Pak. J. Biotechnol. Vol. 13 (special issue on Innovations in information Embedded and Communication Systems)
Pp. 148 - 154 (2016)

ANALYSIS OF DISPERSION COMPENSATION TECHNIQUES IN DWDM OPTICAL NETWORKS

V Sathya*, R Hemalatha and R Mahalakshmi

Department of Electronics and Communication Engineering, Kumaraguru College of Technology, Coimbatore, India - 641049. Email: hemalatha.r.ece@kct.ac.in, vsathyabeece@gmail.com

ABSTRACT

Dense Wavelength Division Multiplexing (DWDM) is an extension of optical networking. DWDM devices combine the output of more than eight optical transmitters for transmission across a single optical fiber. Problems like dispersion, cross talk and other non-linear effects occur in optical networks. Dispersion is the spreading out of a signal as it travels down the fiber. Chromatic dispersion (CD) and polarization mode dispersion affects the DWDM. Chromatic Dispersion is a major factor in the transmission of data over a long haul application. To overcome the loss caused by CD, we can use different techniques.The proposed method focuses on the dispersion and its compensation techniques on DWDM networks. In order to compensate for the dispersion, various compensation techniques like Fiber Bragg Grating, Dispersion Compensation Fiber and Electronic Dispersion Compensation are employed. The DWDM architecture is implemented using OptSim. These dispersion compensation techniques are to be analyzed for DWDM networks. The simulation results show the performance of the DWDM system in terms of Bit Error Rate and Eye diagram.

Keywords: Dense Wavelength Division Multiplexing, Chromatic Dispersion, Fiber Bragg Grating, Dispersion Compensation Fiber, Electronic Dispersion Compensation.

INTRODUCTION

Dense Wavelength Division Multiplexing (DWDM) devices combine the output from different optical transmitters for transmission across a single optical fiber. At the receiver side, another DWDM device separates the combined optical signals and passes each channel to an optical receiver. Single mode fiber is used between DWDM devices (per transmission direction). Instead of requiring one optical fiber per transmitter and receiver pair, DWDM allows several optical channels to occupy a single fiber optic cable [4]-[5]. But the light signals degrade in intensity when they travel inside the fiber. Fibers suffer from dispersion and other nonlinearities due to fiber material and the distance travel inside the fiber. In DWDM network, dispersion, likes modal dispersion, chromatic dispersion and polarization mode dispersion. There are many ways to compensate these dispersion such as Electronic Dispersion compensation (EDC), dispersion compensating fiber (DCF), fiber Bragg grating (FBG) and optical filters[1], [9]. Out of them DCF is considered to be most efficient and easy to implement technique used to compensate dispersion. FBG is compact and low expensive to compensate dispersion. [3].

NEED FOR DISPERSION COMPENSATION

In Fiber optic Communication, when light signal is propagated through the fiber, due to the dispersion the system performance is degraded. In dispersion, different modes travel with different group velocity due to the material and waveguide property of the fiber, which causes a temporal broadening in optical pulses as they propagate through fiber [3]. As a result dispersion is a limiting factor on long haul application of fiber optic communication link. Thus in order to achieve high data rates, different dispersion compensation techniques used in DWDM networks [6].

COMPENSATION TECHNIQUES

A. Fiber Bragg Grating

Fiber Bragg Grating (FBG) is a one of distributed Bragg reflector constructed in a short segment of optical fiber that reflects only particular wavelengths of light and transmits all others. This is achieved by creating a periodic variation in the refractive index of the fiber core, which generates a wavelength-specific dielectric mirror [8]. Fiber Bragg Grating is used as an inline optical filter to block certain wavelengths, or as a wavelength-specific reflector.

B. Dispersion Compensation Fiber

Dispersion compensation essentially means cancelling the chromatic dispersion of some optical elements. The goal can be to avoid excessive temporal broadening of ultra short pulses and/or the distortion of signals.[6]Dispersion compensation is used mainly in mode-locked lasers and in telecommunication systems, but also sometimes in optical fibers transporting light to or from some fiber-optic sensor.

There are two types of compensation schemes pre,and post where the DCF is placed before, after the SMF or symmetrically across the SMF. A DCF should have low insertion loss, low polarization mode dispersion and low optical nonlinearity effects and also it should have large chromatic dispersion coefficient to minimize the size of a DCF [6]-[7]. By placing one DCF with negative dispersion after a SMF with positive dispersion, the net dispersion should be zero.

1. Pre-Compensation technique

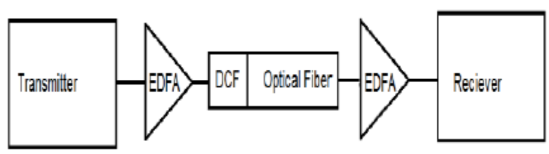

Fig. 1. Block diagram of pre-compensation

In pre-compensation technique, the DCF is placed before the SMF as shown in Fig. 1. This scheme modifies the characteristics of input pulses at transmitter, before they are sent into the fiber link, to compensate the effect of fiber dispersion.

2. Post-Compensation technique

In post-compensation technique, the DCF is placed after the SMF. To compensate the effect of fiber dispersion, this scheme modifies the characteristics of optical pulses at the receiver as shown in Fig 2.

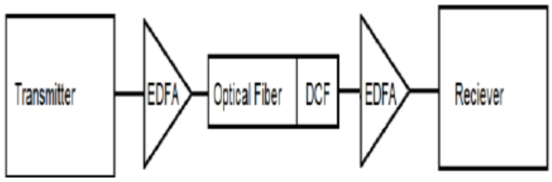

Fig. 2. Block diagram of post compensation

C. Electronic Dispersion compensation

Electronic compensation technique makes use of electronics in conjunction with optics in order to compensate dispersion. Electronic Dispersion Compensation (EDC) has become very important parts of an optical transponder design. At present, most of the installed optical fiber in the current metropolitan environment consists of single mode fiber with a CD value of about 17ps/nm/km at a wavelength of 1550 nm. In the current cost driven metro market, Electronic Dispersion Compensation can become a very important tool in enhancing the existing fiber links to higher bit rates. New applications using feed forward equalizer and decision feedback equalizer are being developed by International Telecommunication Union (ITU-T) to provide seamless up gradation facilities to the existing optical network systems [2].

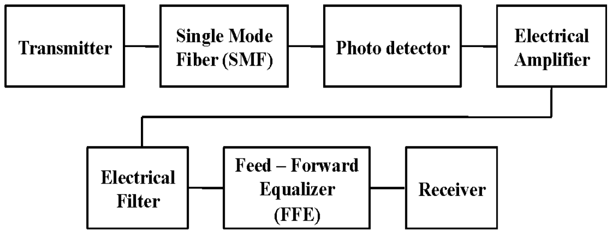

Fig. 3. Block diagram of Electronic Dispersion Compensation

SYSTEM MODELING

A. DWDM-(NO Compensation)

The model for the design of DWDM-(No Compensation) in OPTSIM (Optical Simulator) tool is shown in *Fig.2.*

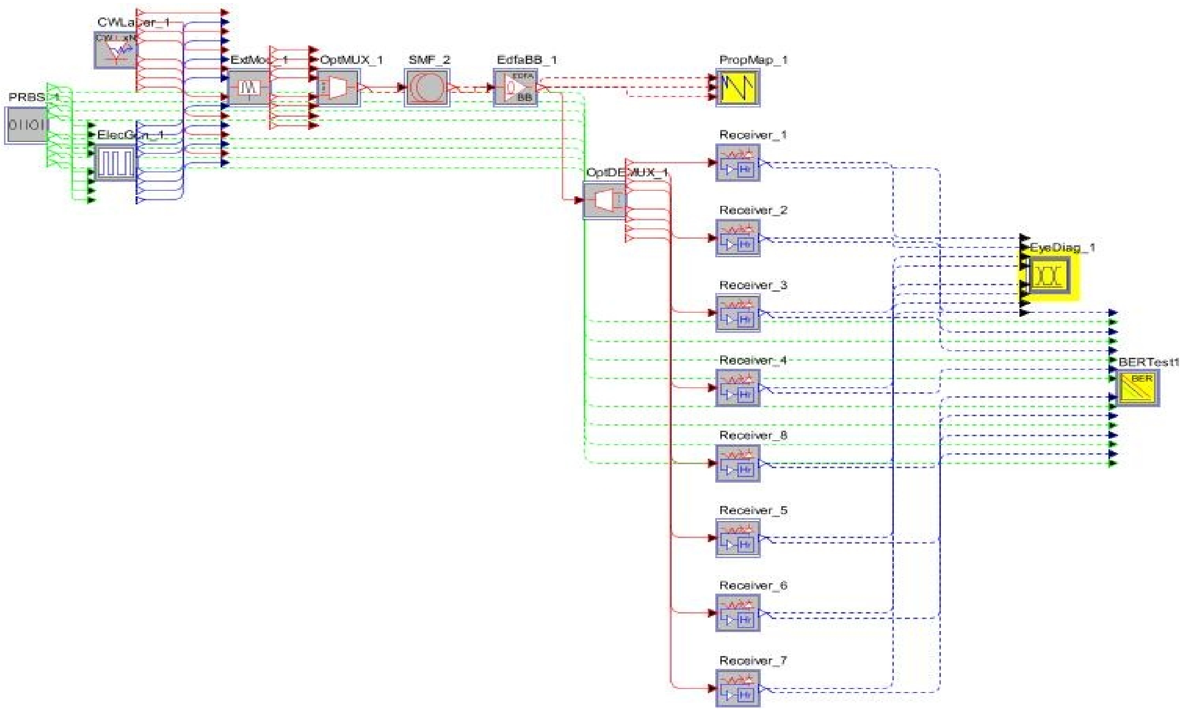

Figure 4 represents eight channel DWDM link with wide channel spacing. The eight channels are specified at the wavelengths 1543 nm to 1550 nm. The PRBS blocks are set to generate sequences which are offset from one another so that each of the signals are not propagating the same bit value at all time points. The component parameter offset determines the number of bits which the sequence should be rotated relative to the default before it is output. After the signals are generated in the direct modulated laser models, they are multiplexed into a single optical signal by the MUX model block. This model is set for ideal multiplexing. At the output of the MUX, the optical signal passes through a length of fiber (140km). After demultiplexing operation the individual signals are sent on eight separate receivers. The received signals are analyzed using BER tester, dispersion analyzer and eye analyzer blocks.

B. Fiber Bragg Grating

The model for the design of DWDM using fiber bragg grating in OPTSIM (Optical Simulator) tool is shown in *Fig.5.*

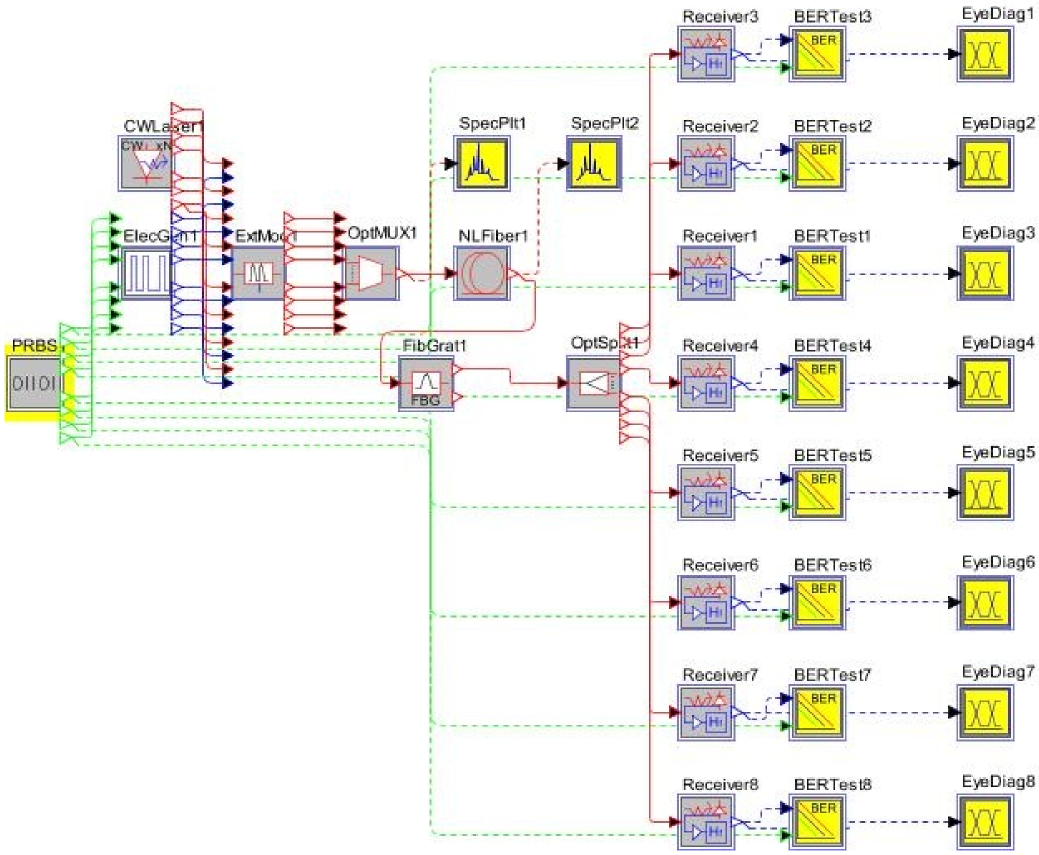

Fig. 5. Design of DWDM using fiber bragg grating

Figure 5 represents eight channel DWDM link with wide channel spacing. The eight channels are specified at the wavelengths 1543 nm to 1550 nm. The PRBS block is to generate the binary sequences of different types. The optical signals are generated in direct modulated laser block and they are multiplexed using MUX model block. The multiplexed optical signal is transmitted along the fiber of length 40 km. After that fiber bragg grating is used to compensate the dispersion and then demultiplexing operation is achieved using DEMUX model block, which outputs the individual signals on eight separate receivers. The received signals are analyzed using BER tester, Q-Factor tester, dispersion analyzer and eye analyzer blocks.

C. Dispersion Compensation Fiber

1. Pre-Compensation

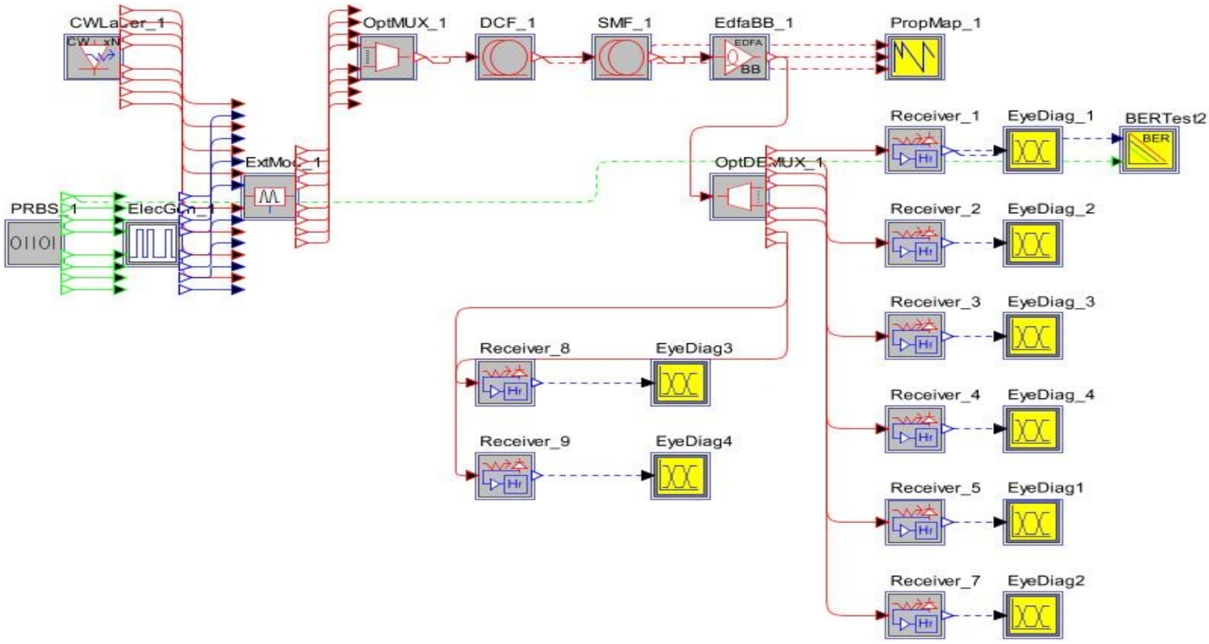

Fig. 6. Design of DWDM using DCF (pre-compensation)

Figure 6 represents eight channel DWDM link with wide channel spacing. The eight channels are specified at the wavelengths 1543 nm to 1550 nm. The PRBS block is to generate the binary sequences of different types. The optical signals are generated in direct modulated laser block and they are multiplexed using MUX model block. The multiplexed optical signal is transmitted along the fiber of length 140 km. which consists of 20 km of DCF with negative chromatic dispersion coefficient is placed at the link front end. After that demultiplexing operation is achieved using DEMUX model block, which outputs the individual signals on eight separate receivers. The received signals are analyzed using BER tester,and eye analyzer blocks.

2. Post-Compensation

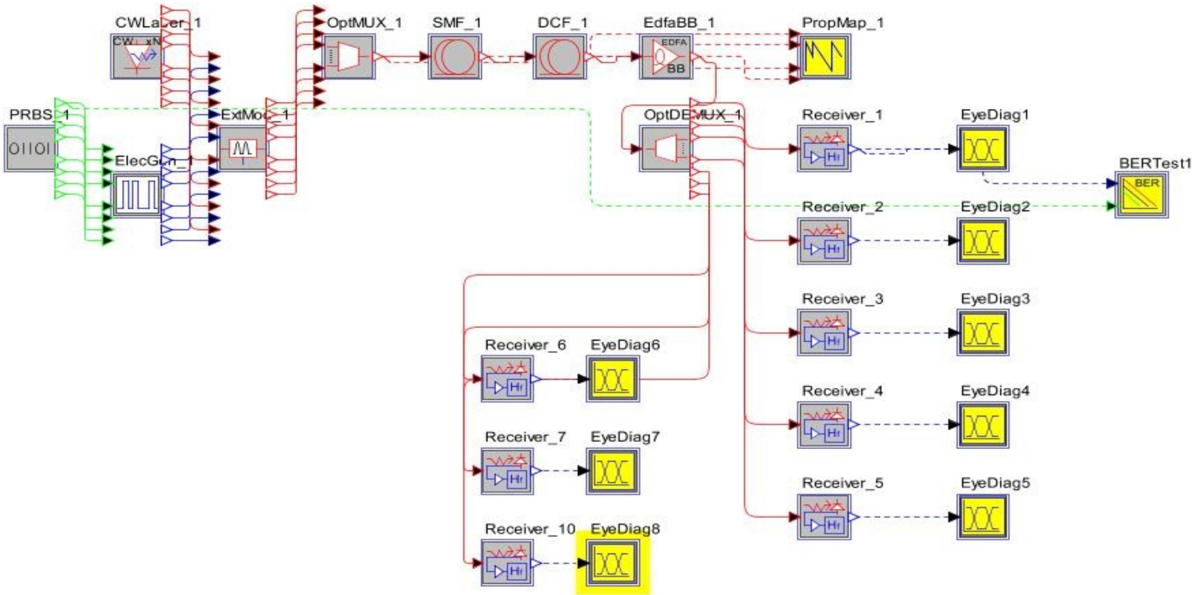

Fig.7 Design of DWDM using DCF (pre-compensation)

Figure 7 represents eight channel DWDM link with wide channel spacing. The eight channels are specified at the wavelengths 1543 nm to 1550 nm. The PRBS block is to generate the binary sequences of different types. The optical signals are generated in direct modulated laser block and they are multiplexed using MUX model block. The multiplexed optical signal is transmitted along the fiber of length 140 km. which consists of 20 km of DCF with negative chromatic dispersion coefficient is placed at the link front end. After that demultiplexing operation is achieved using DEMUX model block, which outputs the individual signals on eight separate receivers. The received signals are analyzed using BER tester, and eye analyzer blocks.

D. Electronic dispersion compensation

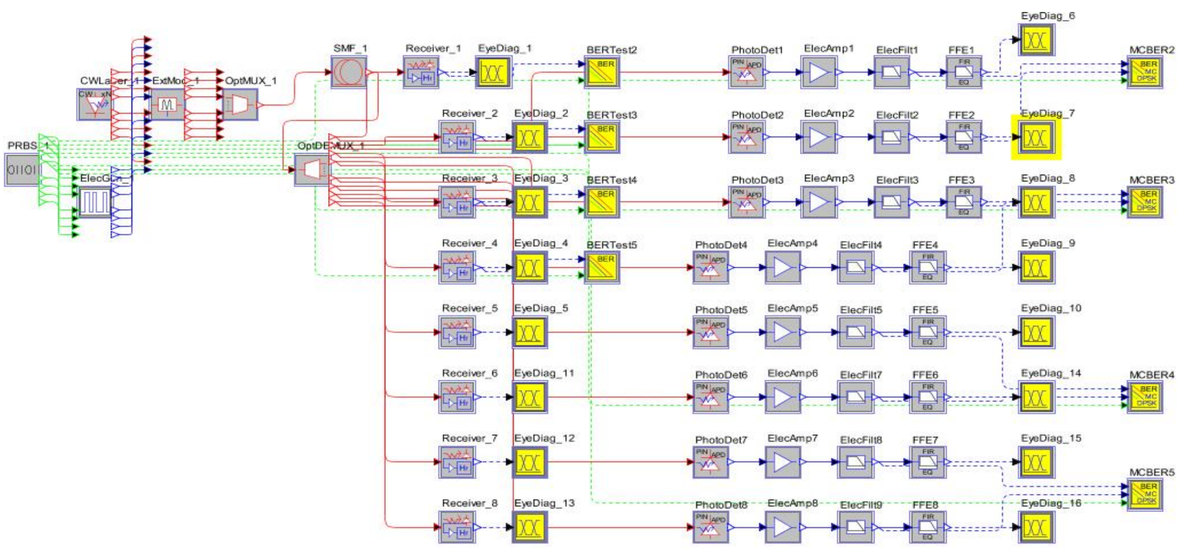

Fig. 8. Design of DWDM using EDC (Electronic Dispersion Compensation)

Pak. J. Biotechnol. Vol. 13 (special issue on Innovations in information Embedded and Communication Systems)
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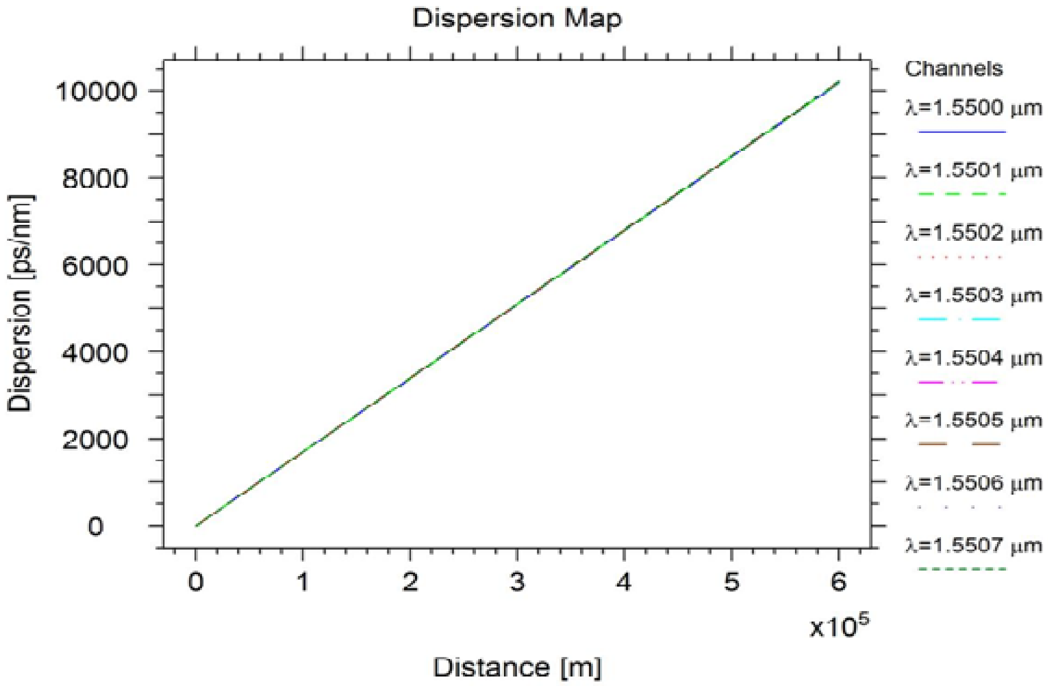
Figure 8 represents eight channel DWDM link with wide channel spacing. The eight channels are specified at the wavelengths 1543 nm to 1550 nm. The PRBS block is to generate the binary sequences of different types. The optical signals are generated in direct modulated laser block and they are multiplexed using MUX model block. The multiplexed optical signal is transmitted along the fiber of length 50 km. The photodetector converts the received optical signal to electrical and then an electrical filter is used to further smooth the received output. Based on the analog or digital signal processing techniques, the parameters may be adjusted automatically using the feedback techniques, thus, minimizing the bit error rate.After that demultiplexing operation is achieved using DEMUX model block, which outputs the individual signals on eight separate receivers. The received signals are analyzed using BER tester, and eye analyzer blocks.

SIMULATION RESULTS

The output of dispersion analyzer block is shown in *Fig.9* The eight different colors correspond to eight DWDM channels with the different wavelength of 1550nm to1557nm.when the length of the fiber increases along with dispersion also increases.



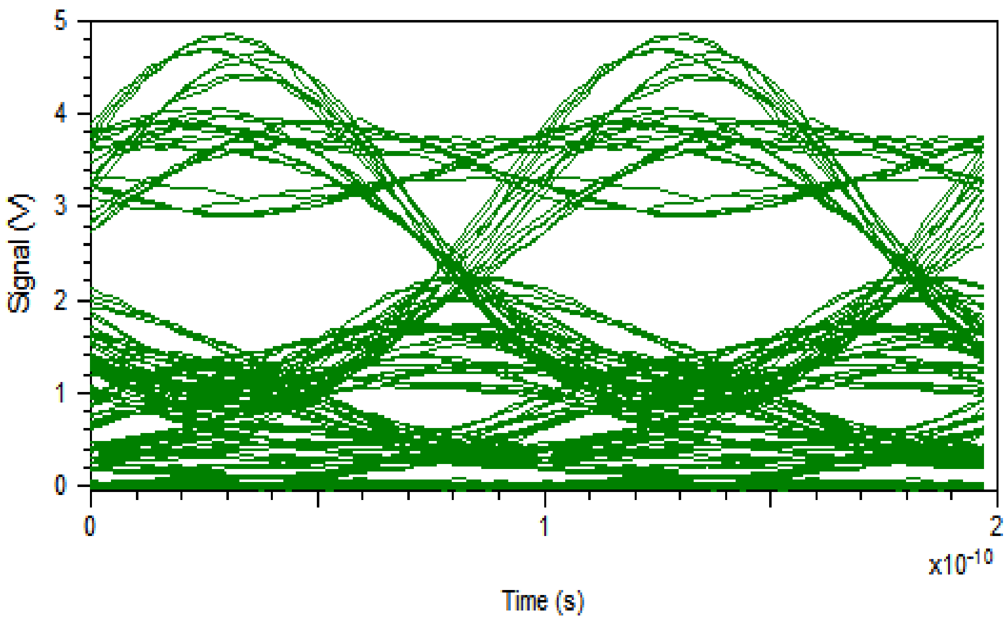


Fig. 10. Eye diagram of receiver 8

The eye diagram for No Compensation technique is shown in *Fig.10.* and is observed that eye opening is closuer but with more interference.

The eye diagram for FBG technique Without EDFA is shown in *Fig.11.*

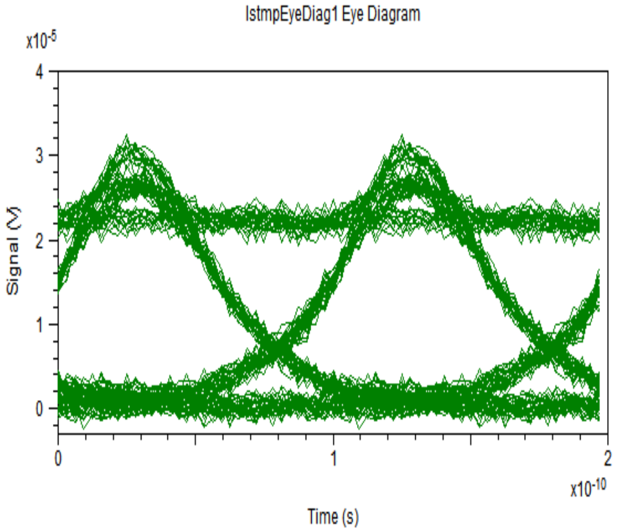


Fig. 11. Eye diagram of receiver 1

The eye diagram for FBG technique with EDFA is shown in *Fig.12.*

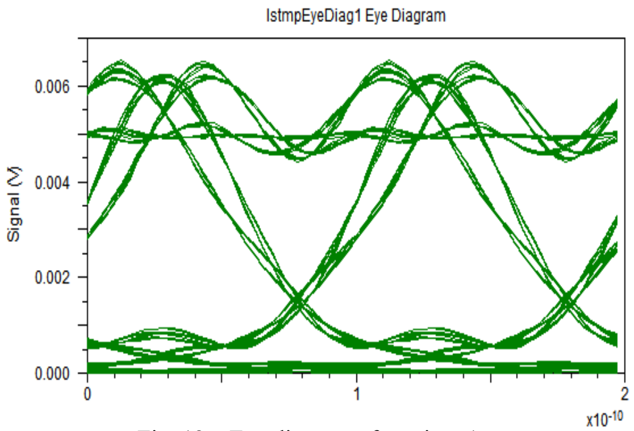


Fig. 12. Eye diagram of receiver 1

The eye diagram for pre compensation technique is shown in *Fig.13.*

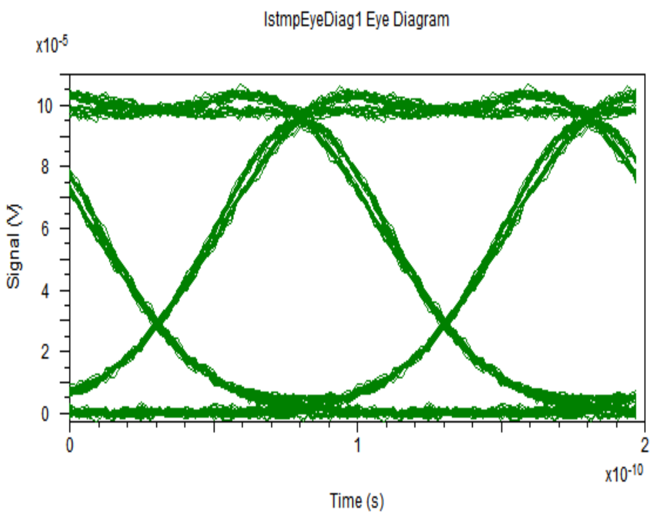


Fig.13. Eye diagram of receiver 1

The eye diagram for post compensation technique is shown in *Fig.14.*

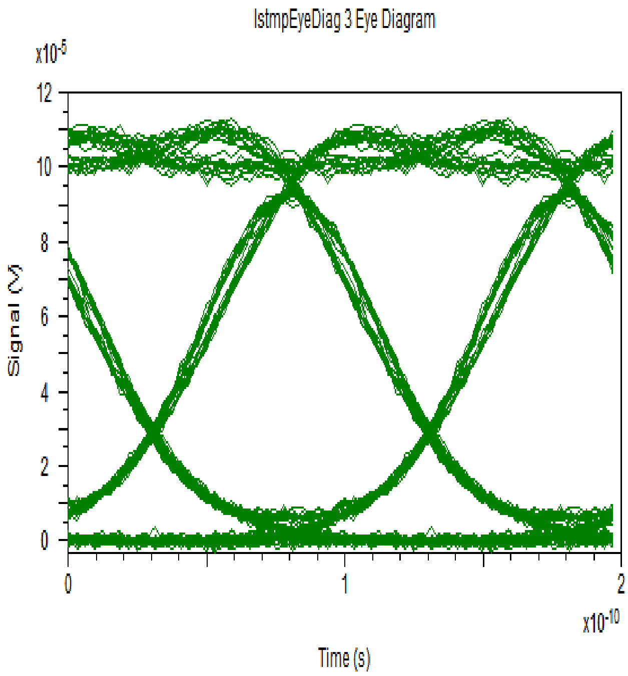


Fig.14. Eye diagram of receiver 1

The eye diagram for Electronic dispersion compensation technique is shown in *Fig. 15.*

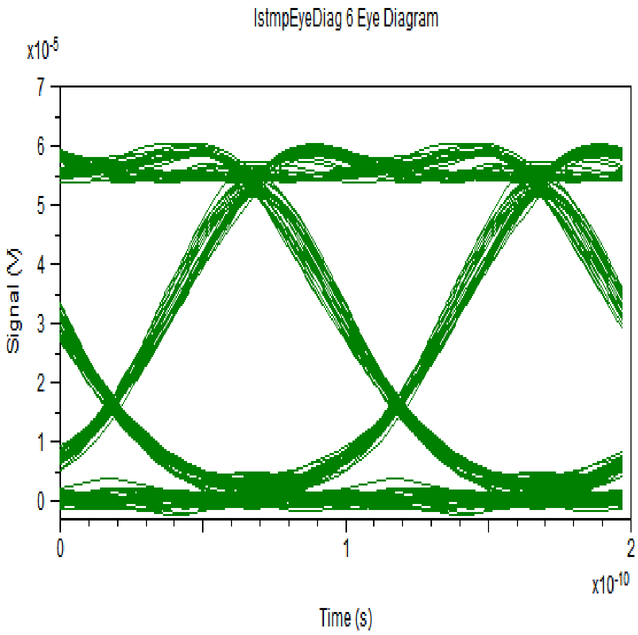


Fig. 15. Eye diagram of receiver 1

Analysis Of Dispersion Compensation

Analysis of Bit Error Rate

Table1.1 Analysis of BER

S. No.	Various Compensation Techniques	Performance metric	Length of Fiber (km)				
			10	50	70	120	140
1	No compensation	BER	$10^0=1$	$10^0=1$	$10^0=1$	$10^0=1$	$10^0=1$
2	FBG (without EDFA)	BER	10^{-100}	$10^{-3.9}$	-	-	-
3	FBG (with EDFA)	BER	0	0	0	$10^{-3.9}$	-
4	EDC	BER	$10^{-1.5}$	$10^{-1.5}$	$10^{-1.5}$	-	-
5	DCF (Pre compensation and Post compensation)	BER	0	0	0	0	0

Table1.1 shows that without any dispersion compensation, DWDM networks exhibit maximum bit error rate. On using FBG (with and without EDFA) for compensation, the former has better BER for increasing fiber length. Compared to all dispersion compensation techniques EDC has less bit error rate performance even for the fiber length of 10km. Of all the Compensation techniques, DCF achieve maximum transmission distance up to 140km with best Bit Error Rate performance.

CONCLUSION

There are many techniques that can be utilized to compensate dispersion in an optical fiber communication link. When the transmission distance increases up to 140km in DWDM networks, dispersion increases and the Bit Error Rate is high. To overcome this problem, in this paper, various dispersion compensation techniques are dealt. Fiber Bragg Grating is a very compact device with low insertion loss and compensates dispersion by compressing the pulse which passes through it.This achieved wider eye opening at a transmission distance upto 50km.Another technique, Electronic equalizer used in Electronic Dispersion Compensation (EDC) makes use of feed forward equalizer to compensate dispersion of about 70km. Dispersion compensating fibers are considered to be the best technique for dispersion compensation for long haul application. DCF achieved maximum transmission distance upto 140km and Bit Error Rate is very low(BER=0).

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