Comparative Analysis of DCF based Dispersion Compensation Techniques in Optical Fiber Communication Link using Different Input Transmitter Conditions at 10 Gbps

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Abstract: In this paper, Dispersion Compensating Fiber (DCF) based various dispersion compensating techniques (pre, post and symmetrical) with different modulation format like Non Return to Zero(NRZ), Return to Zero(RZ), Carrier Suppressed Return to Zero(CSRZ) and Duo Binary(DB) along with PN, FCC and Walsh code input sequences are implemented. Simulation and analysis of these implemented techniques were done at 10 Gbps bit rate and input laser power ranging from 1 mW to 10 mW at transmission distance of 240 km using BER Analyzer in Optisystem 17.0 software. Comparison between different techniques was done in terms of Q factor and BER versus input CW laser power for different modulations and input sequences. From the analysis, it is concluded that when Walsh code as user defined input sequence are used for all the implementation, it gives higher value of Q factor and lower value of Bit Error Rate as compared to PN and FCC codes for most of the input CW laser power.

Keywords: DCF, NRZ, RZ, CSRZ, DB, BER, Q factor, CW Laser Power

1. Introduction

Optical Fiber Communication is one of the most important topics of research in today's world communication systems. Optical communication system like other system faces problems like dispersion, attenuation, and non-linear effects that cause degradation in its performance. Among them, dispersion affects the system the most and it is difficult to overcome it as compared to the other two problems [1]. Dispersion is the main reason for the Inter Symbol Interference of the output pulse rendering them undetectable at the receiving side [2]. Due to ISI, the receiver may not be able to differentiate between 0 and 1. Also, we cannot increase the data rate of the fiber optic communication link beyond a certain limit with the required accuracy. As a result, dispersion is a limiting factor on the data rate of fiber optic communication link [3].Thus in order to achieve high data rates,dispersion compensation is the most important feature in optical fiber communication links to compensate for the dispersion of optical pulses.

In this paper, the whole comparative analysis is based on the type of DCF based dispersion compensation techniques, types of modulation techniques and types of input sequence code used for the simulation.

A. DCF based Dispersion Compensation Techniques

In this technique a fiber having large negative dispersion coefficient is used along with a Single Mode Fiber (SMF) having positive. Therefore the overall dispersion of the fiber link is zero. The length of the DCF is shorter as compared to SMF. The placement of dispersion compensating fiber in the transmission plays an important role, which decides the signal quality at the receiver end [4].

In order to mitigate the dispersion effect three compensation techniques have been presented:

a. Pre-compensation: In Pre compensation scheme, Dispersion Compensation Fiber (DCF) is placed before the SMF to compensate the dispersion of the standard fiber.

b. Post-compensation: In Post compensation scheme, DCF is placed after SMF to mitigate the dispersion introduced.

c. Symmetrical-compensation: In Symmetrical compensation scheme, involves the placement of the DCF before and after the SMF to overcome the effect of dispersion [5-7].

In this paper, analysis has been done on all the three above DCF techniques. The length of the SMF was taken to be 100 km and dispersion coefficient of fiber was taken to be 17 ps/nm-km whereas length of DCF was taken to be 20 km and dispersion coefficient was taken to be -85 ps/nm-km. The loop control system has two loops in post and pre setup. In each loop 100 km SMF and 20 km DCF is used in order to compensate for the dispersion slope and accumulated dispersion in the fiber but in symmetrical setup has one loop only, so the of fiber length of the channel will remains to 240 km.

B. Modulation Techniques

When analyzing the performance of optical communication systems, the data transmission format must be analyzed because it deals directly with the system output. Many coding techniques have been proposed before and have become standard in telecommunication and computer networks. Non-return to zero (NRZ) and Return to zero (RZ) are two very common modulation techniques, which are used to modulate optical pulses in optical networks [8].

Other schemes of modulation techniques were suggested such as carrier suppressed return to zero [9-11] and optical duo-binary [12-14]. In this paper different modulation formats like NRZ, RZ, CSRZ and Duo-Binary are used to analyze and compare between different dispersion compensation techniques.

C. Input Sequence Code

Basically PN Code sequences generated by Pseudo Random Bit Sequence generator are used to generate a digital sequence in optical fiber communication. In this paper, other two codes FCC and Walsh codes are used for the analysis. The FCC code can be designed by using tri diagonal matrix property, at any given number of users and weights. Walsh-Hadamard (WH) codes [15] are binary orthogonal and can easily be generated from Hadamard matrices. The orthogonal sequences generated from Hadamard matrices are called Walsh-Hadamard matrices [16], [17]. Orthogonality is that the most vital property of Hadamard-Walsh codes. Due to this orthogonality property, and when system is perfectly synchronized, the cross-correlation between any two WH codes of the same matrix (set) is zero.

2. Simulation Setup

We have used Optisystem 17.0 software to simulate our design. In the simulation setup at the transmitter side, CW laser is used as a source of light at the single frequency of 193.1 THz with the power level ranging from 1 mW to 10 mW. The digital sequence is generated by both pseudo random and user defined bit sequence generator at the transmission rate of 10 Gbps. To convert a digital sequence into electrical pulse different modulation format like Non Return to Zero (NRZ), Return to Zero (RZ), Carrier Suppressed Return to Zero (CSRZ), and Duo-Binary (DB) are used. Mach-Zehnder (MZ) modulator is used for the modulation of the optical signals whose another input is fed from the laser diode causes an optical modulation before entering into the medium. The medium includes optical fibers, DCF and optical amplifiers. Optical amplifiers are inserted after each fiber and DCF components for the compensation of attenuation. A PIN detector is used along with low pass Bessel filter is used at receiving end of the link to detect the optical pulses and convert it to the electrical signals. This electrical signal is applied to the BER analyzer through 3R generator to analyze the different fiber parameters.

Different simulation parameters of single channel optical system and fiber are tabulated in Table I and II respectively.

TABLE I. SINGLE CHANNELOPTICAL SYSTEM PARAMETERS

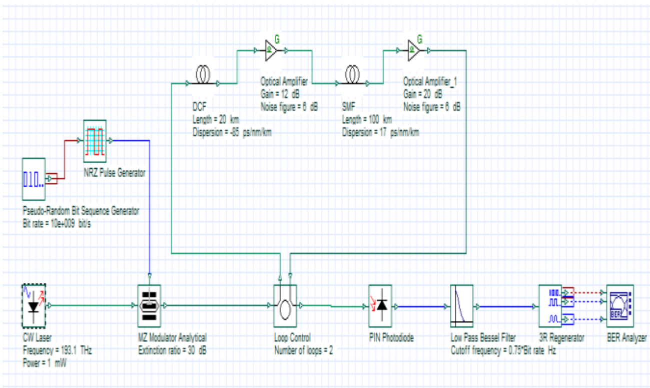
PARAMETERS	VALUE
Bit Rate(Gb/s)	10
Sequence Length	1024
Samples/bit	32
Sample Rate (Hz)	3.2e+011
Number of Samples	32768
CW Laser frequency (THz)	193.1
CW Laser Power (mW)	1 to 10
Reference Wavelength (nm)	1550

TABLE II. FIBER PARAMETERS

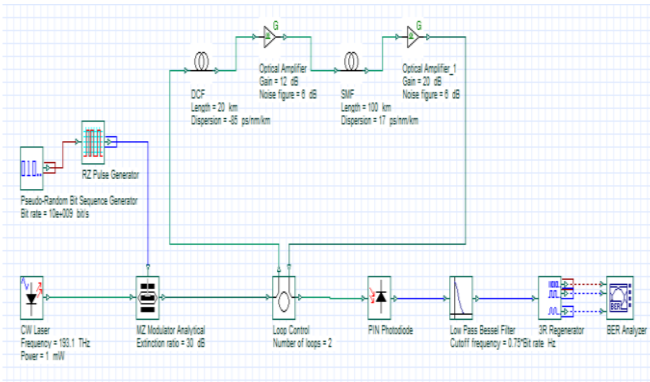
PARAMETERS	SMF	DCF

Length(KM)	100	20
Dispersion(ps/nm /km)	17	-85
Dispersion Slope	0.075	-0.3
Attenuation	0.2	0.6
Differential Group Delay(ps/nm)	0.5	0.5

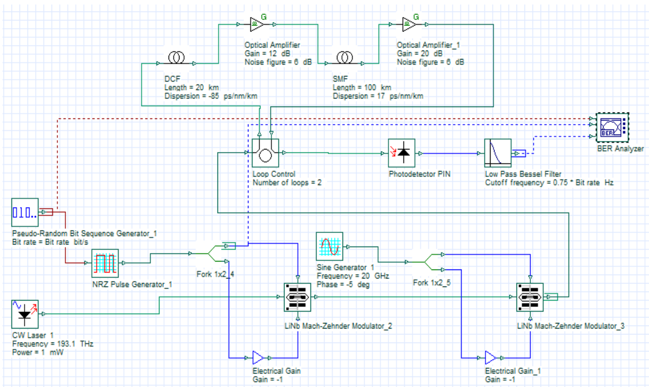
In this setup, three DCF based dispersion compensation techniques using three different types of input sequences and four different modulations with different CW laser power are implemented. Fig. 1, 2 and 3 shows the simulation setup for the Pre, Post and Symmetrical DCF techniques for NRZ, RZ, CSRZ and Duo-Binary modulations using PN code generated by PRBS generator.



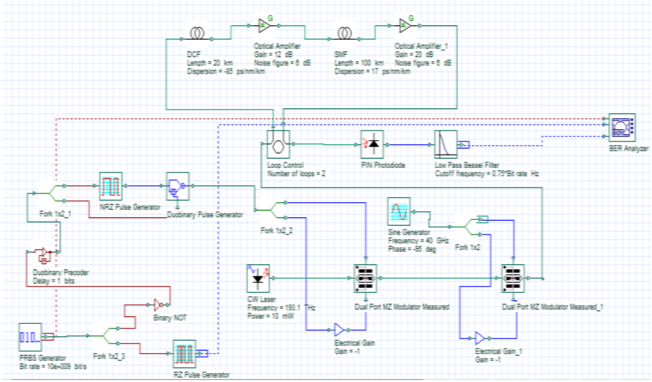
(a) Using NRZ modulation



(b) Using RZ modulation

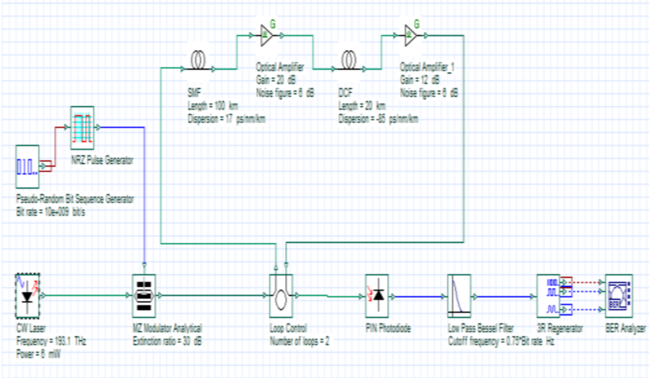


(c) Using CSRZ modulation

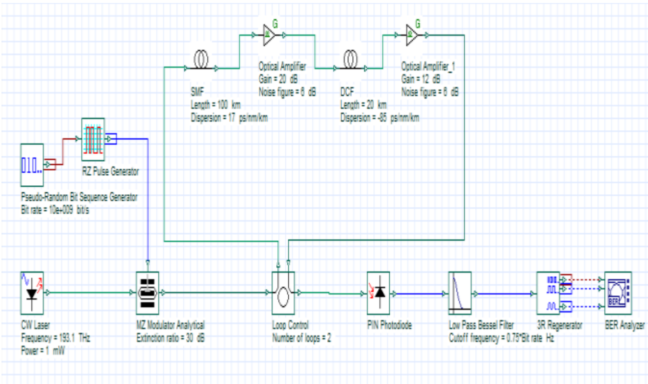


(d) Using Duo-Binary modulation

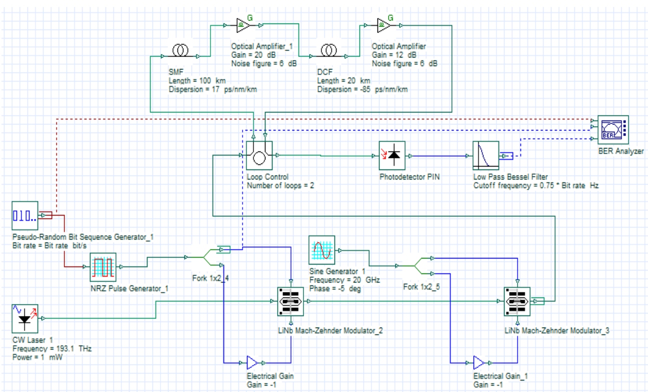
Fig. 1 Simulation setup for Pre DCF compensation using (a) NRZ (b) RZ (c) CSRZ and (d) Duo-Binary modulation.



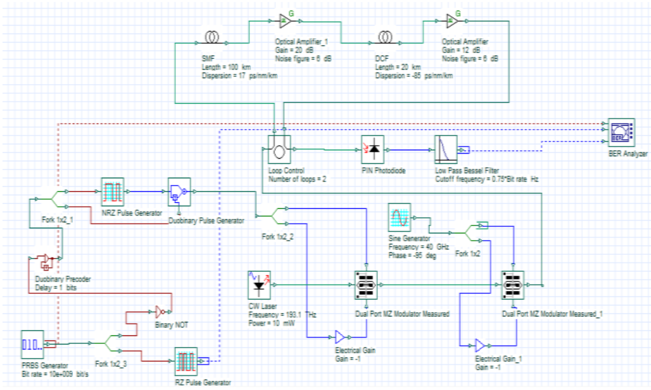
(a) Using NRZ modulation



(b) Using RZ modulation

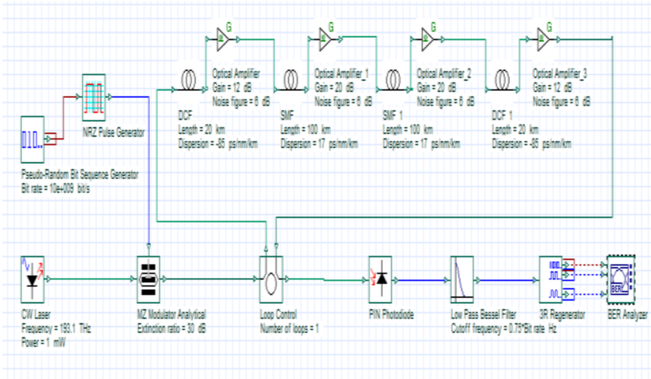


(c) Using CSRZ modulation

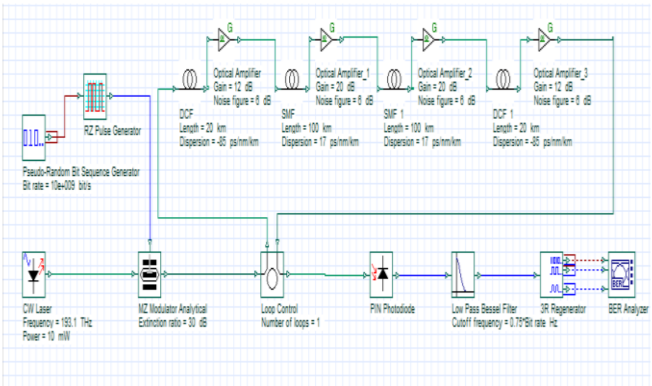


(d) Using Duo-Binary modulation

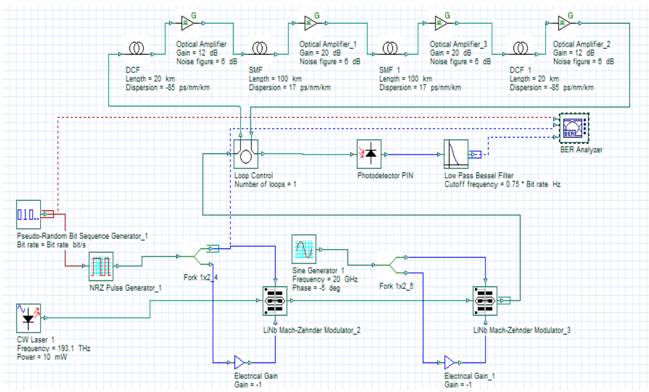
Fig. 2 Simulation setup for Post DCF compensation using (a) NRZ (b) RZ (c) CSRZ and (d) Duo-Binary modulation.



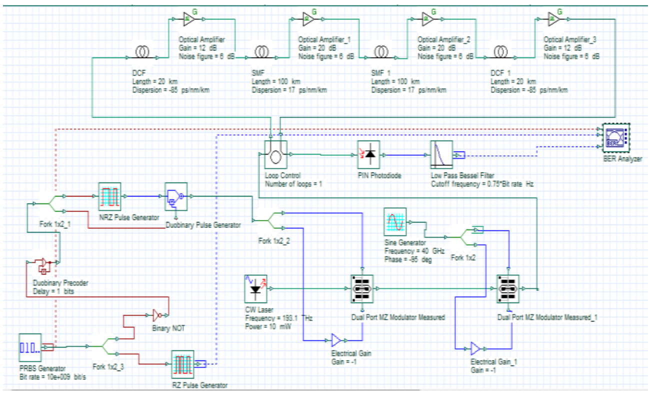
(a) Using NRZ modulation



(b) Using RZ modulation



(c) Using CSRZ modulation



(d) Using Duo-Binary modulation

Fig. 3 Simulation setup for Symmetrical DCF compensation using (a) NRZ (b) RZ (c) CSRZ and (d) Duo-Binary modulation.

For the next simulation setup to apply FCC and Walsh code, PRBS generator is replaced by the user defined bit sequence generator in the entire Fig, where 16 bits of FCC Codes (0110111001010001) and Walsh codes (0110011001100110) are used for the simulation.

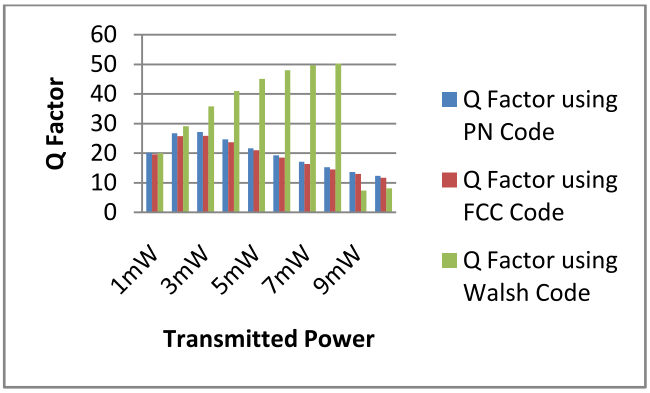
3. Simulation Results

All the simulated designs have been analyzed at 10 Gbps in terms of Q factor and BER using BER analyzer in Optisystem 17.0 software and comparison between them was done on the basis of input sequences like PN, FCC and Walsh code, modulation formats (NRZ, RZ, CSRZ and Duo Binary) with CW laser power level from 1mW to 10 mW.

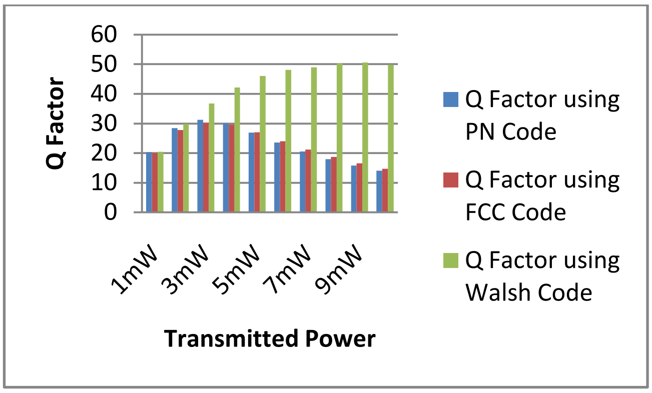
A. Q factor versus Transmitted Power

Fig. 4 shows the comparative analysis between Q factor and CW laser power ranges from 1 mW to 10 mW for the Pre, Post and Symmetrical DCF compensation technique using NRZ modulation. It provides the high value of Q factor = 50.2574 at 8 mW for Pre DCF, Q factor=50.5778 at 9 mW for Post DCF and Q factor=61.863 for Symmetrical DCF technique using Walsh code.

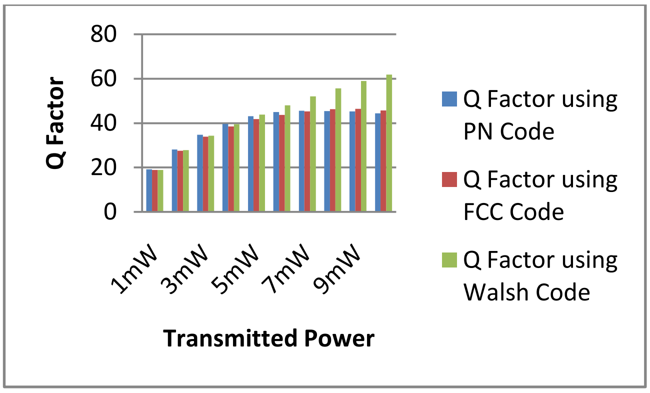
Fig. 5 shows the comparison graph for the Pre, Post and Symmetrical DCF compensation technique using RZ modulation. It provides the high value of Q factor = 53.9792 for Pre DCF, Q factor=55.3907 for Post DCF and Q factor=52.4185 for Symmetrical DCF technique using Walsh code at 10 mW CW laser power.



(a) Pre DCF Compensation

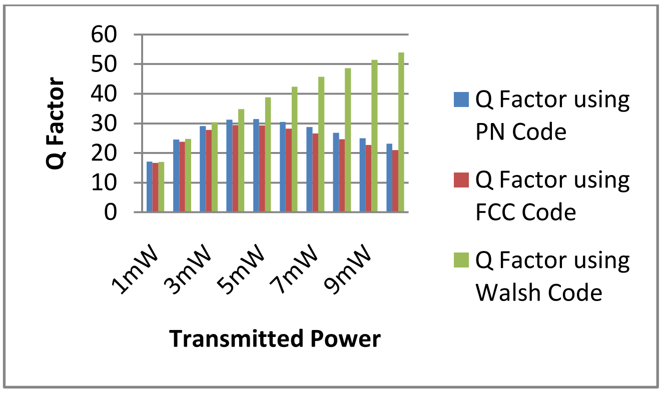


(b) Post DCF Compensation

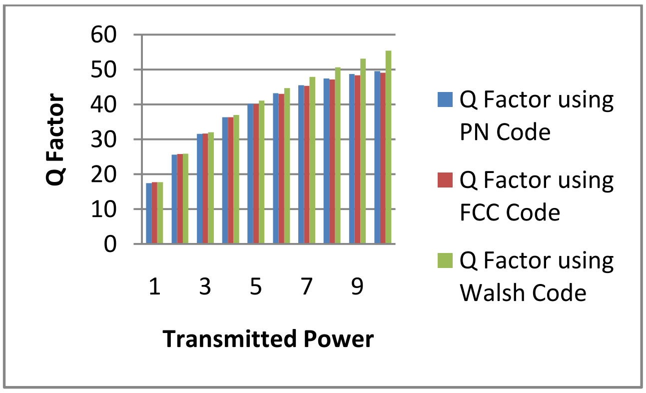


(c) Symmetrical DCF Compensation

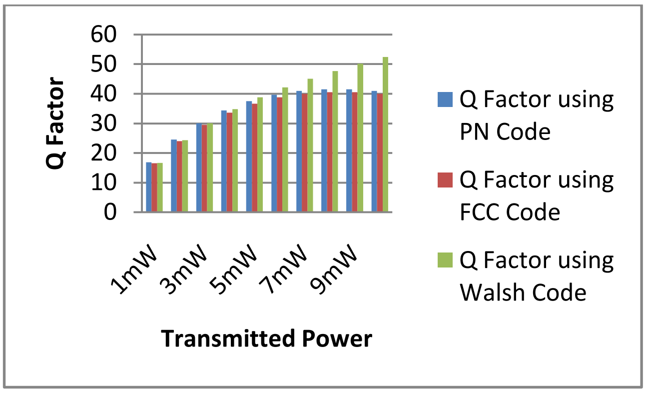
Fig. 4 Q factor versus Transmitted Power for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using NRZ modulation



(a) Pre DCF Compensation



(b) Post DCF Compensation

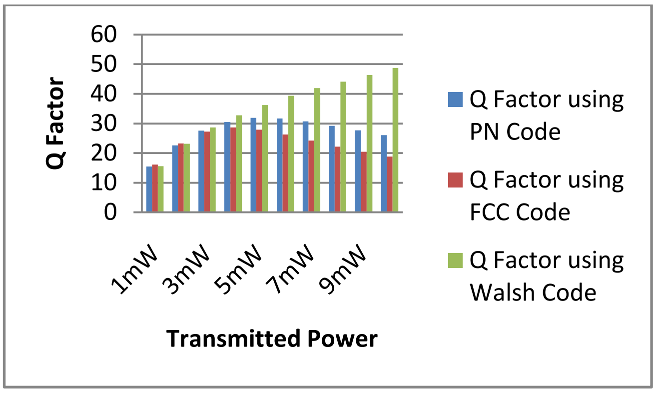


(c) Symmetrical DCF Compensation

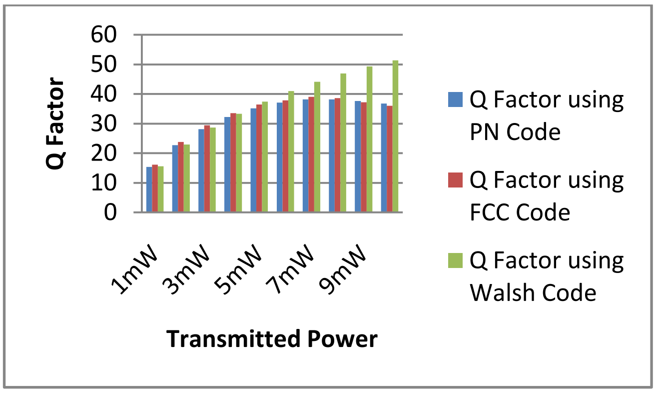
Fig. 5 Q factor versus Transmitted Power for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using RZ modulation

Fig. 6 shows the comparative graph for the Pre, Post and Symmetrical DCF compensation technique using CSRZ modulation. It provides the high value of Q factor = 48.7397 for Pre DCF, Q factor=51.3228 for Post DCF and Q factor=51.9043 for Symmetrical DCF technique using Walsh code at 10 mW CW laser power.

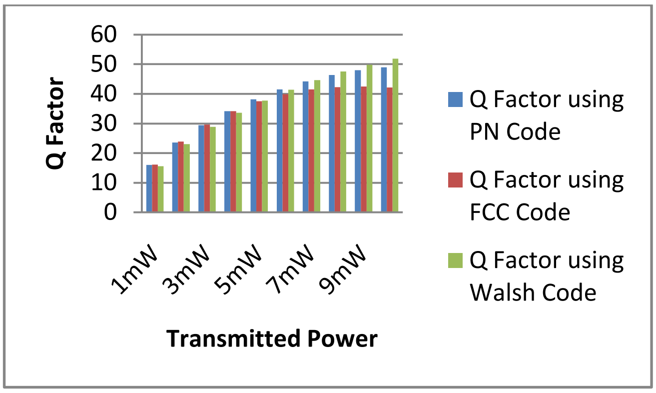
Fig. 7 shows the comparison graph for the Pre, Post and Symmetrical DCF compensation technique using CSRZ modulation. It provides the high value of Q factor = 44.0233 for Pre DCF, Q factor=47.4019 for Post DCF and Q factor=44.8085 for Symmetrical DCF technique using Walsh code at 10 mW CW laser power.



(a) Pre DCF Compensation

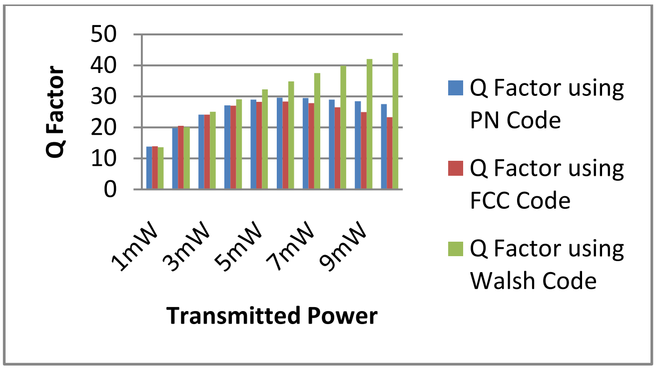


(b) Post DCF Compensation

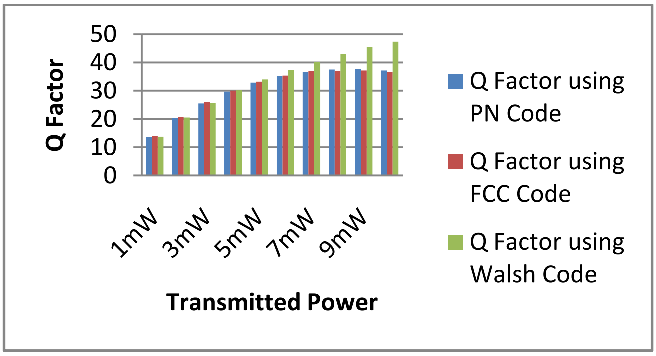


(c) Symmetrical DCF Compensation

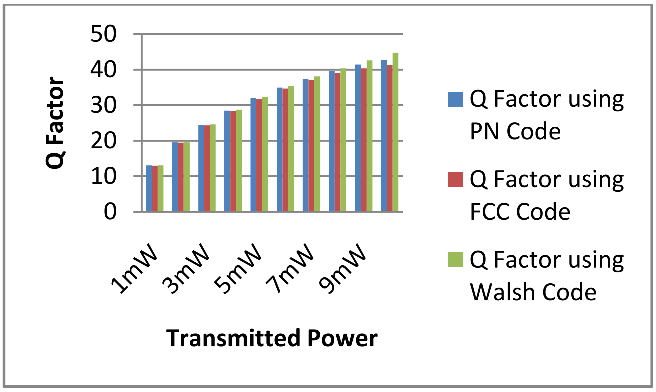
Fig. 6 Q factor versus Transmitted Power for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using CSRZ modulation



(a) Pre DCF Compensation



(b) Post DCF Compensation

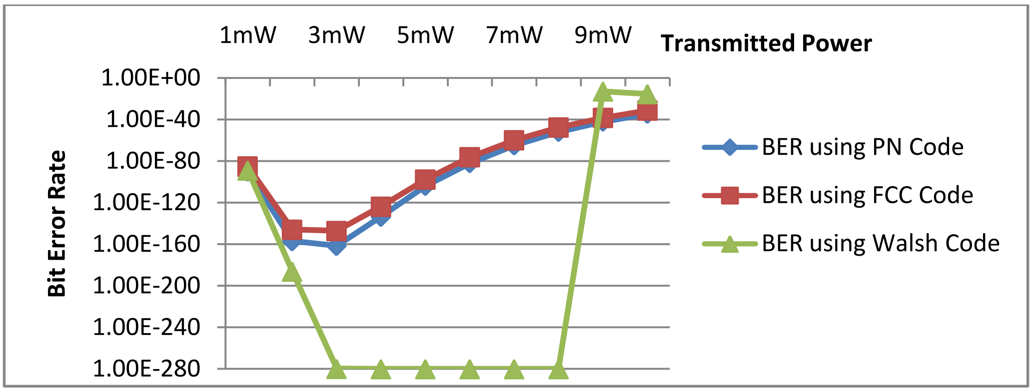


(c) Symmetrical DCF Compensation

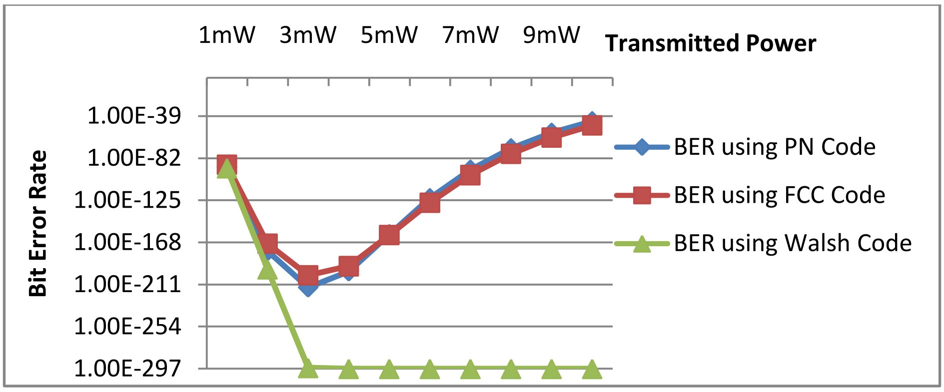
Fig. 7 Q factor versus Transmitted Power for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using Duo-Binary modulation

B. BER versus Transmitted Power

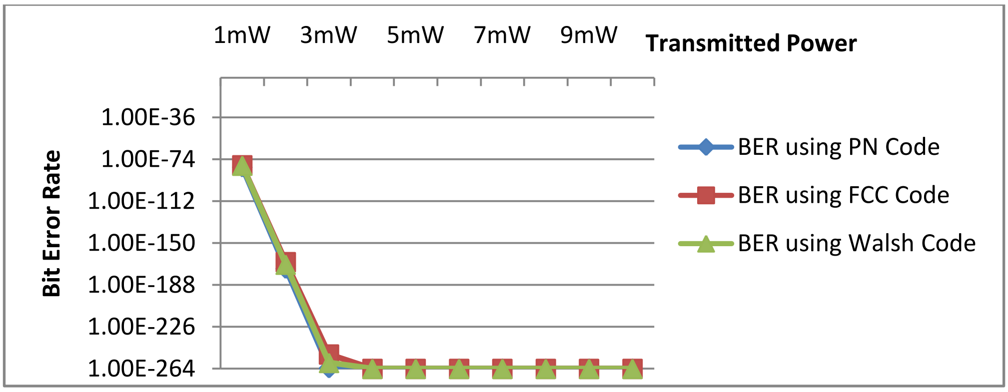
Fig. 8, 9,10 and 11 shows the comparative analysis between Bit Error Rate (BER) and transmitted CW laser power for the Pre, Post and Symmetrical DCF techniques using NRZ, RZ, CSRZ and Duo-Binary Modulation using PN, FCC and Walsh codes. From the graphs it is concluded that we get BER=0 using Walsh code for all the implemented techniques at 10 mW CW laser power.



(a) Pre DCF Compensation

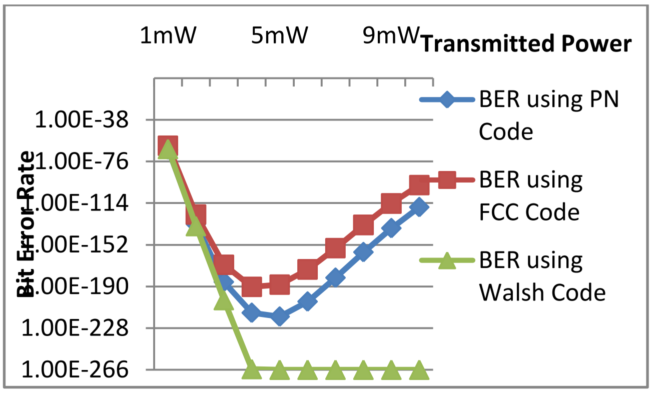


(b) Post DCF Compensation

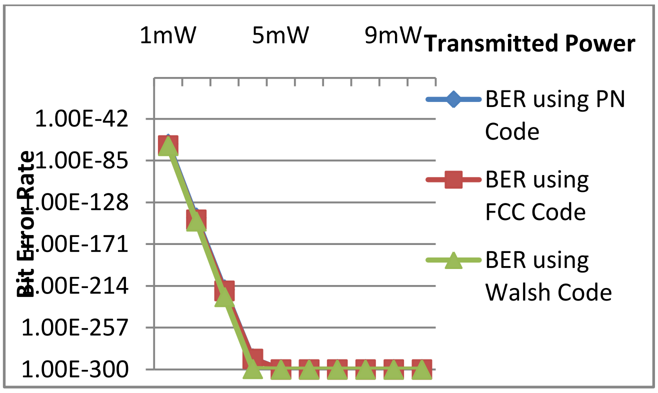


(c) Symmetrical DCF Compensation

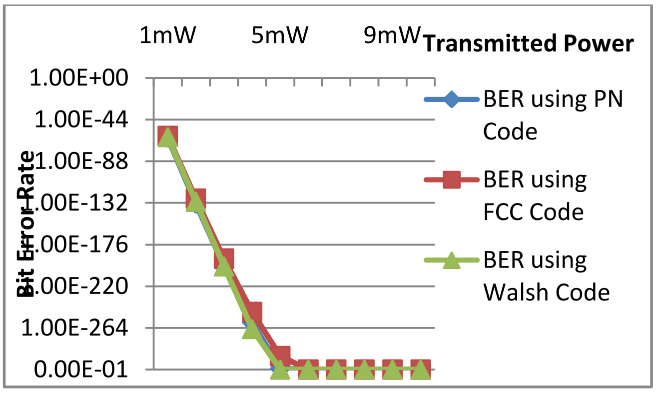
Fig. 8 BER versus Transmitted Power for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using NRZ modulation



(a) Pre DCF Compensation

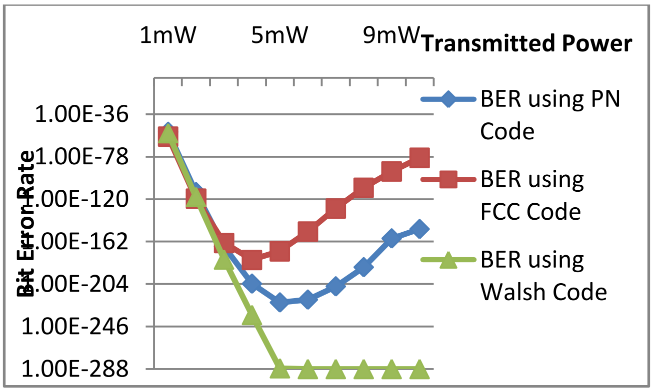


(b) Post DCF Compensation

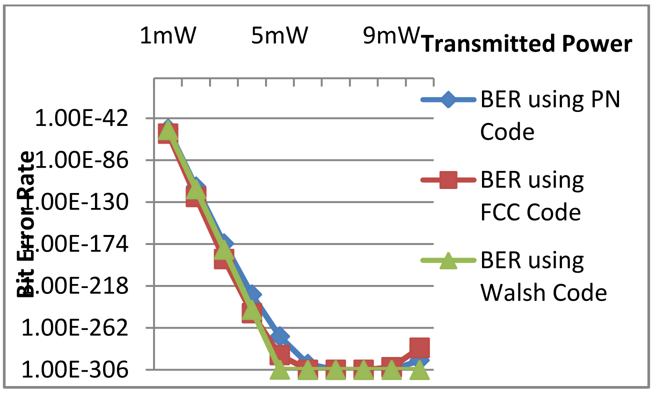


(c) Symmetrical DCF Compensation

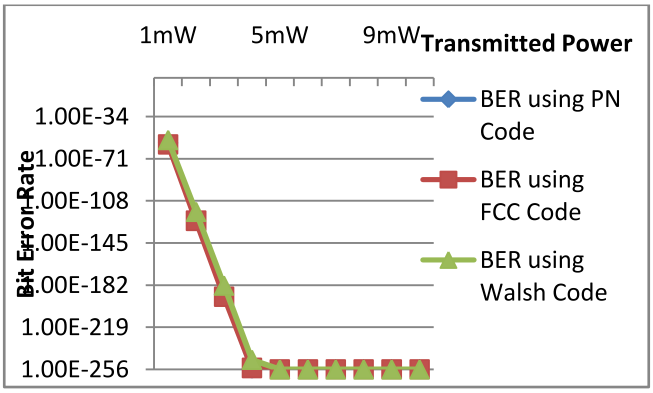
Fig. 9 BER versus Transmitted Power for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using RZ modulation



(a) Pre DCF Compensation

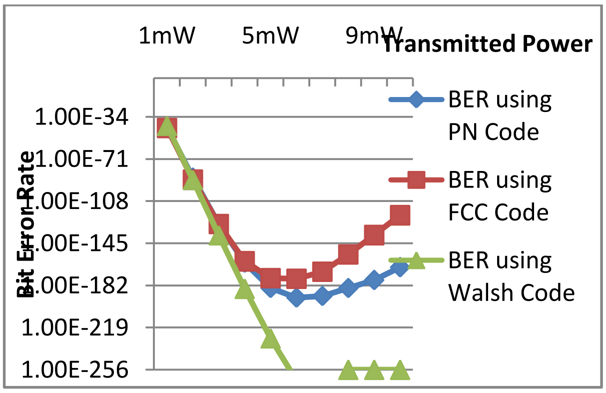


(b) Post DCF Compensation

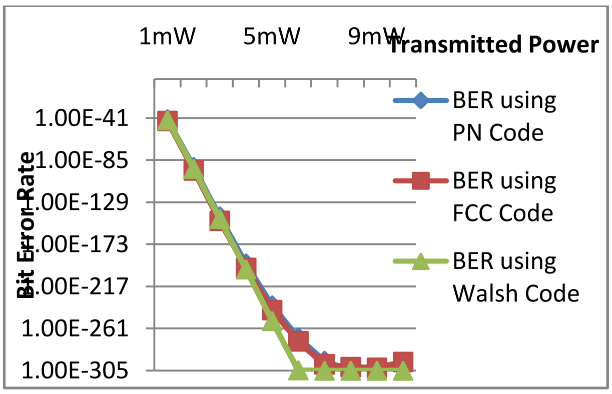


(c) Symmetrical DCF Compensation

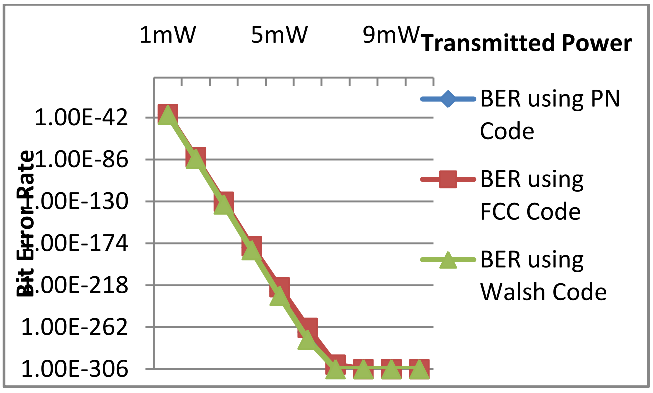
Fig. 10 BER versus Transmitted Power for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using CSRZ modulation



(a) Pre DCF Compensation



(b) Post DCF Compensation

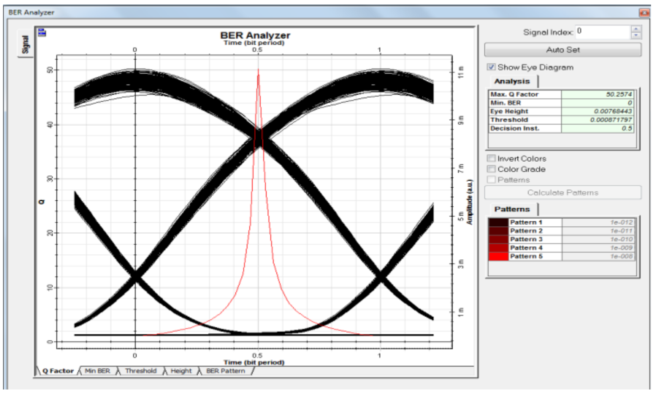


(c) Symmetrical DCF Compensation

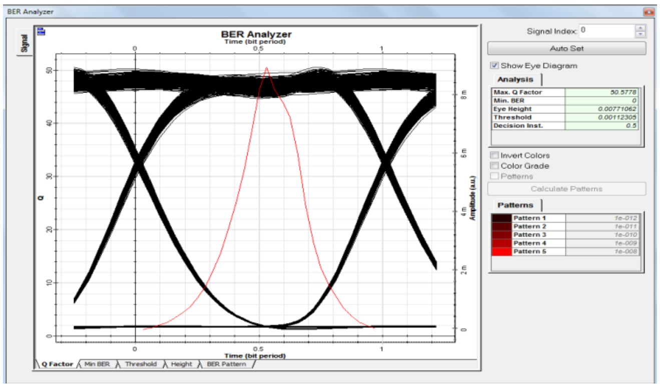
Fig. 11 BER versus Transmitted Power for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using Duo-Binary modulation

C. BER Diagram

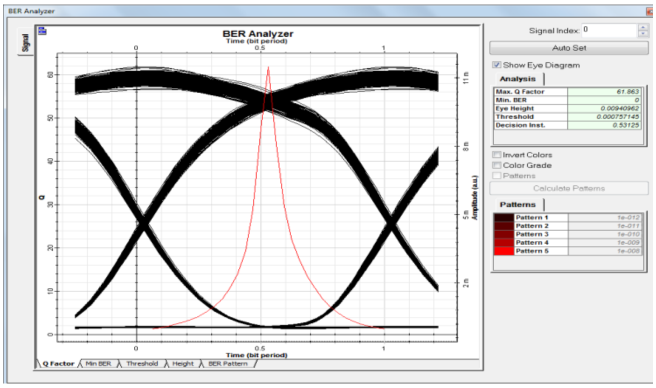
Fig.12, 13, 14, and 15 shows the Eye diagram or BER diagram for Pre, Post and Symmetrical DCF techniques using NRZ, RZ, CSRZ and Duo- Binary Modulation for only those value of CW laser power and Input sequence code in which we are getting the higher value of Q factor and minimum value of BER.



(a) Qfactor= 50.2574 and BER= 0 at 8 mw

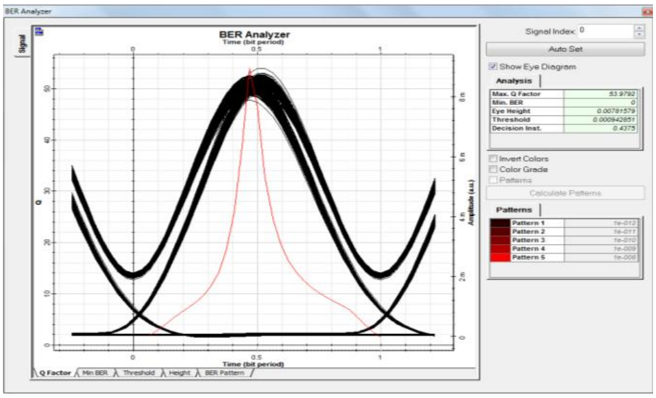


(b) Qfactor= 50.5778 and BER= 0 at 9 mw

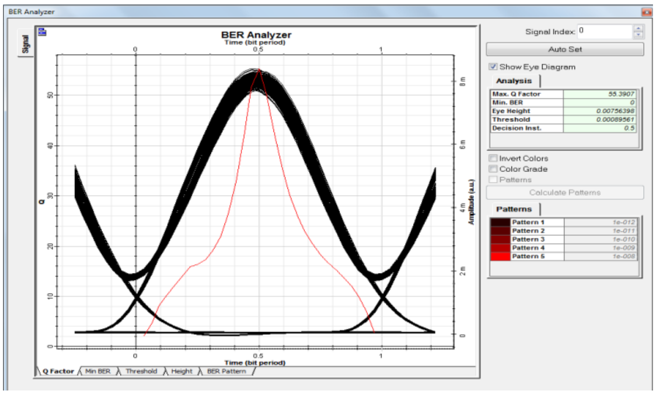


(c) Qfactor= 61.863 and BER= 0 at 10 mw

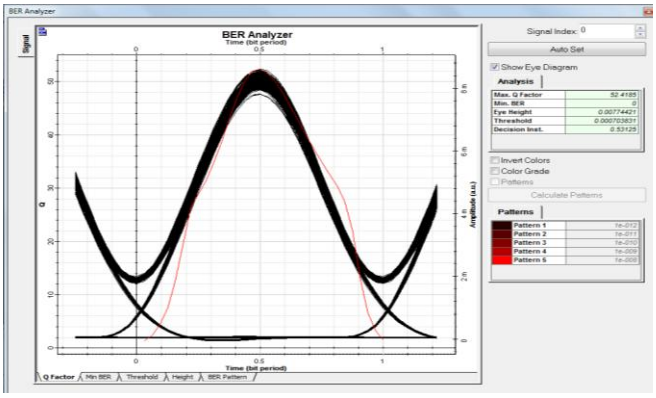
Fig. 12 BER analyzer diagram for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using NRZ modulation for Walsh code



(a) Q factor= 53.9792 and BER= 0 at 10 mW

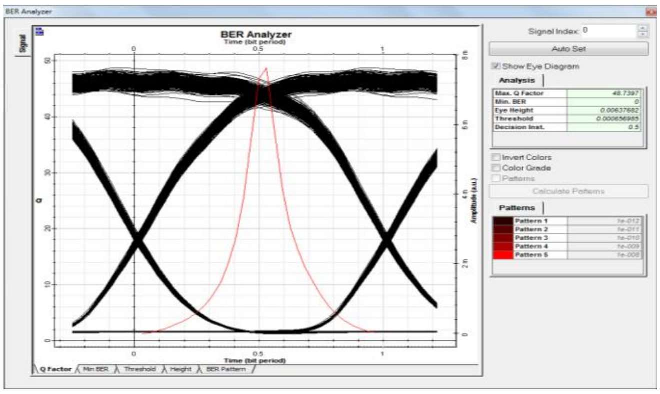


(b) Q factor= 55.3907 and BER= 0 at 10 mW

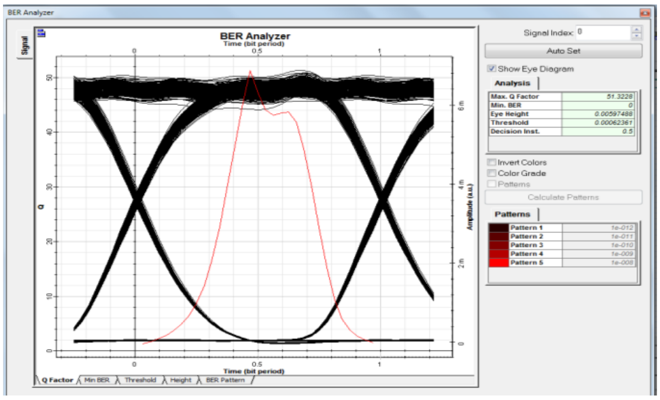


(c) Q factor= 52.4185 and BER= 0 at 10 mW

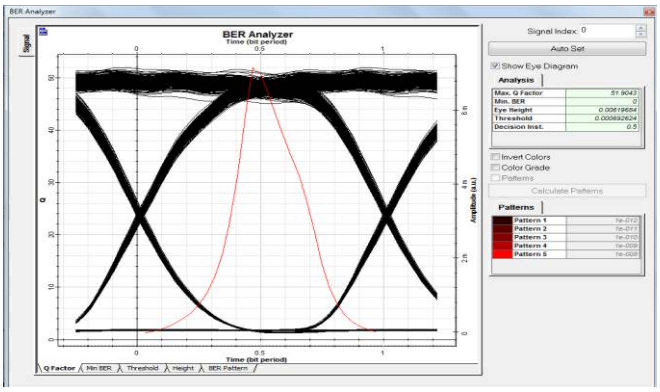
Fig. 13 BER analyzer diagram for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using RZ modulation for Walsh code



(a) Q factor= 48.7397 and BER= 0 at 10 mW

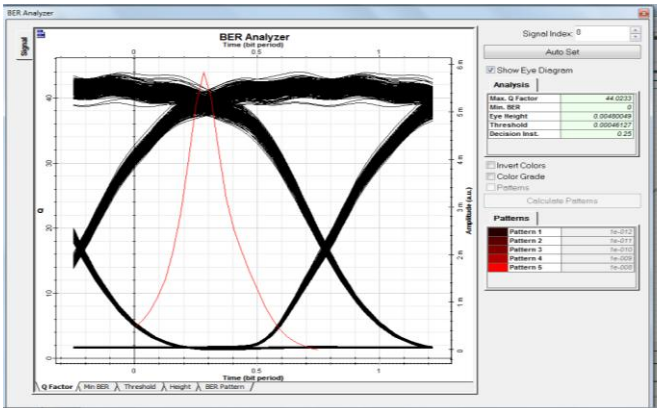


(b) Q factor= 51.3228 and BER= 0 at 10 mW

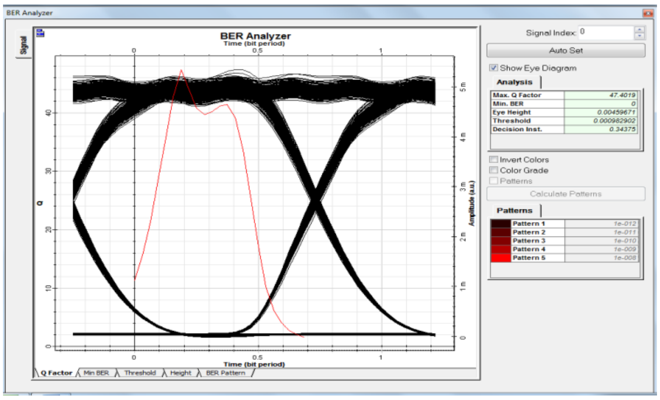


(c) Q factor= 51.9043 and BER= 0 at 10 mW

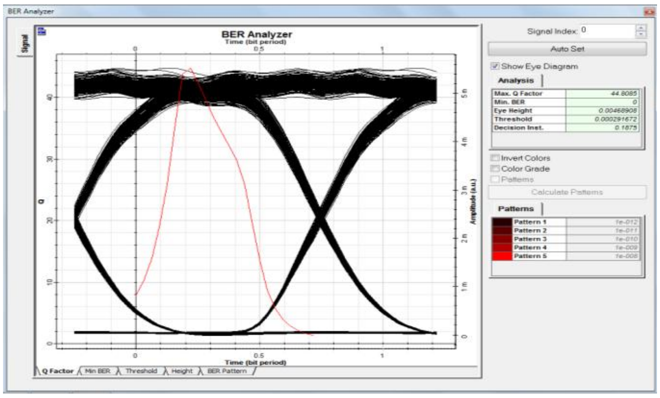
Fig. 14 BER analyzer diagram for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using CSRZ modulation for Walsh code



(a) Q factor= 44.0233 and BER= 0 at 10 mW



(b) Q factor= 47.4019 and BER= 0 at 10 mW



(a) Q factor= 44.8085 and BER= 0 at 10 mW

Fig. 15 BER analyzer diagram for (a) Pre (b) Post and (c) Symmetrical DCF compensation technique using Duo-Binary modulation for Walsh code

4. CONCLUSION AND FUTURE SCOPE

The Inter Symbol Interference is decreased with the increment of Q factor and decrement of BER. BER is the function of system quality factor Q. In this paper we have done the comparative analysis for different DCF based dispersion compensation techniques using different modulation formats, input code sequences and input CW laser power to find out the efficient dispersion compensation techniques at 10 Gbps data rate and channel length of 240 km. From the paper it is concluded that when Walsh code are used as input data sequence it gives the higher value of Q factor and minimum value of BER in almost all simulations as compared to PN and FCC codes used. In the future work, we will use this methodology for other dispersion compensation technique also for further comparative analysis to find out the efficient dispersion compensation techniques.

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