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

5 GBPS Data Rate Transmission in a WDM Network using DCF with FBG for Dispersion Compensation

Priya Ranjan Meher*
Assistant Professor
Deptt. of Electronics
Gandhi Institute of Engineering & Technology,
Gunupur, Rayagada, India

Balram Panigrahi
B. Tech.
Electronics & Communication Engineering,
Gandhi Institute of Engineering & Technology,
Gunupur, Rayagada, India

M Mohit Kumar
B. Tech.
Electronics & Communication Engineering,
Gandhi Institute of Engineering & Technology,
Gunupur, Rayagada, India

Aman Singh
B. Tech.
Electronics & Communication Engineering,
Gandhi Institute of Engineering & Technology,
Gunupur, Rayagada, India

Abstract

Optical fiber communication brought about a revolution in the field of communication. Researchers around the globe were quick enough to realize its' efficiency and brought further changes to enhance its capabilities. In order to avail the benefit of higher bandwidth we must send multiple signals through a single channel and Wavelength Division Multiplexing (WDM) allows us to send multiple signals at a time through single channel. But along with many advantages there are some limiting factors such as dispersion, attenuation, insertion loss, etc. However in long haul communication it is dispersion that affects the most. It causes spreading of pulses in time domain which causes interference. In this paper we have concentrated on the major limiting factor i.e. dispersion and ways to overcome it. We have used two dispersion compensation techniques i.e. Fiber Bragg Grating (FBG) along with Dispersion Compensation Fiber (DCF) to compensate dispersion and achieve 5 GBPS of data rate using WDM technique. The simulation is carried out using Optisystem 7.0 and the results were evaluated on the basis of Q-factor, eye height, min. BER and threshold value. Thus, from the obtained values, we can conclude that symmetrical compensation technique is the most suited method in DCF complemented with FBG to compensate dispersion.

***Keywords**: WDM, DCF, FBG, dispersion Compensation.*

****Author for correspondence*** meher.situ05@gmail.com

1. Introduction

Origin of optical fibers heads back to 1790's when the French Chappe brothers invented the first "optical telegraph". In later centuries optical science went through many modifications. However the very idea of using glass to transmit information signal in the form of light over long distance was developed by Kao and Hockman in 1966. Optical communication systems use high carrier frequencies (100 THz) in the visible or near-infrared region of the electromagnetic spectrum. Fiber-optic communication systems are lightwave systems of transmitting information from one place to another by sending pulses of light through optical fiber. Such systems have been deployed worldwide since 1980 and have indeed revolutionized the technology behind telecommunications. Indeed, the lightwave technology, together with microelectronics, is believed to be a major factor in the advent of the "information age." 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. Dispersion is the spreading of light pulse as its travels down the length of an optical fiber. Dispersion limits the bandwidth or information carrying capacity of a fiber. The bit-rates must be low enough to ensure that pulses are farther apart and therefore the greater dispersion can be tolerated. Dispersion is the main performance limiting factor in optical fiber communication. Dispersion greatly hampers the performance of optical fiber communication. Due to dispersion, broadens optical pulse as they travel in single mode fiber. Limiting the ultimate data rate supported by fiber which causes spreading and overlapping of chips and degrades system performance due to increase inter chip interference and reduced received optical power. So if dispersion can be minimized then a further performance can be obtained from optical fiber communication. There are a lot of methods of dispersion compensation. Several techniques, including Dispersion Compensating Fiber or Fiber Bragg Grating, can be used to compensate the accumulated dispersion in the fiber. In the following example we will show three different schemes, pre-, post-, and symmetrical compensation, to compensate the fiber dispersion. First we will use dispersion compensating fibers (DCFs).

2. Dispersion Compensation Fiber

The idea of using dispersion compensating fibers (DCF) was proposed in 1980. As the components of DCF are more stable, it is not easily affected by temperature and bandwidth, so DCF has become a most suitable method for dispersion compensation. The use of DCF is an efficient way to reduce the overall dispersion in WDM network. As they have higher negative dispersion coefficient and therefore can be connected to the transmission fiber having the positive dispersion coefficient. Therefore the overall dispersion of the link is zero.

$$D_{SMF} \times L_{SMF} = -D_{DCF} \times L_{DCF}$$

Where D, and L are the dispersion and length respectively. There are three compensation schemes for dispersion.

- Pre-Compensation: In this Compensation scheme, the DCF is placed before the SMF to compensate the dispersion in the standard fiber.
- Post-Compensation: In Post Compensation scheme, the DCF is placed after the SMF to compensate the dispersion of the standard fiber.
- Symmetric Compensation: In Symmetric Compensation scheme, the DCF is placed before and after the standard fiber.

3. Simulation Setup

A SMF is standardized by using a dispersion compensating scheme. In a Wavelength Division Multiplexing (WDM) scheme, in order to achieve high data rate and high capacity, there exists some of the most effective compensating schemes such as FBG, DCF, electrical dispersion compensation and optical phase conjugation method etc. There exist three compensation schemes if DCF technique is considered. The schemes are Pre-Compensation, Post-Compensation and Symmetric-Compensation. In our project we used post compensation for desired results.

Post compensation scheme has been used here. Fig 1 gives a brief idea about the experimental setup of WDM network using DCF that has been used in this simulation. The setup comprises of transmitter, fibers and receiver. Pseudo random bit generator, NRZ pulse generator, CW Laser, and Mach Zehnder Modulator combines to form a transmitter. The transmitted signal is then sent to WDM network which multiplexes these signals. Once the signal is multiplexed it is sent to SMF. EDFA present after the SMF amplifies the signal that it receives from SMF. The amplified signal is passed to DCF where the compensation of dispersion takes place. Once the dispersion has been compensated, the compensated signal is again amplified by using another EDFA having different optical amplification gain as compared to the EDFA used before. After the amplification of the signal, the amplified signal is sent to WDM DEMUX where de-multiplexing takes place. As soon as the signal is de-multiplexed, the receiver will receive the transmitted signal without any kind of loss.

4. Post Compensation

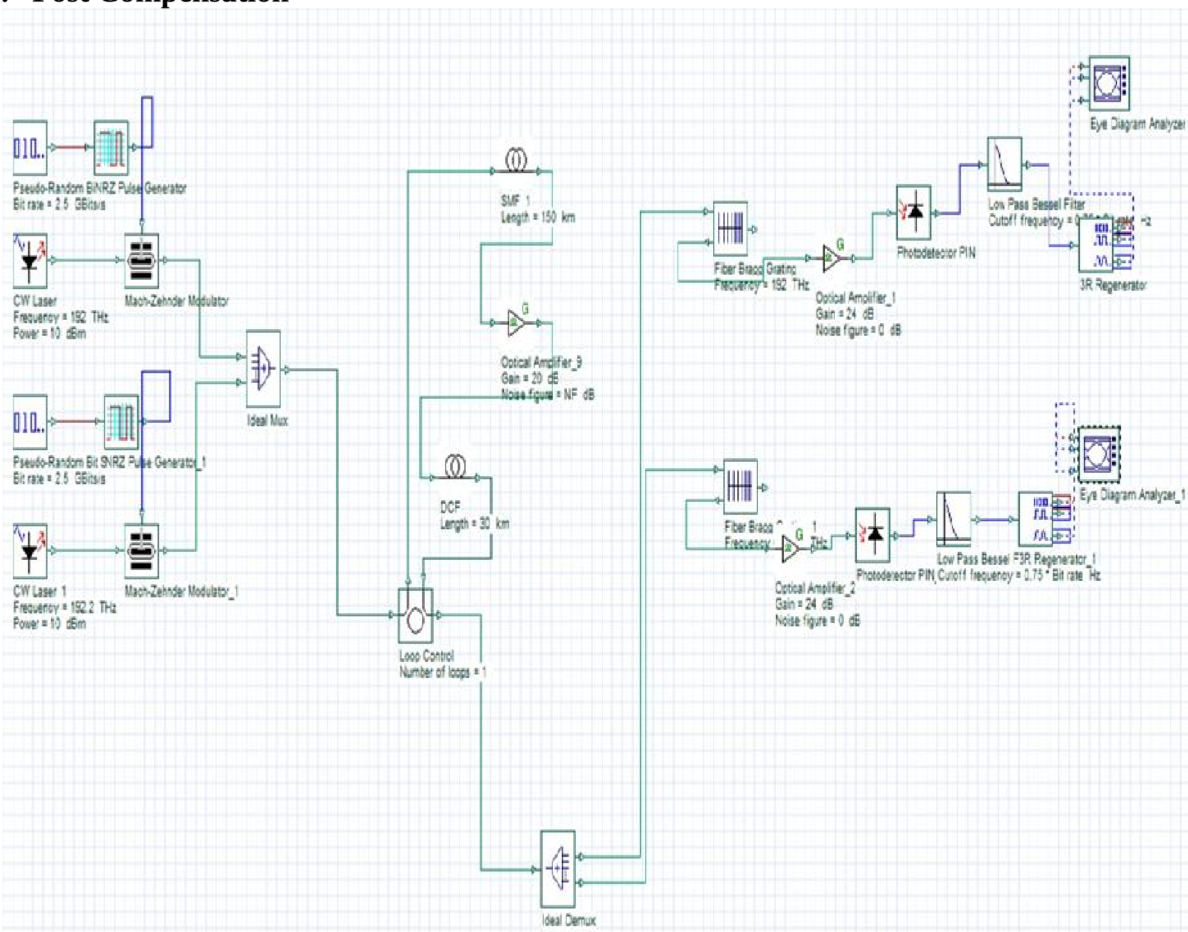

Fig. 1: Simulation setup of the post compensation

Table 1: Simulation parameters of post compensation

Parameters	**Values**
Length of SMF	150Km (post)
Reference Wavelength in SMF	1550 nm
Attenuation in SMF	0.2dB/Km
Dispersion Coefficient in SMF	17 ps/nm/Km
Dispersion Slope in SMF	0.08 ps/nm^2/Km
Differentiation Group Delay in SMF	3 ps/Km
Dispersion coefficient in DCF	-85ps/nm/Km(pre, post), -68ps/nm/Km (symmetric)
Length of DCF	30 Km
Gain of EDFA	20 dB
Gain of EDFA	24 dB

In this post simulation, transmitter consists of 2 pseudo random bit sequence generator each operating at a bit rate of 2.5 GBits/s. Pseudo random bit sequence generator generates a random code consisting of 0’s and 1’s. The EDFA used just prior to the DCF is having an optical amplifier gain of 20 dB and the one used just after the DCF is having an optical amplifier gain of 24dB. DCF used to compensate dispersion is 30 Km long for post compensation. The dispersion value of DCF used to compensate dispersion is taken to be -85ps/nm/Km at receiver side. There is a WDM DEMUX whose channel band width is same as the channel band width of WDM MUX used in the transmitter side. PIN Photodiode is used here to retrieve the optical signal and convert it into electrical signal. The electrical signal is passed through low pass filter. LPF filters the high frequency noises and transfer the filtered signal to BER analyzer to determine the parameters like eye height, BER and Q-Factor.

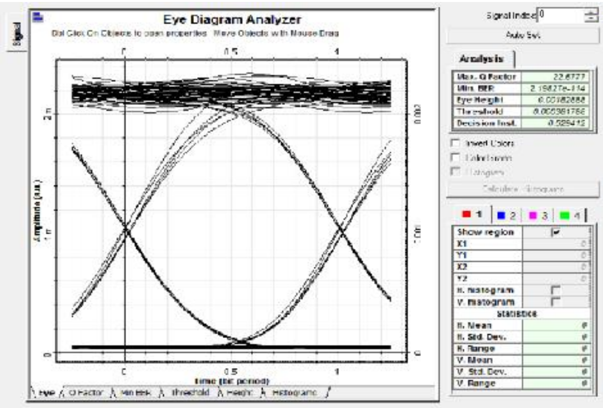

Fig. 2: Channel 1 eye diagram for post

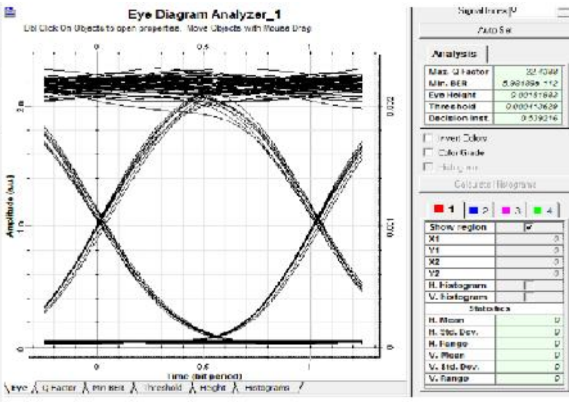

Fig. 3: Channel 2 eye diagram for post

5. Pre Compensation

In this simulation, transmitter consists of 2 pseudo random bit sequence generator each operating at a bit rate of 2.5 GBits/s. Pseudo random bit sequence generator generates a random code consisting of 0’s and 1’s. The EDFA used just prior to the DCF is having an optical amplifier gain of 20 dB and the one used just after the DCF is having an optical amplifier gain of 24dB. DCF used to compensate dispersion is 30 Km long for post compensation. The dispersion value of DCF used to compensate dispersion is taken to be -85ps/nm/Km at receiver side. There is a WDM DEMUX whose channel band width is same as the channel band width of WDM MUX used in the transmitter side. PIN Photodiode is used here to retrieve the optical signal and convert it into electrical signal. The electrical signal is passed through low pass filter. LPF filters the high frequency noises and transfer the filtered signal to BER analyzer to determine the parameters like eye height, BER and Q-Factor.

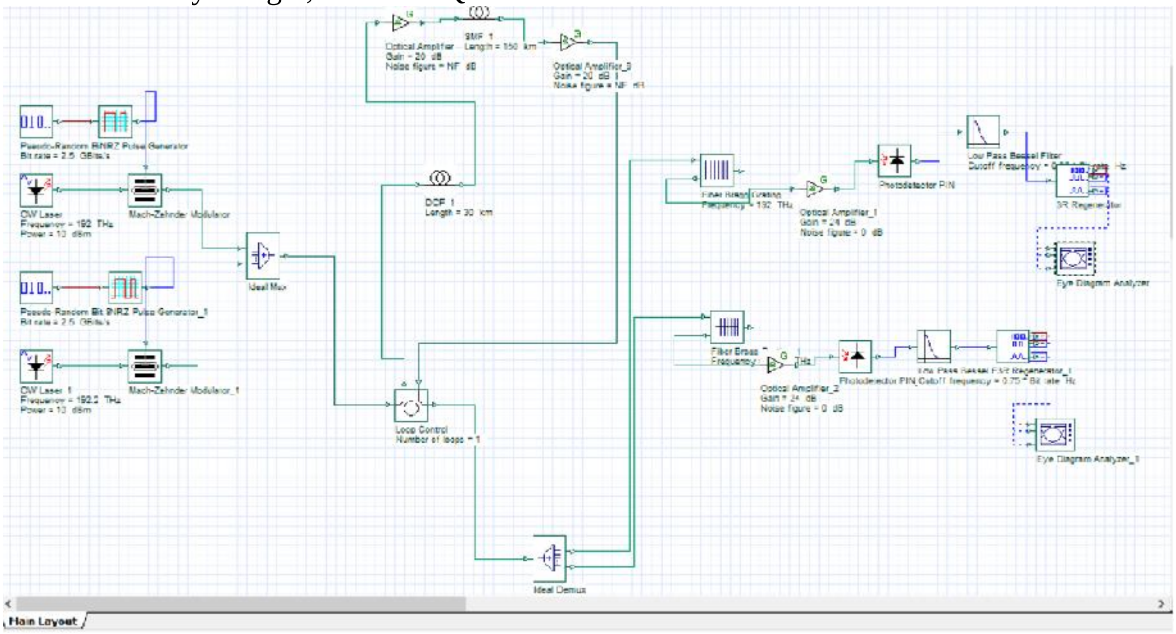

Fig. 4: Simulation setup of the pre compensation

Table 2: Simulation parameters of pre compensation

Parameters	**Values**
Length of SMF	150 Km
Reference Wavelength in SMF	1550 nm
Attenuation in SMF	0.2dB/Km
Dispersion Coefficient in SMF	17 ps/nm/Km
Dispersion Slope in SMF	0.08 ps/nm^2/Km
Differentiation Group Delay in SMF	3ps/Km
Dispersion Coefficient in DCF	-85ps/nm/Km(pre, post), -68ps/nm/Km (symmetric)
Length of DCF	30 Km
Gain of EDFA	20 dB
Gain of EDFA	24 dB

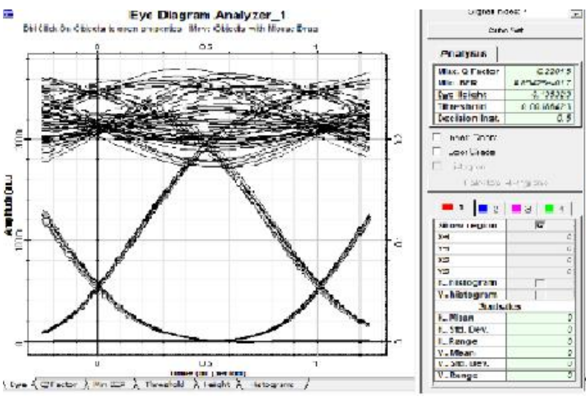

Fig. 5: Channel 1 eye diagram for pre

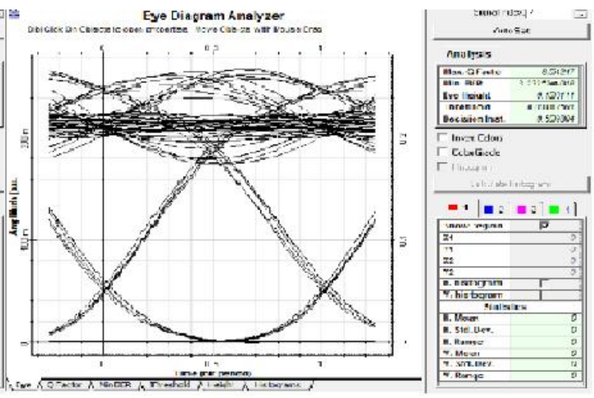

Fig. 6: Channel 2 eye diagram for pre

6. Symmetric Compensation

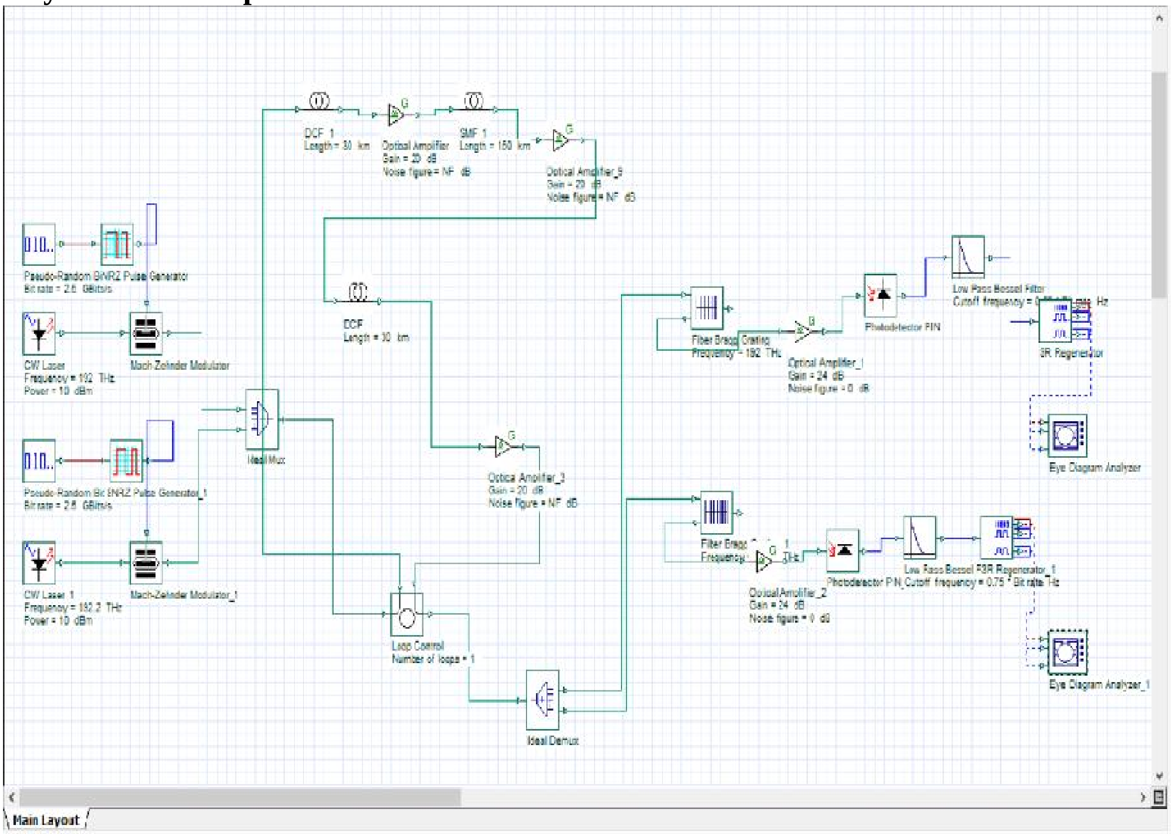

Fig. 7: Simulation layout of symmetric compensation

Table 3: Simulation parameters of symmetric compensation

Parameters	**Values**
Length of SMF	150 Km
Reference Wavelength in SMF	1550 nm
Attenuation in SMF	0.2dB/Km
Dispersion Coefficient in SMF	17ps/nm/Km
Dispersion Slope in SMF	0.08 ps/nm^2/Km
Differentiation Group Delay in SMF	3ps/Km
Dispersion Coefficient in DCF	-85ps/nm/Km(pre, post), -68ps/nm/Km (symmetric)
Length of DCF	30 Km
Gain of EDFA	20 dB
Gain of EDFA	24 dB

In this simulation, transmitter consists of 2 pseudo random bit sequence generator each operating at a bit rate of 2.5 GBits/s. Pseudo random bit sequence generator generates a random code consisting of 0's and 1's. The EDFA used just prior to the DCF is having an optical amplifier gain of 20 dB and the one used just after the DCF is having an optical amplifier gain of 24dB. DCF used to compensate dispersion is 30 Km long for post compensation. The dispersion value of DCF used to compensate dispersion is taken to be -85ps/nm/Km at receiver side. There is a WDM DEMUX whose channel band width is same as the channel band width of WDM MUX used in the transmitter side. PIN Photodiode is used here to retrieve the optical signal and convert it into electrical signal. The electrical signal is passed through low pass filter. LPF filters the high frequency noises and transfer the filtered signal to BER analyzer to determine the parameters like eye height, BER and Q-Factor.

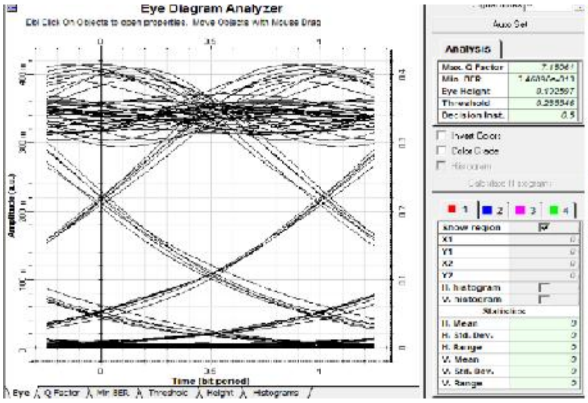

Fig. 8: Channel 1 eye diagram for symmetric

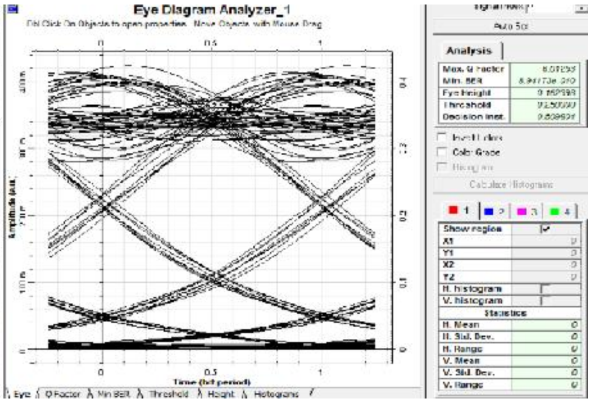

Fig. 9: Channel 2 eye diagram for symmetric

7. Result and Discussion

Table 4: Analysis of dispersion compensation scheme

CHANNEL	EYE HEIGHT	THRESHOLD	Q-FACTOR	Min. BER
Post CHANNEL 1	0.00182888	0.000381788	22.677	2.19827e-114
Post CHANNEL 2	0.00181983	0.000413629	22.4388	5.98489e-112
Pre CHANNEL 3	0.138111	0.00412591	8.51247	3.23252e-018
Pre CHANNEL 4	0.135323	0.003868423	8.22015	4.85426e-017
Symmetric CHANNEL 5	0.192597	0.235546	7.18061	3.46898e-013
Symmetric CHANNEL 6	0.162398	0.250308	6.01253	8.94173e-010

In this system evaluation has been done on the performance of FBG in order to compensate dispersion. Here all the parameters have been changed to get an optimized output at the end, and the SMF length has kept constant 150km. Here will have changes the parameters like grating length in order to carry out various simulations. Optisystem 7.0 has been used. The difference of height and Q-factor has been compared in the table 4.

8. Conclusion

Fiber optic communication is becoming an important mode of communication and due its high bandwidth and high data rate it has gain wide popularity among all users. For any system to work effectively it must have the Q factor that determines the quality of service of that system about 7dB and the next factor which is very crucial for the system is it’s eye height value, the wider the eye opening the better the system gets. Comparing above obtained results we can very well see that symmetric compensation has the best eye height and it also has satisfactory value for the Q factor and hence it is the best employed for transmission of data upto a medium range.

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