STM JOURNALS

Trends in
Opto-electro & Optical Communication

ISSN: 2231-0401 (Online)
ISSN: 2347-9957 (Print)
Volume 11, Issue 1, 2021
DOI (Journal): 10.37591/ TOEOC

http://engineeringjournals.stmjournals.in/index.php/TOEOC/index

Research TOEOC

Simulation of Wavelength Division Multiplexing Based Fiber Optic Link by Using Different Types of Dispersion Compensating Fiber

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Abstract

Wavelength division multiplexing (WDM) multiplies various optical signals on a single optical fiber by using different wavelengths of laser light at the transmitter end and demultiplex them into multiple optical signal at the receiver end. We want to improve overall system performance and reduced as much as possible the transmission performance influenced by the dispersion, several dispersion compensation technologies are involved. In this paper, we have studied the WDM based fiber optical link using dispersion compensating fiber techniques such as post, pre and mix compensation and their results will be compared on the basis of bit error rate and eye pattern obtained at the receiver.

Keywords: BER performance, dispersion compensated fiber (DCF), pre, post and mix compensation

INTRODUCTION

Wavelength-division multiplexing (WDM) is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelength of laser light to carry different signals. This allows for a multiplication capacity, in addition to enabling bidirectional communications over one strand of fiber. Enormous bandwidth (huge capacity of carrying information) and ultra-high speed are the major advantages of WDM systems [1]. Apart from the major advantages, it also has ability to form highly flexible networks. Passive Optical Network (PON), short haul network and long haul network, and undersea systems are the best applications of WDM systems [1].

Opti-system Software

Opti-system is an innovative optical communication system simulation package, which was explored by Optical Wave Company in order to meet the requirement of system designers, optical communications engineers, and researchers. It integrates design, test and optimize all types of broadcast optical network physical layer functions such as virtual optical connections. From long distance communication system to LANs and MANs, it can be well used. We have listed the library components which have been used in the simulation of fiber optic link using Dispersion compensated fiber (DCF) at 1550 nm wavelength (Table 1).

Library Components of Opti-system Used for Simulation

Dispersion Compensated Fiber Link

Dispersion-shifted fibers may suffer from four-wave mixing which causes inter-modulation of the independent signals, when used in WDM system. Hence the use of DSF is avoided, but compensation of dispersion is necessary. That is why DCFs come into picture.

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Received Date: May 24, 2021
Accepted Date: June 20, 2021
Published Date: June 30, 2021

Citation: Pooja Mishra. Simulation of Wavelength Division Multiplexing Based Fiber Optic Link by Using Different Types of Dispersion Compensating Fiber. Trends in Opto-electro & Optical Communication. 2021; 11(1): 19–24p.

Table 1. Description of library components used in simulation.

Components	Specifications
P R B S Generator	Bit rate = 10 Gbps
N R Z Pulse Generator	Rectangular pulse
Continuous Wave L A S E R	Frequency in THz
M Z Modulator	Extinction ratio = 30 dB
MUX DEMUX	Bandwidth = 10GHz
Optical Fiber	Attenuation = 0.2 dB/km
Optical Amplifier	Gain = 20 dB, Noise figure = 4dB
Optical Attenuator	Attenuation = 0 dB
Photo detector	Dark current = 10 nA
Low Pass Filter	Cut off frequency = 7.5 GHz

Several techniques, including dispersion compensating fiber can be used to compensate the accumulated dispersion in the fiber. In the following example, we will show three different schemes to compensate the fiber dispersion such as: post, pre and mix compensation schemes.

In our simulations, we have used optical amplifiers after each fiber to compensate for the span loss. The dispersion parameter of SMF is 60 km long and 16 ps/nm-km. Therefore, total accumulated dispersion is 16 × 60 = 960 ps/nm. This much dispersion can be compensated by using a 12 km long DCF with -80 ps/km-nm dispersion [2]. Therefore, total compensated dispersion is 12 x (-80) = -960 ps/nm. Means finally we get zero dispersion (960-960 = 0) as per given formula [2].

Since,

$D_1L_1 + D_2L_2 = 0$

Where, D_1 is the dispersion per km in SMF, L_1 is the total length of SMF, D_2 is the dispersion per km in DCF, L_2 is the total length of DCF.

Pre-compensation

In this compensation scheme, the dispersion compensating fiber of negative dispersion is placed before the standard fiber to compensate positive dispersion of standard fiber.

Post-compensation

In this compensation scheme, the dispersion compensation fiber of negative dispersion is placed after the standard fiber to compensate positive dispersion of standard fiber.

Mix Compensation

In this compensation scheme, the dispersion compensating fiber of negative dispersion is placed before and after the standard fiber to compensate positive dispersion of standard fiber [3, 4].

Simulation of Pre, Post, Mix DCF Links

To simulate the designs in 10 Gbps, one needs to set the global parameter bit rate to 10 Gbps. From several observations taken by simulation, we can conclude that the best performance is obtained by using mix dispersion compensation followed by post- and then pre-compensation. The worst case is dispersion pre-compensation (Figure 1).

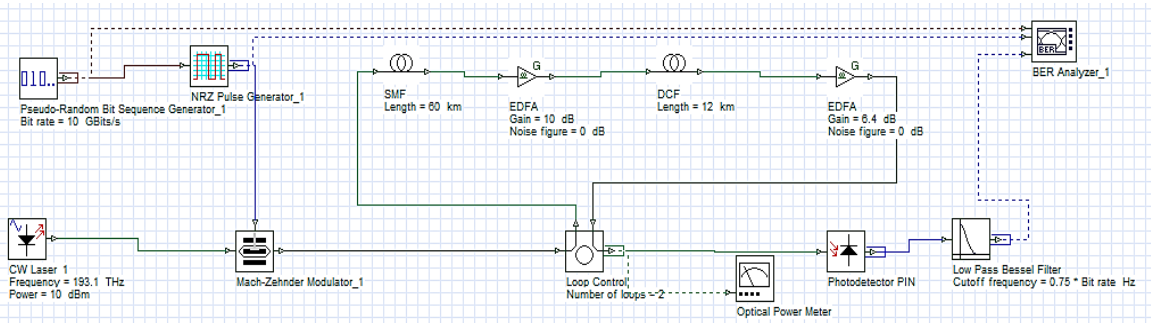

Figure 1. Schematic of post DCF link.

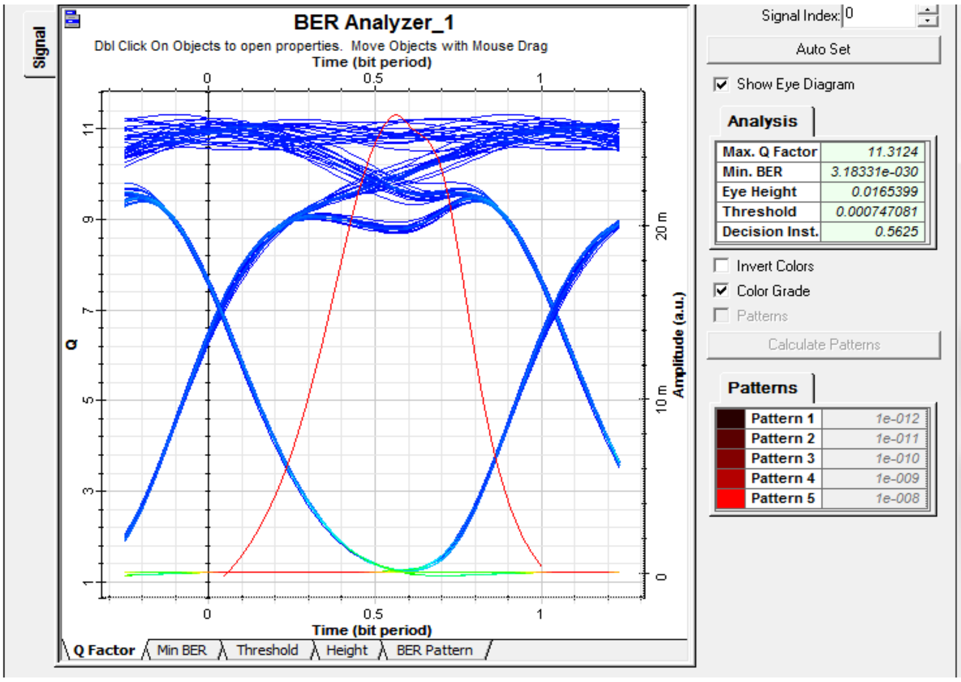

Figure 2. Eye pattern obtained for post DCF link.

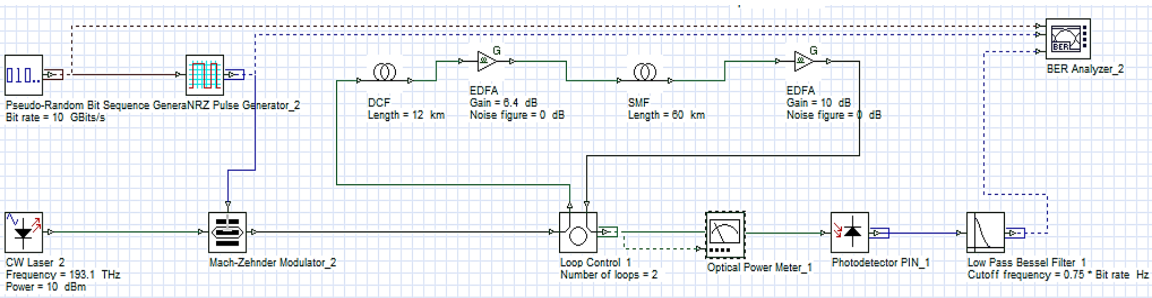

Figure 3. Schematic of post DCF link.

Simulation of Post DCF Link

Result obtained after the simulation of post DCF link at can be listed as follows (Figure 2): Max (Figure 3). Q-factor = 11.3124 and Min. BER = 10^{-30}

Simulation of Pre DCF Link

Result obtained after the simulation of pre DCF link at 1550 nm can be listed as follows (Figure 4): Max (Figure 5). Q-factor = 6.25481 and Min. BER = 10^{-10}

Simulation of Mix DCF Link

Result obtained after the simulation of mix DCF link at 1550 nm can be listed as follows:
Max (Figure 6). Q-factor = 48.0619 and Min. BER = 0

We can see from the eye diagram obtained from pre, post, mix DCF links that less error is introduced in the case of mix dispersion compensating fiber case as the BER is zero. So we have a clean eye pattern at the receiver [7, 8].

RESULTS

On the basis of results listed in the Table 2 shown below, one can draw a combined plot for the comparison among post, pre and mix DCF link showing the variation of Q-factor with respect to Received power in dBm [5].

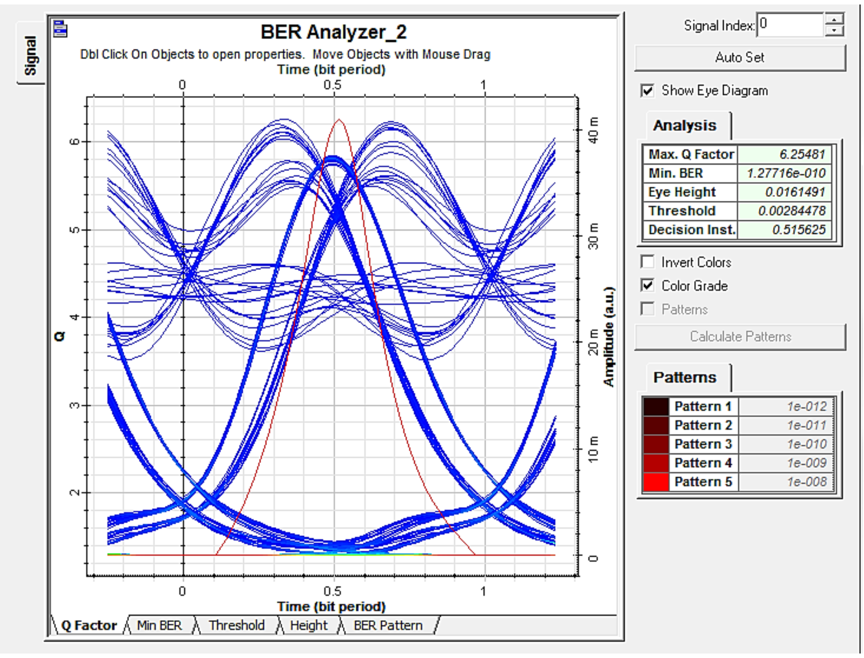

Figure 4. Eye pattern obtained for pre DCF link.

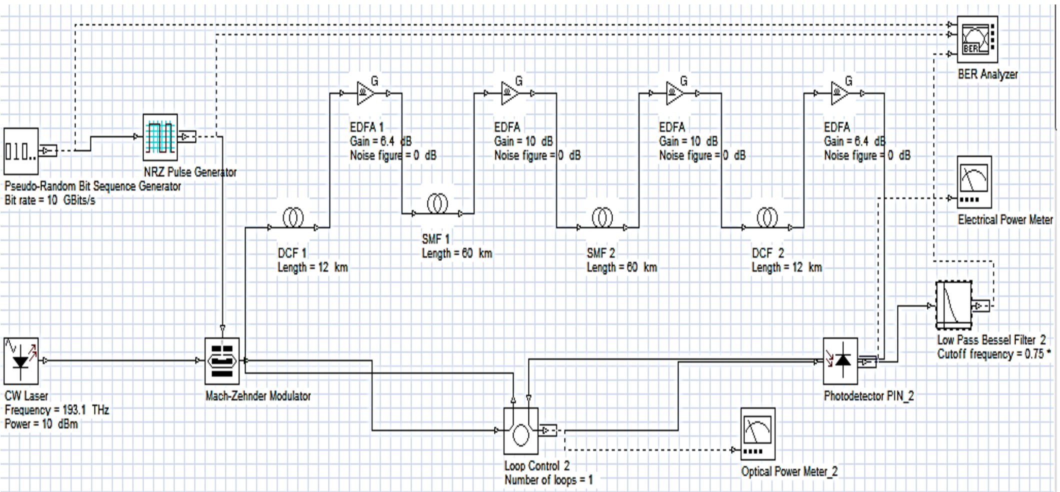

Figure 5. Schematic of mix DCF link.

From the above plot showing the variation of Received power wrt Q-factor one can conclude the followings (Figure7):

1. Worst performance can be achieved by using Pre Dispersion Compensation Scheme.
2. Good performance can be achieved by using Post Dispersion Compensation Scheme.
3. Best performance can be achieved by using Mix Dispersion Compensation Scheme [6].

Table 2. Received power vs. Q-factor variation for post, pre and mix DCF link.

Post *Received Power in dBm*	**Post** *Q-Factor*	**Pre** *Received Power in dBm*	**Pre** *Q-Factor*	**Mix** *Received Power in dBm*	**Mix** *Q-Factor*
-5.16	41.90	-5.365	66.23	-5.06	62.72
-3.794	54.746	-3.639	72.20	-3.457	79.87
1.234	83.678	1.02	37.44	1.037	96.91
3.097	69.562	2.95	26.126	2.945	79.596
5.976	39.051	5.90	13.78	5.864	50.776
9.902	14.75	9.874	6.86	9.814	31.508

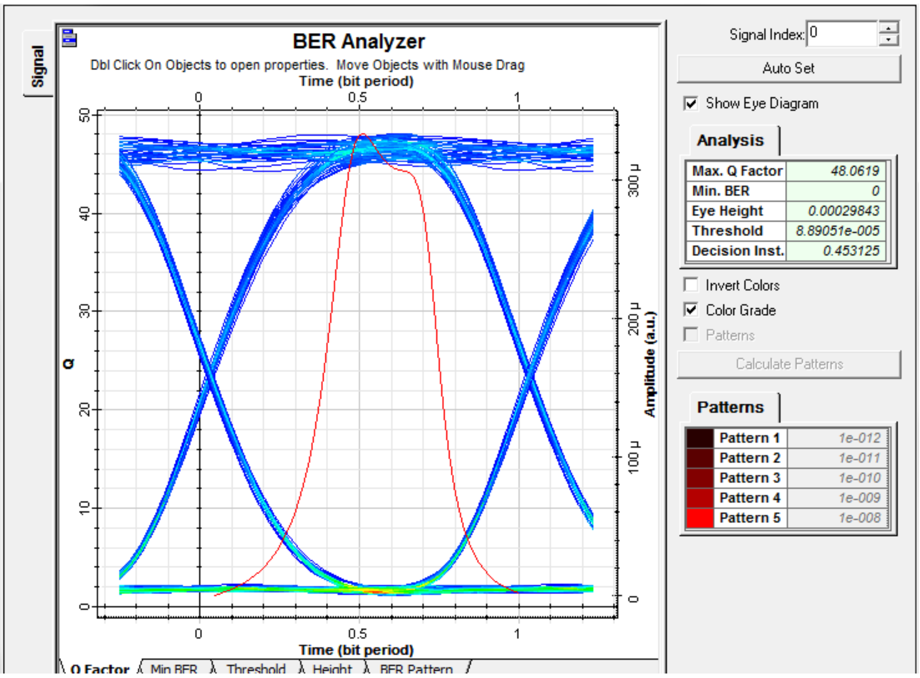

Figure 6. Eye pattern for mix DCF link.

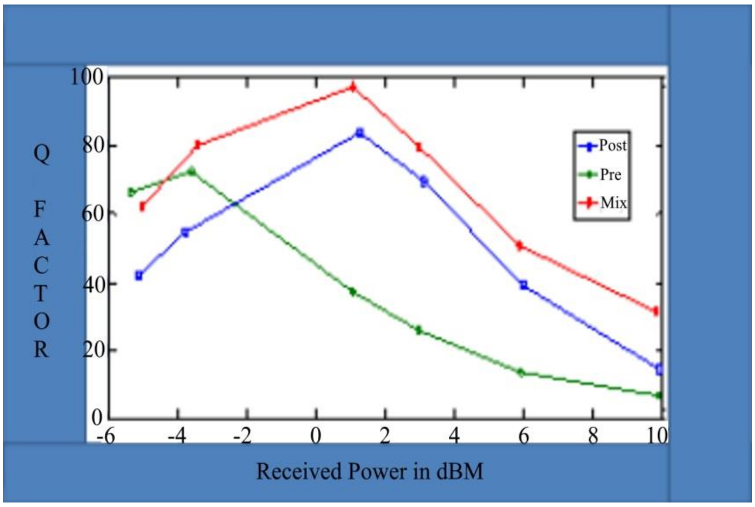

Figure 7. Received power in dBm vs Q-factor plot.

CONCLUSION

Simulation of post, pre and mix DCF link shows that best performance is obtained by using mix dispersion compensation followed by post and then pre-compensation. The worst case is dispersion pre-compensation. To obtain the better signal at the receiving end, we check for different combinations of dispersion compensation components and different length of DCF. In first technique, we used pre DCF for minimizing core and cladding losses. DCF are used in all circuits for removing these losses for improvement in signal strength and to minimize dispersion, we use DCF. This DCF can be placed before and after the fiber. Dispersion can be compensating by using DCF for a particular length. In all the simulations, we find that the maximum Q-factor is in mix DCF compensation technique. Because of better Q-factor in mix DCF, the received signal will be less dispersed.

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