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Performance Comparison of Dispersion Compensation Schemes Using DCF in DWDM Optical Network

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Abstract — The dense wavelength division multiplexing (DWDM) system enhances bandwidth capacity for long-haul communications system, but the system performance is affected by a chromatic dispersion especially in the high bitrate communication caused by different refractive index in pulse propagation for optical link. Using the Dispersion compensating fiber (DCF) can compensate for the positive dispersion in the optical link because it has negative dispersion value and can reduce the effect of the chromatic dispersion. We look for the suitable DCF scheme in our DWDM System using 16 channels with bitrate 40 Gbps per channel, channel spacing 200 GHz and optical link length 300 km and discuss the system performance to compensate dispersion in DWDM systems with the optical launch power variation. Based on the result, the system with the symmetrical scheme with optical power launch had the best performance with BER 8.33×10^{-86} and Q-factor 19.572. Optical power launch had the effect to the system performance, the optical power launch 0 dBm in the all DCF scheme was not meet with ITU-T standard for optical link. In sequentially Q-factor of the pre-compensating, post compensating, and symmetrical compensating fiber schemes is 6.007, 6.209, and 6.608 which are not meet the ITU-T standard that Q-factor has to more than 7.20. The increasing optical power launch improved the system performance for all DCF scheme. In sequentially Q-factor of the symmetrical scheme with input power 0 dBm, 2 dBm, 4 dBm, 6 dBm, 8 dBm, and 10 dBm is 6.680, 8.510, 10.724. 13.340, 16.319, 19.572. This work obtains that the system with symmetrical compensating fiber more suitable than pre-compensating fiber and post-compensating fiber and the system with high optical launch power has better performance than low power.

Keywords – DCF, DWDM, BER, Q-Factor

I. INTRODUCTION

Optical Fiber Communication is a technology for transmission system using lightwave source which has large bandwidth. In addition, the optical fiber networks enable high capacity interconnection between transmitter and receiver with high speed internet and low bit error rate [1] [2]. The usability bandwidth of optical fiber communications is determined by multiplexing techniques which based on sending multiple information in a single optical fiber [3] using the scheme combining a number of wavelength [4]. Dense Wavelength Division Multiplexing (DWDM) is a technology based on sending multiple channel information in an optical fiber transmission using wavelength. DWDM characteristics are reducing the channel spacing of wavelength [5]. So it's provide large bandwidth and it's necessary for long haul optical communications system [6]. But DWDM system has interference called chromatic dispersion. Chromatic Dispersion is a signal distortion which causes by different refractive index propagation in optical fiber transmission to lead signal degradation thus affecting the system performance [7]. With 40 Gb/s transmission, the effect of chromatic dispersion should be anticipated [8]. Dispersion Compensating Fiber (DCF) is a solution to compensate chromatic dispersion [9]. The characteristic of DCF is a compensator with tunable negative dispersion, which could decrease the positive dispersion in the fiber transmission and make residual dispersion value become zero [10].

This research based on previous research for the literature review [11-15]. Mehtab Singh [11] compared the dispersion compensation schemes using DCF in Optical fiber communication link for Pre Compensation, Post Compensation, and Symmetrical Compensation using single wavelength channel. The result is symmetrical compensation give better performance for the system than Pre Compensation and Post Compensation. M. Tosson [12] compared the dispersion compensation techniques between Dispersion Compensation Fiber (DCF) and Fiber Bragg Grating (FBG) in DWDM systems. The result is FBG has a better performance for the system but in application is not efficient because it needs to put in all channels, where DCF is only used in the transmission link. Smith J. Anderson [13] compared two different optical amplifiers that are Erbium Doped Fiber Amplifier and Soliton Optical Amplifier for different schemes in WDM network. The result is EDFA amplifier gives better performance for all position than SOA amplifier. Berny D. Moses [14] compared the system performance using Direct Modulation and External Modulation for DWDM system using 16 channels. The result is modulation techniques using external modulation gives better performance than direct modulation in DWDM system. Rajat Paliwal [15] compared RZ and NRZ format modulation for DWDM optical network performance with channel spacing 100 GHz and 200 GHz. The result is NRZ modulation gives better performance for the system performance but narrow channel spacing gives worst performance for the system compare to the wide channel spacing.

In this paper, three schemes of dispersion compensation using DCF (Pre Compensating fiber, Post Compensating fiber, and Symmetrical Compensating fiber) are analysed to compensate chromatic dispersion in DWDM optical network. Modelling system is using 16 channels with 200 GHz channel spacing and 40 Gbps bitrate. Length of the transmission is 300 km and also use EDFA amplifier to minimize the power for the transmission system. The system performance will compare with input power variation for 0, 2, 4, 6, 8, and 10 dBm. The result is determined from BER and Q Factor parameters using software simulation OptiSystem 15.0.

II. RESEARCH METHOD

A. Dispersion Compensating Schemes

Dispersion compensation schemes are using DCF as the compensator. DCF is one of the most appropriated methods to compensate dispersion with characteristic negative dispersion that decrease the positive dispersion of the transmission lines to make the residual dispersion become zero [10]. There are three type of dispersion compensation schemes for DCF, as shown in Fig. 1 (a) Pre Compensating schemes placed DCF in the side before Single Mode Fiber and placed EDFA amplifier afterwards. In Fig. 1 (b) Post Compensating schemes placed DCF after the Single Mode Fiber and then followed by EDFA amplifier. In Fig. 1 (c) for Symmetrical Compensating schemes is a combination scheme of Pre Compensating and Post Compensating then followed by EDFA amplifier afterwards.

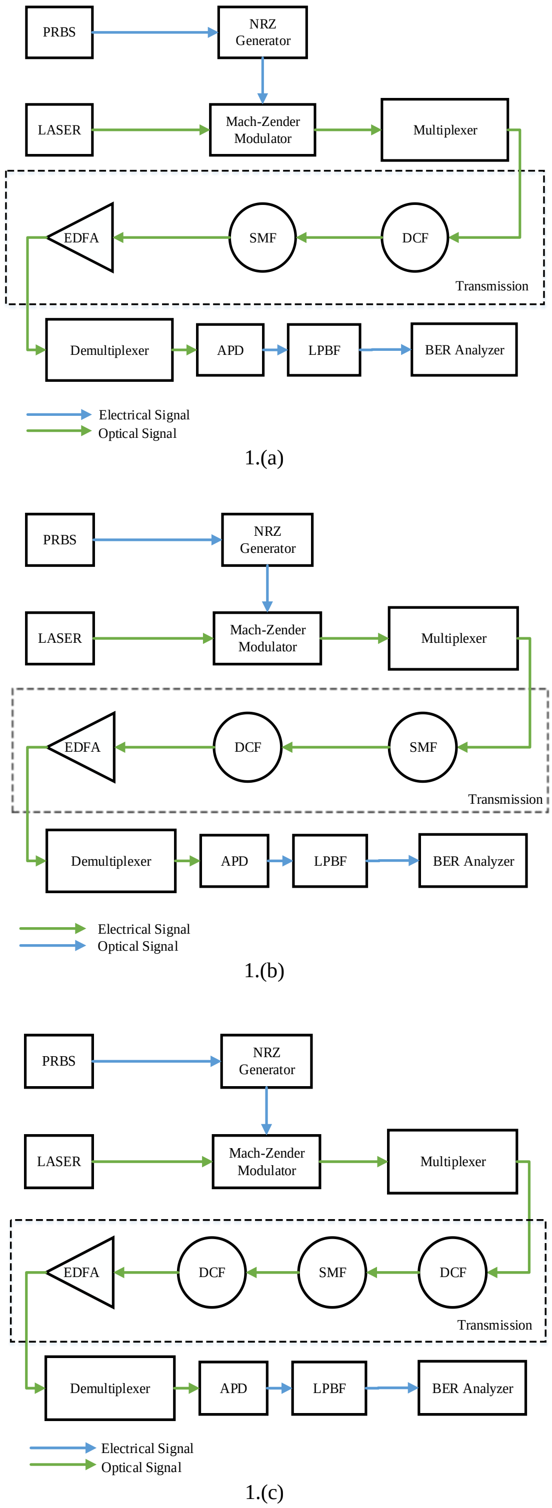


Fig.1. Block Diagram System of (a) Pre Compensating (b) Post Compensating (c) Symmetrical Compensating fiber schemes

B. Simulation Setup

The system for dispersion compensation schemes has been performed using OptiSystem 15.0 simulation software for Pre Compensating, Post Compensating, and Symmetrical Compensating fiber schemes. As can be seen in Fig.1, the system composed of 3 blocks. In transmitter block using CW laser as the light source, Pseudo Random Bit Sequences (PRBS) send the bit as electrical signals to NRZ Generator to generate into NRZ encoding. As shown in Table.1, we use optical launch power of 0, 2, 4, 6, 8, and 10 dBm. The optical signal from the laser and electrical signal is modulated in Mach Zender Modulator to transmit in optical fiber transmission. The signals from 16 channels using frequency 193.1 – 196.1 THz with channel spacing 200 GHz are combined in multiplexer to transmit in optical fiber transmission with length 300 Km for 40 Gbps bitrate in each channel. Transmission Block is using three schemes of DCF position that is Pre Compensating, Post Compensating, and Symmetrical Compensating fiber, single mode fiber, and EDFA amplifier minimize the attenuation.

Table 1. Simulation Parameters

Parameters	Value
Bitrate	40 Gbps
Central Frequency	193.1 THz
Channel Spacing	200 GHz
Number of Channel	16 Channel
Optical Power Launch	0, 2, 4, 6, 8, 10 dBm

Single mode fiber is used as the media transmission. Table.2 show the fiber parameter, the length of single mode fiber is 200 km with dispersion value is 18.5 ps/(km.nm) and attenuation 0.18 dB/km. Dispersion Compensating Fiber lengths has calculated to negative dispersion and it has lengths 100 km with dispersion value -37 ps/(km.nm) and attenuation 0.24 dB/km. EDFA amplifier is used to overcome the attenuation with 35 dB gain. In the receiver block, the signals are separated in demultiplexer to send to the photodetector. Photodetector is a component that used to receive the signal from the transmitter. In photodetector, optical signals are changed back to electrical signal. Low Pass Bessel Filter used as noise filter that come from the transmission system. BER analyzer also used to display the result of the system performance.

Table 2. Fiber Parameters

Parameters	SMF	DCF
Length	200 km	100 km
Attenuation	0.18 dB/km	0.24 dB/km
Dispersion	18.5 ps/(km.nm)	-37 ps/(km.nm)
Dispersion Slope	0.05 ps/(nm^2.km)	-0.12 ps/(nm^2.km)

III. RESULT

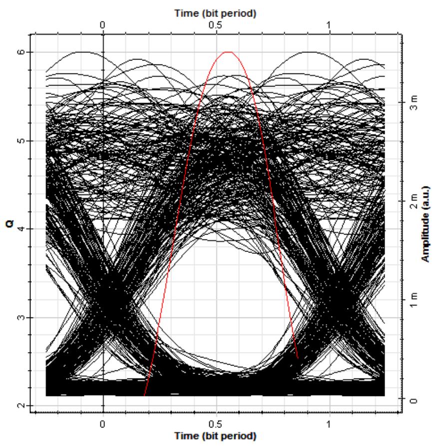
The simulation system for dispersion compensation in 16 Channels DWDM system using different dispersion compensation schemes in 40 Gbps bitrate has done. The results are obtained from BER and Q Factor parameters that simulated in OptiSystem 15.0 software. Table. 3 show the Q factor results from a channel which has the highest value of Pre compensating, post compensating, and symmetrical compensating schemes using different input power for 0, 2, 4, 6, 8, and 10 dBm. Table. 4 show the Bit Error Rate (BER) results from a channel which has minimum BER value at different dispersion compensation schemes using different input power for 0 dBm to 10 dBm.

Table 3. Maximum Q Factor parameters for Pre Compensating, Post Compensating, and Symmetrical Compensating schemes.

Input Power (dBm)	Pre Compensation	Post Compensation	Symmetrical Compensation
0	6.007	6.209	6.680
2	7.702	7.904	8.510
4	9.774	9.933	10.724
6	12.257	12.305	13.340
8	15.137	14.987	16.319
10	18.334	17.904	19.572

Table 4. Minimum BER parameters for Pre Compensating, Post Compensating, and Symmetrical Compensating schemes.

Input Power (dBm)	Pre Compensation	Post Compensation	Symmetrical Compensation
0	6.563×10^{-10}	1.837×10^{-10}	8.058×10^{-12}
2	4.494×10^{-15}	9.011×10^{-16}	5.716×10^{-18}
4	4.703×10^{-23}	9.724×10^{-24}	2.492×10^{-27}
6	4.913×10^{-35}	2.741×10^{-35}	4.280×10^{-41}
8	2.905×10^{-52}	2.843×10^{-51}	2.268×10^{-60}
10	1.398×10^{-75}	3.524×10^{-72}	8.336×10^{-86}



2.(a)

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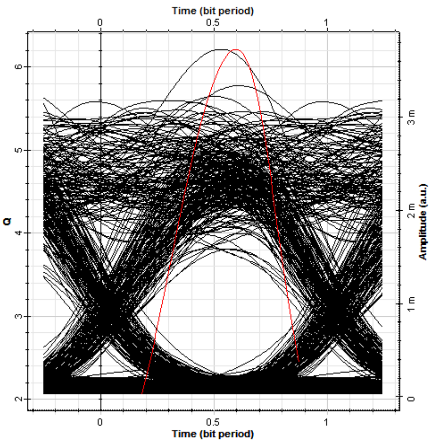
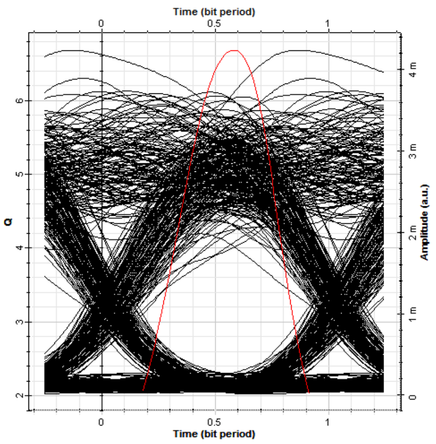


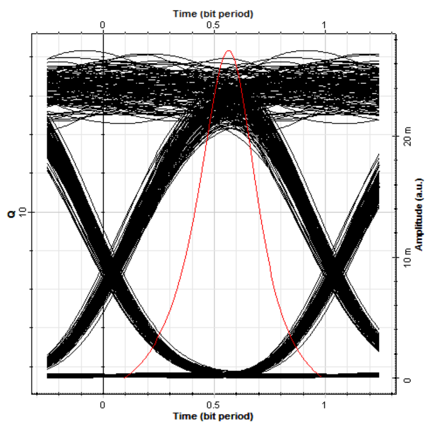
2.(b)



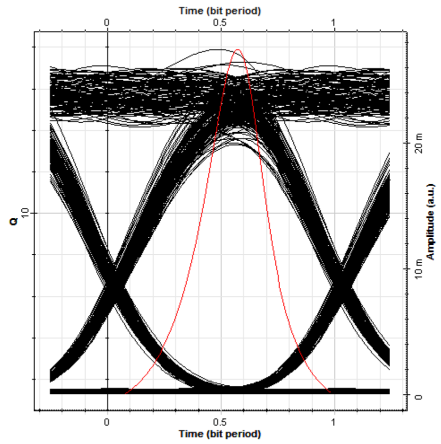
2.(c)

Fig.2 Eye diagram of (a) Pre Compensating (b) Post Compensating and (c) Symmetrical Compensating using 0 dBm input power

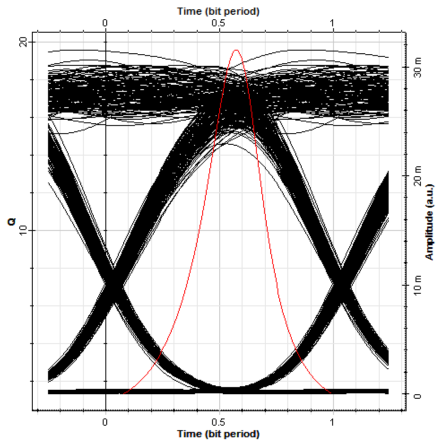
As shown in Fig.2, the eye diagram of all schemes are not opening well because it has many signal distortion in the system. Lowest input power is giving worst performance for the system. It's necessary to increase the input power to optimaze the system performance. In Fig.3 shows the eye diagram of three schemes using high input power at 10 dBm and shown that diagram eyes are opening well and it has less signal distortion in the system



3.(a)



3.(b)



3.(c)

Fig.3 Eye diagram of (a) Pre Compensating (b) Post Compensating (c) Symmetrical Compensating using 10 dBm input power.

IV. DISCUSSION

In this section, it discusses about the comparison of the system performance results of different dispersion compensation (Pre Compensating, Post Compensating, and Symmetrical Compensating) using DCF in BER and Q Factor using different input power. As a graph of Q factor in different input power that shown in Fig.4, increasing the input power is giving better performance for the system. It's because chromatic dispersion is fully compensated in dispersion compensating fiber. So the systems are working properly. But for the system using minimum input power is not working properly because it used for long haul communications system using length 300 km which causes many signal attenuation. As shown in Table. 3, Q value of 0 dBm input power is giving result of pre compensating 6.007, post compensating 6.209, and the highest result for 0 dBm input power is symmetrical compensating. This results are not recommended for the system because it has to reach the standard value for the quality system performance by Q factor parameter that Q>7. For the input power of 2, 4, 6, 8, and 10 dBm is reached the standard and its increasing continuously. The highest result is reach using 10 dBm input power with result of pre compensating is 18.334, post compensating is 17.904, and the higher is symmetrical compensating with result of Q factor is 19.572. For different scheme comparison using different input power, symmetrical compensating schemes gives higher results than pre compensating and post compensating schemes in 0 dBm to 10 dBm input power. Fig. 4 has shown a graph that symmetrical compensating gives the highest result for Q factor parameter than the other schemes, it's because symmetrical compensating is a combination scheme of pre compensating and post compensating where dispersion compensation is placed on each side of the single mode fiber and then it gives better results in the system performance because dispersion interference in the transmission is totally compensated better than Pre Compensating and Post Compensating.

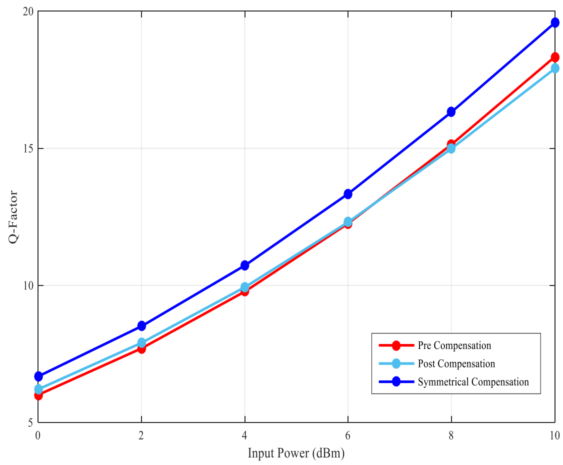


Fig.4 Q Factor of Pre Compensating, Post Compensating, and Symmetrical Compensating fiber schemes

The performance comparison of each scheme with different input power is shown in Bit Error Rate parameter. Bit Error Rate is a parameter that shows the number of error bits from the transmission system with value between 0 to 1. Fig. 5 shows the graph comparison of minimum BER for different schemes of dispersion compensation using different input power from 0 dBm to 10 dBm.

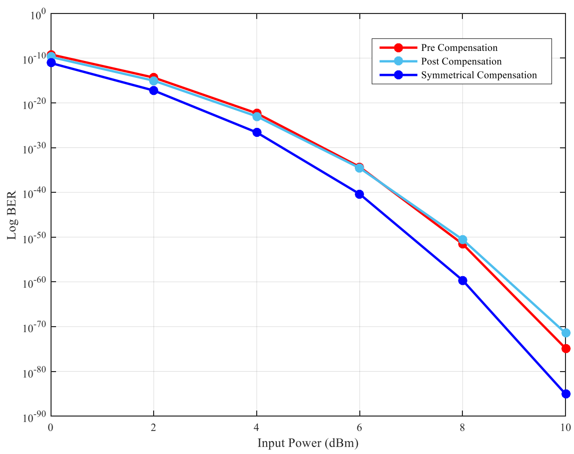


Fig.5 Log BER of Pre Compensating, Post Compensating, and Symmetrical Compensating fiber schemes

In Fig.5 shows that using high input power is decreasing the bit error. At 0 dBm is resulting bit error 6.563×10^{-10} for pre compensating schemes, post compensating schemes give results 1.837×10^{-10}, and symmetrical compensating give results 8.058×10^{-12}. Those results for Pre Compensating and Post Compensating are not recommended for the system because it has to reach the standard value for BER < 10^{-12}, and symmetrical compensating has reached the standard because it gives result under 10^{-12} in 0 dBm input power. In 2 to 10 dBm input power give result for BER parameters has reached under the standard with the lowest minimum BER has taken in 10 dBm. For the results in 10 dBm input power is giving bit error 1.398×10^{-75} for pre compensating, post compensating is 3.524×10^{-72}, and symmetrical compensating has resulted the minimum BER for 8.336×10^{-86}. It also obtains that symmetrical compensating schemes gives the lowest minimum BER than other schemes for each input power.

V. CONCLUSSION

This work obtained that Dispersion Compensating Fiber can be used to improve the DWDM system performance. For the DWDM system in this work, the symmetrical scheme has better performance than pre-compensating and post-compensating scheme. Based on result, enlarging the optical power launch increased the system performance. The design of DCF-DWDM in this works was not suitable with 0 dBm power launch especially for pre-compensating and post-compansating.

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