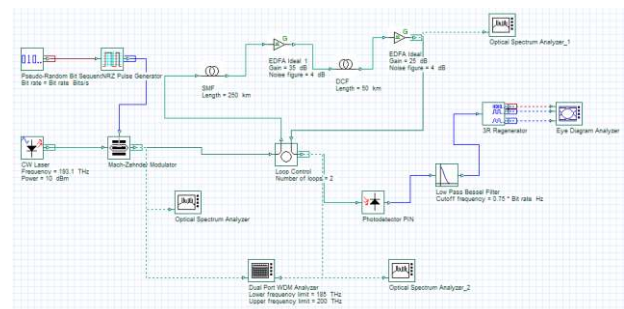
laser source is CW type at frequency 193.1 THz and output power of 5 dBm. The modulator is of Mach-Zehnder modulators have the Excitation ratio 30db. The loop control system has two loops. Each span consists of 250 km of transmission fiber (SMF) and 50 km DCF in order to fully compensate for the dispersion slope and accumulated dispersion in the transmission fiber. The total length of fiber channel remains same i.e. 300 km; however it is segmented in the ratio of 1:5 i.e. 50 km DCF and 250 km SMF. Two EDFAs in front of transmission fiber and DCF with 35 dB, 25 dB gain and 4 dB noise figures each are used to adjust input power levels. At the receiver side, the optical signal is transformed into an electrical signal by a PIN photodiode The PIN photo detector have the responsivity 1A/W and Dark current 10nA. The electrical signal is filtered by a low pass Bessel filter.

Table 1. Simulation parameters

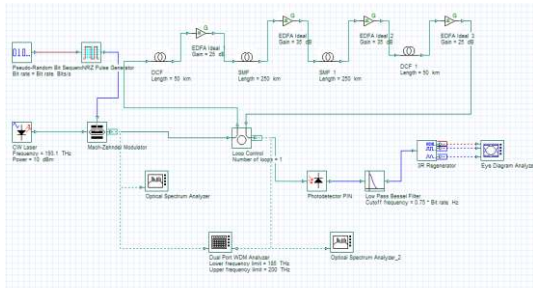
SMF Parameters	Value
Reference wavelength	1550 nm
Length	250 km
Attenuation	0.25 db/km
Dispersion	17.25 ps/nm/km
Dispersion slope	0.08 ps/nm <sup>2</sup> /km
PMD coefficient	0.5 ps/km
Differential group delay	3 ps/km
DCF Parameters	Value
Reference wavelength	1550 nm
Length	50 km
Attenuation	0.6 db/km
Dispersion	-80 ps/nm/km
Dispersion slope	0.08 ps/nm <sup>2</sup> /km
PMD coefficient	0.5 ps/km
Differential group delay	3 ps/km



(a) Pre-compensation



(b) Post-compensation



(c) Symmetrical/mix-compensation

Fig. 1: Three dispersion compensation schemes

## VI. RESULTS AND ANALYSIS

The eye diagrams for the three schemes are shown in Fig. 2. The parameters such as Q-factor, Min. BER, Eye height and Threshold value, for the three dispersion compensation schemes are tabulated into table 2 and compared.

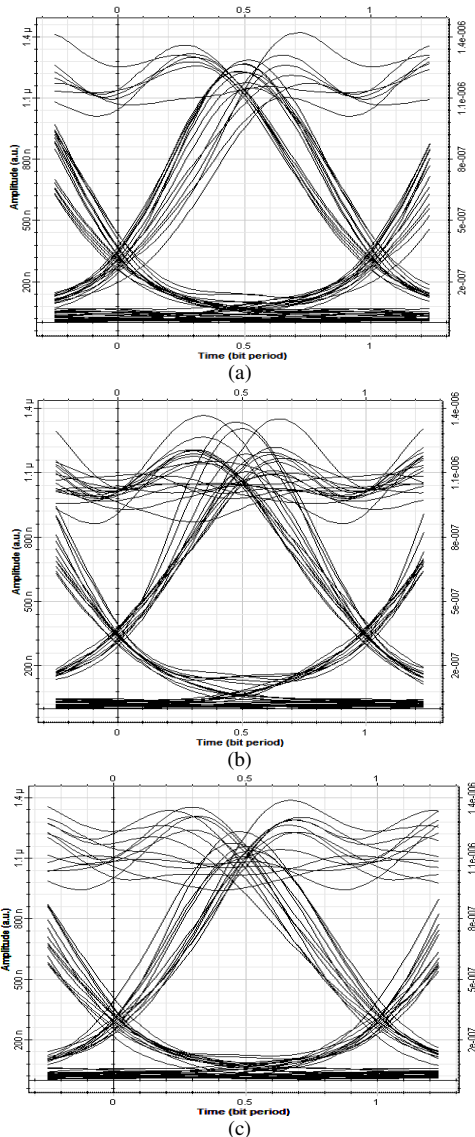


Fig. 2: Eye diagrams for (a) Pre-compensation, (b) Post-compensation and (c) Symmetrical/mix-compensation.

Table 2. Comparison of three dispersion compensation schemes

	Pre-compensation	Post-compensation	Symmetrical-compensation
Q-factor (db)	9.5471	7.80473	10.4526
BER	5.12141e-022	2.76965e-015	5.86482e-026
Eye height	7.53315e-007	6.37824e-007	7.48539e-007
Threshold value	3.90667e-007	3.98982e-007	3.67807e-007

From the Table 2 and eye diagrams, we can see that the symmetrical-compensation scheme performs better than the pre-compensation and post-compensation schemes.

## VII. CONCLUSION

We have analyzed dispersion compensation with dispersion compensating fibers (DCF) at 10 Gbits/sec for 250 km of SMF and 50 km 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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