Investigation of 40-Gbps Dispersion Compensated DWDM System Incorporating Different Optical Pulses

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ABSTRACT

The focus of this paper is to report a detailed investigation of dispersion compensated DWDM system with equal channel spacing incorporating pre-, post- and symmetrical- dispersion compensation techniques (DCF) with different optical pulses. The proposed high speed DWDM system is demonstrated with dispersive standard single-mode fiber (SSMF), which is compensated with proportionate length of DCF fiber under different DCF compensation schemes. Further, a performance comparison of pre-, post- and symmetrical- DCF schemes is reported by computing Q-parameter, and required optical power at receiver sensitivity at varied values of laser line-width to underscore the best possible performance. A connection among the attributes like laser line-width, different optical pulses and different DCF schemes is reported at 10Gbps.

General Terms

Optical Fiber Compensation, Dispersion Compensation Technique.

Keywords

Dispersion, DCF compensation techniques, dense wavelength division multiplexing (DWDM)

1. INTRODUCTION

Dispersion is an important impairment that degrades overall system performance of a high speed long haul optical communication system and causes crosstalk. The introduction of erbium-doped amplifiers (EDFAs) operating in the 1550 nm region has increased the link distance as limited by fiber loss in optical communication systems. But, it introduces nonlinear effects, when several channels are co-propagating in the same fiber, which further degrade the system performances. Nonlinear effects arise as data rate, repeater-less transmission length, number of wavelengths, and optical power levels are increased. The interaction of propagating light with fiber leads to interference, distortion, or excess attenuation of the optical signals. The nonlinear effects tend to manifest themselves when optical power is very high and become prominent in WDM/DWDM systems. Nonlinear effects along with dispersion are the destructive forces for pulse propagation in ultra-high bit-rate optical transmission system and cause power penalty and other impairments in the system. Therefore, in order to realize the high data rates over long distances down the SM fiber, several methods have been proposed to overcome these degradations including initial pre-chirp[1], optical phase conjugation[2], dispersion compensating devices [3], differential delay method [4]. The use of dispersion compensated fiber is an important method for dispersion compensation and to upgrade the already installed links of single mode fiber [5]. Dispersion compensated fibers are specially designed fibers with high value of negative dispersion used to compensate for positive dispersion of ordinary fiber. Spans made of SSMF fibers and dispersion compensated fibers are good candidates for long distance transmission to overcome the signal degradations due to combined effects of group velocity dispersion, Kerr nonlinearity and accumulation of amplified spontaneous emission due to periodic amplification. This compensation is done by three methods, pre-, post- and symmetrical compensation. In earlier literature, pre-, post- and symmetry-DCF compensation methods were discussed by evaluating only few parameters like Q factor, bit error rate, eye diagram and power levels using different optical pulses [6-11]. In this paper, a detailed investigation of a dispersion compensated DWDM system with equal channel spacing of different optical pulses such as RZ soliton, NRZ and RZ raised cosine pulses at 10Gbps with varied laser line width using pre-, post- and symmetric-dispersion compensation techniques is reported. The performance of these three compensation schemes is compared by computing Q-parameter, required optical power at receiver sensitivity and Eye closure at varied values of laser line-width to highlight the optimum performance. In Section II, the optical simulated project and parameters are reported. In Section III, a comparison results have been reported for these compensation methods and finally in Section IV, conclusion is drawn.

2. SIMULATION SETUP

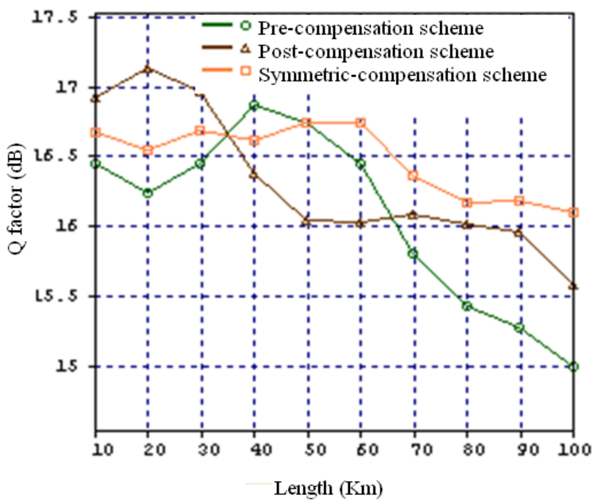
For simulation of high speed DWDM system using pre-, post- and symmetrical-DCF schemes with equal channel spacing of 0.25 nm, each transmitter section consists of four continuous wave lasers of varying line-width from 100 MHz to 100 KHz. The frequency for channel 1 is 1552 nm, for channel 2 is 1552.25 nm, for channel 3 is 1552.50 nm and for channel 4 is 1552.75 nm. This proposed dispersion compensated high speed DWDM system consist of a data source of bit rate is 10Gbps. An electrical driver is used to generate the desired data transmission format such as NRZ, RZ and RZ soliton by converting the logical input signal into an electrical signal. In the first case, the optical communication system is pre-compensated by the dispersion compensated fiber of -80ps/nm/km of proportionate length, calculated as L_{DCF}/L_{SMF} ~ 1/6, against the SSMF of 16ps/nm/km of length 100 km. In the second case, the optical communication system is post-compensated by the DCF fiber of -80ps/nm/km of proportionate length against standard fiber of 16ps/nm/km of length 100 km. In the third case of symmetrical compensation configuration, the system is symmetrically compensated by using two DCF fibers of -80 ps/nm/km of proportionate length against SSMF fiber. The output is detected at the receiver by PIN detector and is passed through an electrical filter.

3. RESULT& DISCUSSION

3.1 Evaluation of Q-parameter, Required Optical Power at Receiver Sensitivity and Eye closer with NRZ Optical pulse

An evaluation of Q-parameter of our simulative DWDM system after an optical span of 100 Km using pre-, post- and symmetric-dispersion compensation techniques at 10Gbps transmission rate at laser line-width of 100 KHz for NRZ optical pulse is carried out. It is observed that Q-parameter decreases with respect to optical span at the same rate for all channels for all DCF schemes as shown in Figure 1. An improvement of 1 dB and 0.5 dB is achieved for symmetric-DCF as compare with pre- and post- DCF respectively for channel 1 as shown in Figure 1 (a). An improvement of 1.1 dB and 0.7 dB is achieved for symmetric-DCF as compare with pre- and post- DCF respectively for channel 4 as shown in Figure 1 (c). Also, less variations in Q-parameter with optical span is observed with symmetric-DCF as compare to pre- and post- DCF for all the channels. The simulated results also put light on the fact that less value of Q-parameter is computed for the intermediate channels as shown in Figure 1 (b).

Further, an investigation of the required optical power at sensitivity to compensate the dispersive impact in our simulative dispersion compensated optical communication system after an optical span of 100Km is reported using Pre-, Post- and Symmetric-dispersion compensation techniques at varied laser line-width as shown in Figure 2. It has observed that the required optical power at sensitivity increases with respect to optical span for all the simulated channels and is a function of laser line-width. The optical power required at receiver sensitivity for compensating the dispersion-degradation after an optical span of 100 Km is computed as [-24.2dBm, -24.5dBm and -24.5dBm]; [-22.5dBm, -23.4dBm and -23.4dBm] and [-24.2dBm, -24.8dBm and -24.82dBm] for channel 1, 2 and 4 respectively at 10Gbps with 100MHz line width as shown in Figure 2. At laser line-width of 100 KHz, it is computed as [-20.85dBm, -21.2dBm and -21.5dBm]; [-19.8dBm, -19.2dBm and -19.4dBm] and [-20.8dBm, -21.4dBm and -22dBm] for channel 1, 2 and 4 respectively as shown in Figure 3.



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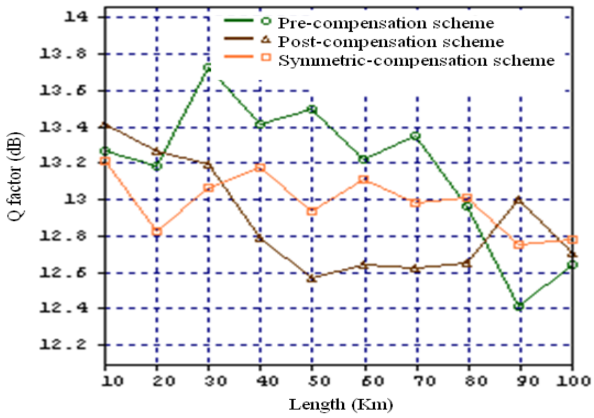

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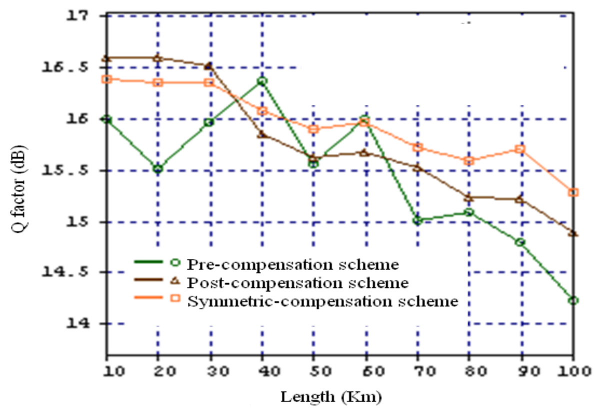

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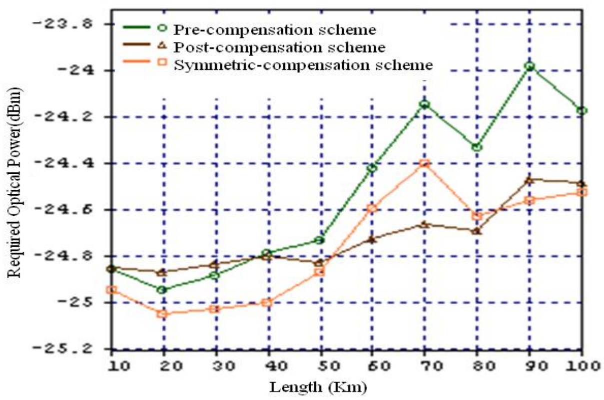
Fig 1: Evaluation of Q-parameter vs Optical Span with laser line-width of 100 KHz using different DCF schemes of (a) Channel 1, (b) Channel 2, and (c) Channel 4 with NRZ format at 10Gbps with equal channel spacing of 0.25 nm

This concludes that by reducing the laser line-width, the optical power required for receiver sensitivity can be reduced. Further, it is also observed that post-and symmetric-DCF schemes perform equally well for all the channels at laser line width of 100 MHz and 100 as shown in Figure 2-3.



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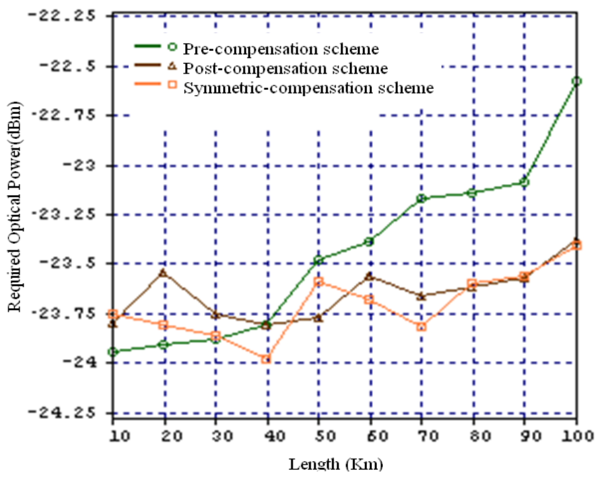

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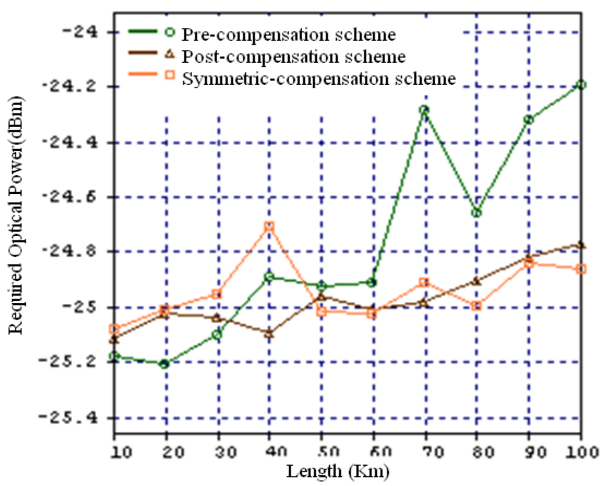
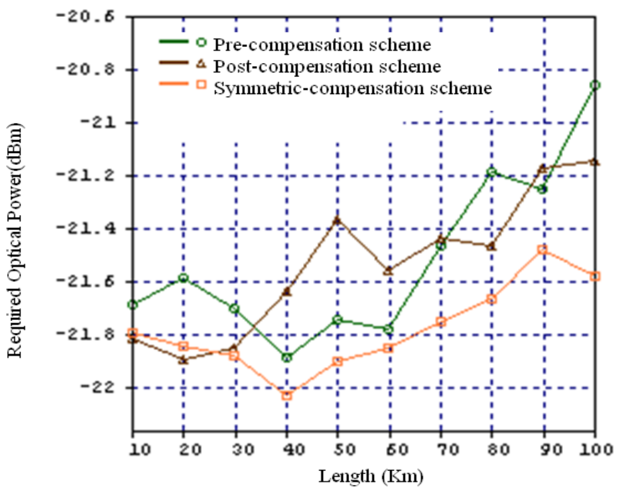


(c)

Fig 2 : Evaluation of Required Optical Power at sensitivity vs Optical Span with laser line-width of 100 MHz using different DCF schemes of (a) Channel 1, (b) Channel 2, and (c) Channel 4 with NRZ format at 10 Gbps with equal channel spacing of 0.25 nm



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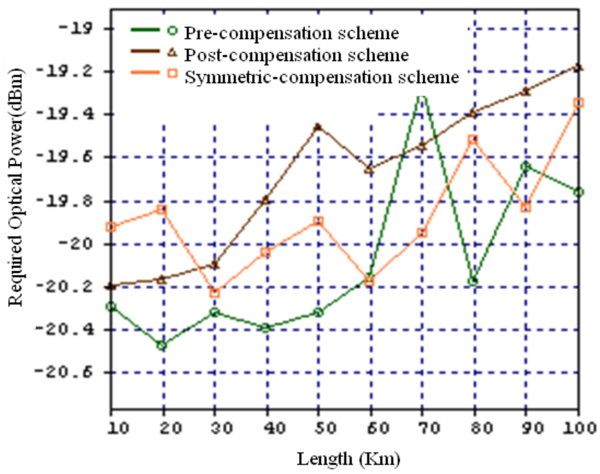

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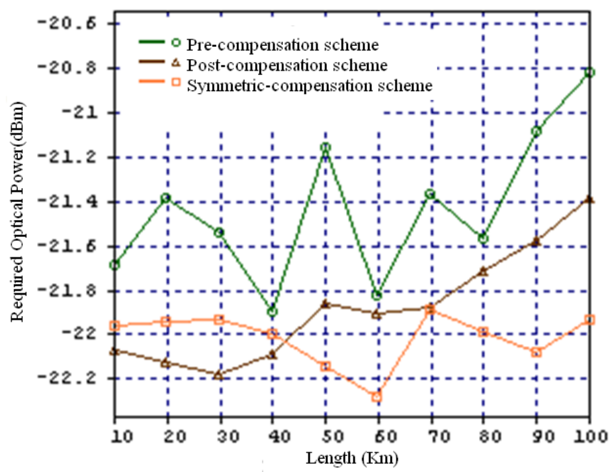

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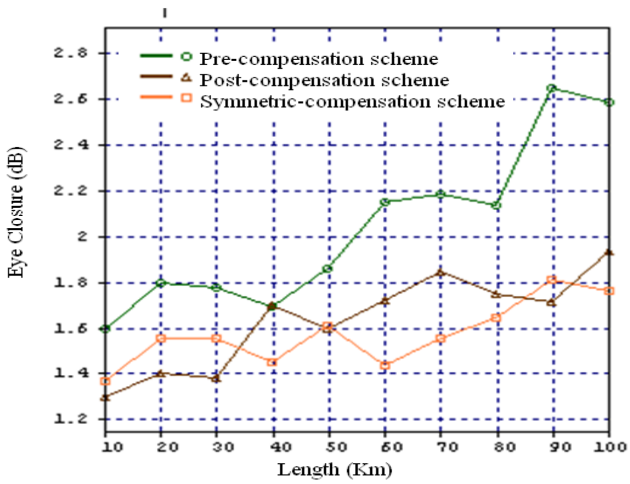
Fig 3 : Evaluation of Required Optical Power at sensitivity vs Optical Span with laser line-width of 100 KHz using different DCF schemes of (a) Channel 1, (b) Channel 2, and (c) Channel 4 with NRZ format at 10 Gbps with equal channel spacing of 0.25 nm

Further, we have computed the eye-closer of our simulative dispersion compensated DWDM system using pre-, post- and symmetric-dispersion compensation techniques at different values of laser line-width. It is seen that the eye closer increases with respect to optical span for all the simulated DCF schemes, but the rate of increment is maximum for pre-DCF scheme for all the channels as shown in Figure 4-5. An improvement of approx. 1 dB is observed with symmetric-DCF as compare to pre- DCF for channel 1 and channel 4 at 100MHz. The post- DCF also performs well as compare to pre- DCF for channel 1 and channel 4 at 100MHz.

It is also observed that the intermediate-channels are suffered more as compare to side-channels as shown in Figure 4-5. On reducing the laser line-width from 100 MHz to 100 KHz, it is institute that eye closure reduces for all channels and showing the same behavior as that of at 100 MHz.



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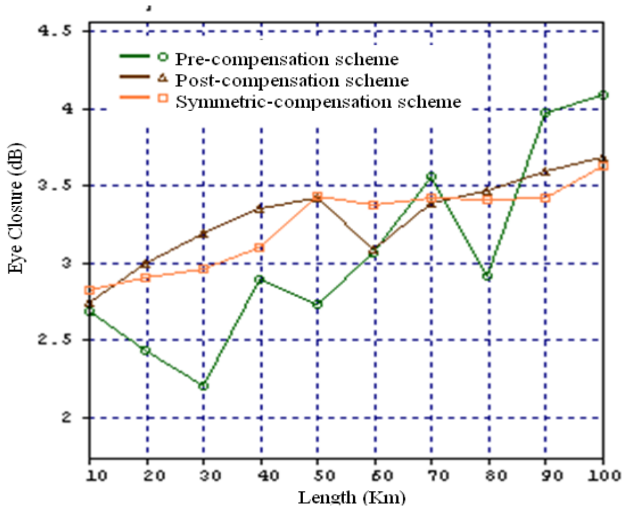

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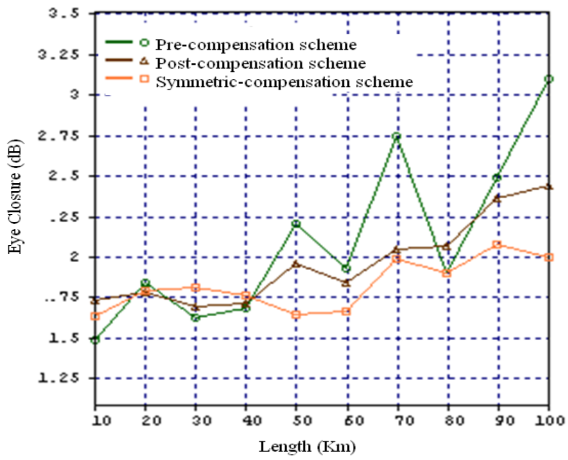

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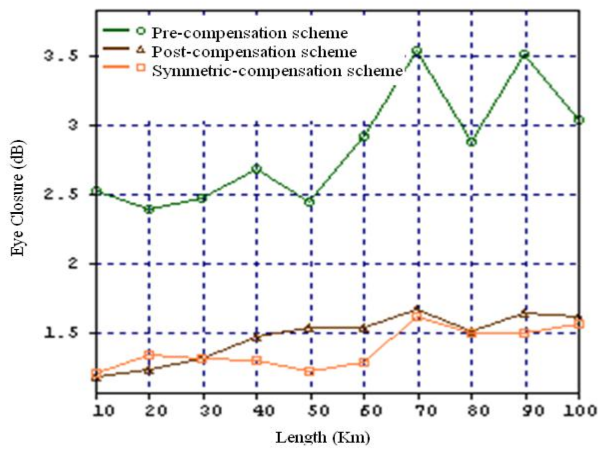
Fig 4 : Evaluation of Eye closure Vs Optical Span with laser line-width of 100 MHz using different DCF schemes of (a) Channel 1, (b) Channel 2, and (c) Channel 4 with NRZ format at 10 Gbps with equal channel spacing of 0.25 nm



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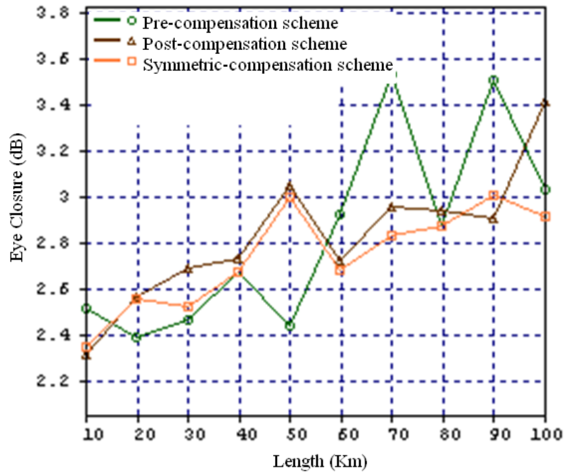

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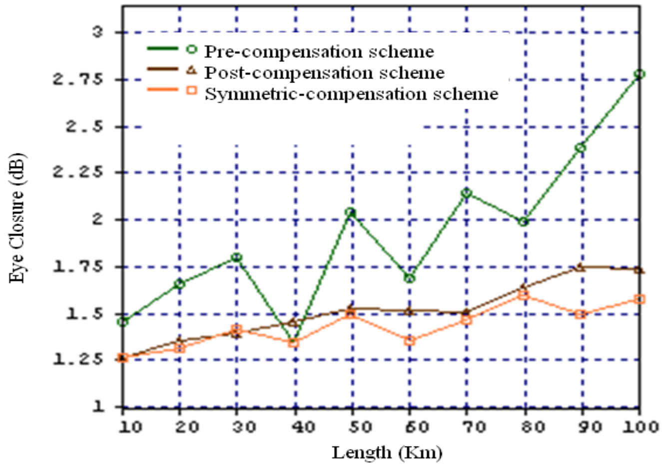
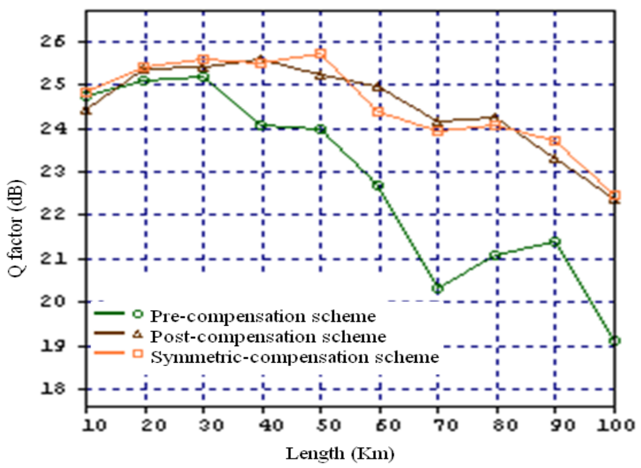


(c)

Fig 5 : Evaluation of Eye closure Vs Optical Span with laser line-width of 100 KHz using different DCF schemes of (a) Channel 1, (b) Channel 2, and (c) Channel 4 with NRZ format at 10 Gbps with equal channel spacing of 0.25 nm

3.2 Evaluation of Q-parameter, Required Optical Power at Receiver Sensitivity and Eye closer with RZ Optical pulse

An evaluation of Q-parameter of our simulative DWDM system after an optical span of 100 Km using pre-, post- and symmetric-dispersion compensation techniques at 10 Gbps transmission rate at laser line-width of 100 KHz for RZ optical pulse is carried out. It is observed that Q-parameter decreases with respect to optical span at the same rate for all channels for all DCF schemes as shown in Figure 6. An improvement of 3.5 dB, 2.5 dB and 2.5 dB is achieved for symmetric- and post- DCF as compare with pre- DCF respectively for channel 1, 2 and 4 respectively as shown in Figure 6. Also, less variations in Q-parameter with optical span is observed with symmetric- and post- DCF as compare to pre- DCF for all the channels. It is also observed that less value of Q-parameter is computed for the intermediate channels as shown in Figure 6 (b).



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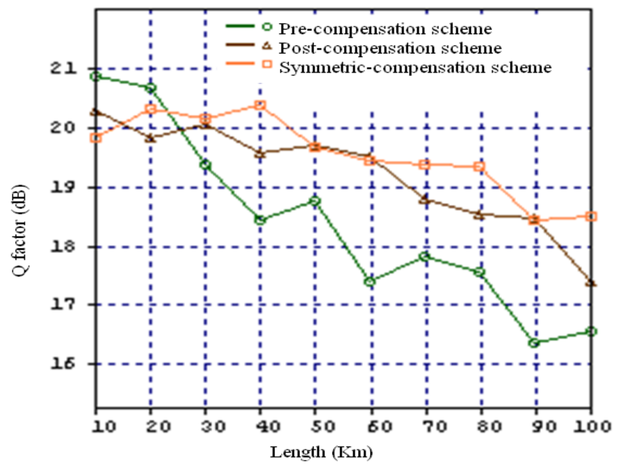

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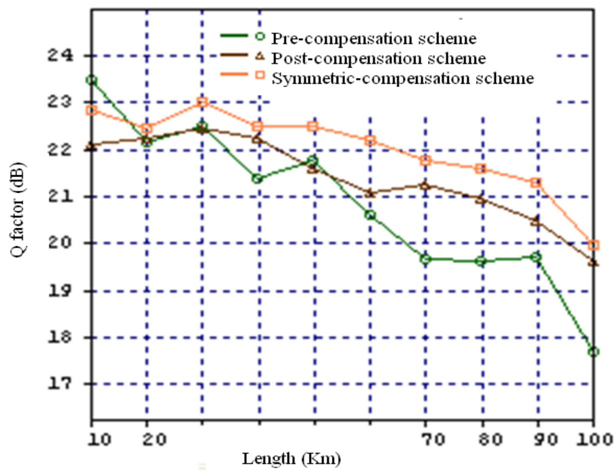
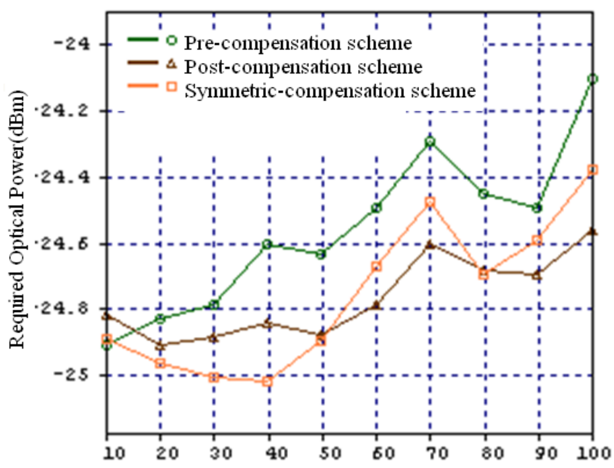


(c)

Fig 6 : Evaluation of Q-parameter vs Optical Span with laser line-width of 100 KHz using different DCF schemes of (a) Channel 1, (b) Channel 2, and (c) Channel 4 with RZ format at 10 Gbps with equal channel spacing of 0.25 nm

The optical power required at receiver sensitivity for compensating the dispersion-degradation after an optical span of 100 Km is computed as [-24.1dBm, -24.5dBm and -24.4dBm]; [-22.25dBm, -23.15dBm and -23.15dBm] and [-22.7dBm, -24.5dBm and -24dBm] at laser line-width of 100 KHz for channel 1, 2 and 4 respectively as shown in Figure 7. It is observed that symmetric- and post- DCF schemes perform better than pre-DCF for all channels. Also, intermediate channels require more optical power at receiver sensitivity as compare to side-channels. Eye closure parameter for RZ optical pulse at 100 KHz after an optical span of 100 km, it has been observed that eye closure is less for all the channels for symmetric- and post- DCF schemes as compare to pre-DCF scheme and computed as [0.85 dB and 1.5 dB] for channel 1 and 4 respectively as shown in Figure 8.



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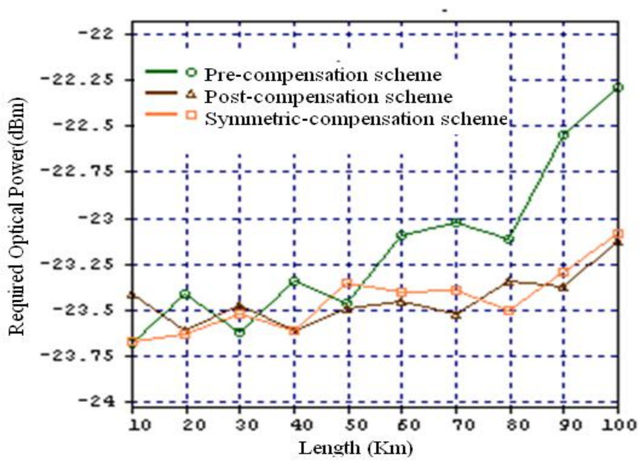

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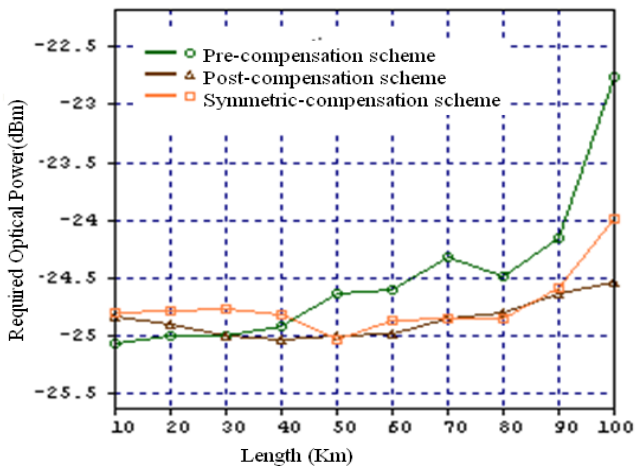
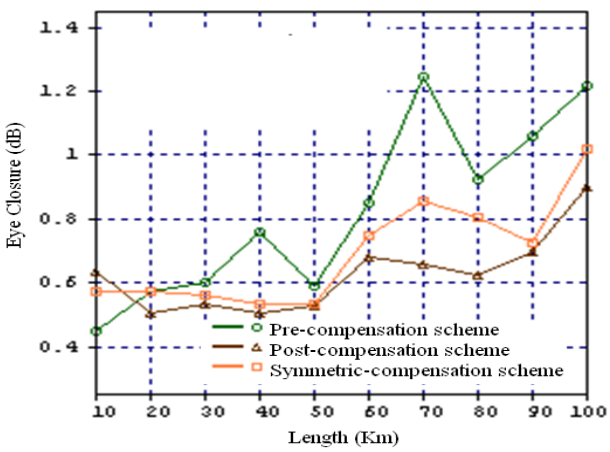


(c)

Fig 7 : Evaluation of Required Optical Power at sensitivity vs Optical Span with laser line-width of 100 KHz using different DCF schemes of (a) Channel 1, (b) Channel 2, and (c) Channel 3 with RZ format at 10 Gbps with equal channel spacing of 0.25 nm



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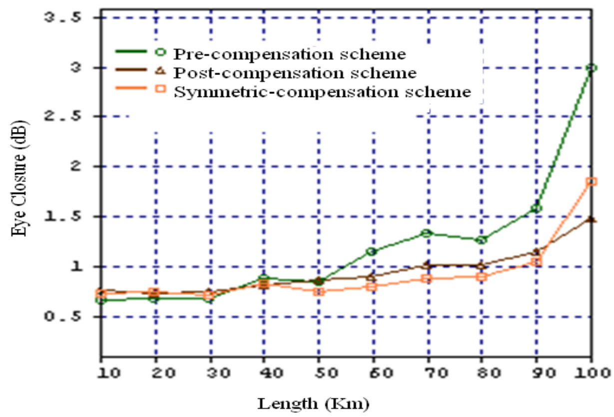


(b)

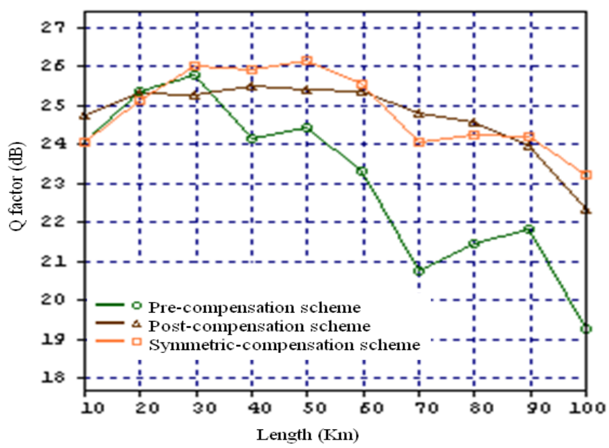
Fig 8 : Evaluation of Eye closer vs Optical Span with laser line-width of 100 KHz using different DCF schemes of (a) Channel 1, (b) Channel 2 with RZ format at 10 Gbps with equal channel spacing of 0.25 nm

3.3- Evaluation of Q-parameter, Required Optical Power at Receiver Sensitivity and Eye closer with RZ soliton optical pulse

Figure 9 depicts the evaluation of Q-parameter at 100 KHz after an optical span of 100 Km and an improvement of 3.7 dB and 2.7 dB has been observed for symmetric- and post-DCF schemes as compare to pre-DCF fro channel 1. For channel 4, an improvement of 3 dB is achieved for both the schemes as compare to the pre-DCF scheme.

The required optical power at sensitivity for compensating the dispersion degradation for RZ Soliton optical pulse is computed as at 100 KHz [-24.1dBm, -24.8dBm and -24.9dBm] and [-24.2dBm, -24.8dBm and -24.9dBm] for channel 1, and 4 as shown in Figure 10. It has been observed that the symmetric- DCF scheme performs better than other two DCF schemes for all the channels.

Eye closure for RZ soliton optical pulse at 100 KHz, it has been observed that for channel-1 symmetric- and post- DCF schemes perform better with an improvement of eye closure of 0.7 dB and for channel-4, with an improvement of eye closure of 0.9 dB than pre-DCF scheme.



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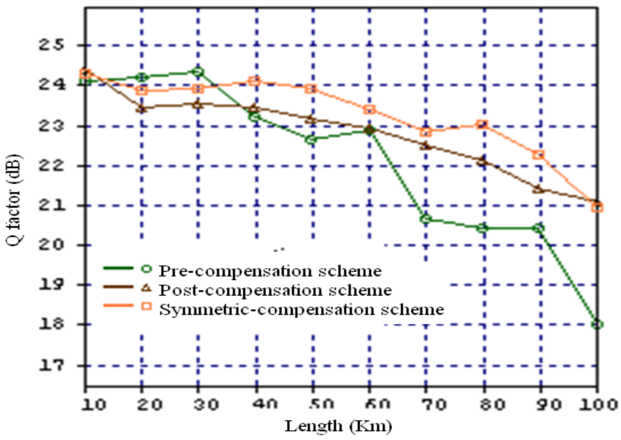
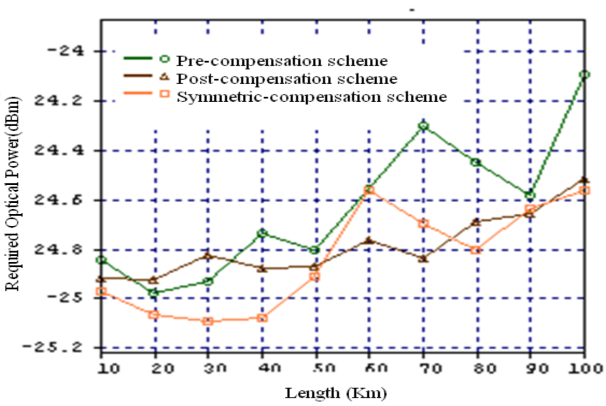


(b)

Fig 9: Evaluation of Q-parameter vs Optical Span with laser line-width of 100 KHz using different DCF schemes of (a) Channel 1, and (b) Channel 4 with RZ Soliton at 10 Gbps with equal channel spacing of 0.25 nm



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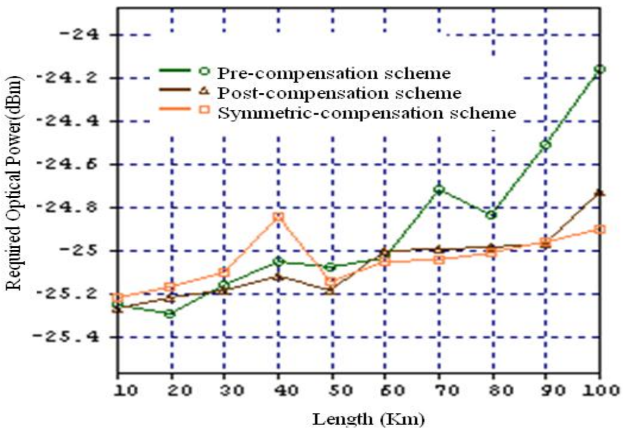

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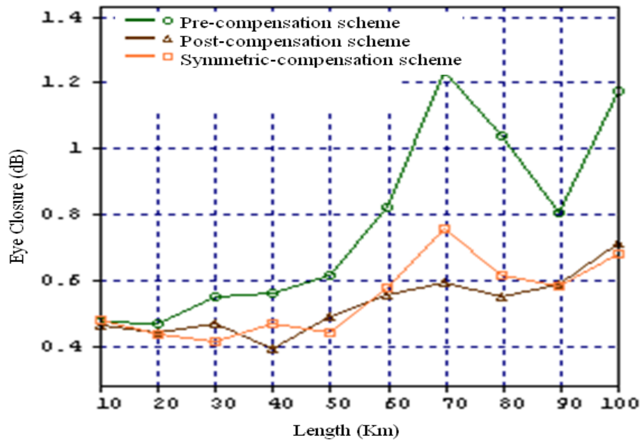
Fig 10: Evaluation of Required Optical Power at sensitivity vs Optical Span with laser line-width of 100 KHz using different DCF schemes of (a) Channel 1and (b) Channel 4 with RZ soliton format at 10 Gbps with equal channel spacing of 0.25 nm



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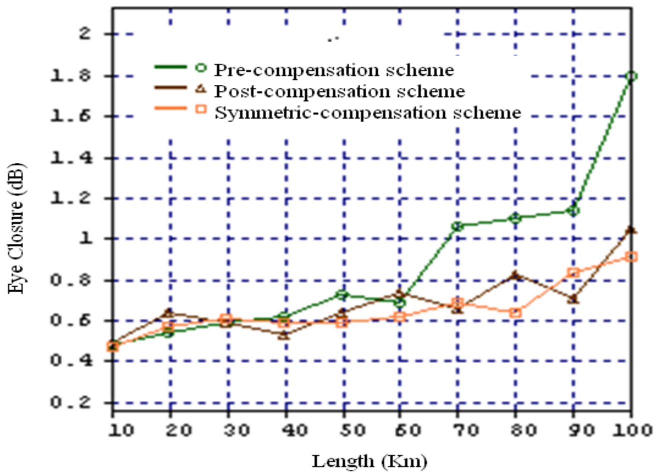

(b)

Fig 11 : Evaluation of Eye closer vs Optical Span with laser line-width of 100 KHz using different DCF schemes of (a) Channel 1, and (b) Channel 4 with RZ soliton format at 10 Gbps with equal channel spacing of 0.25 nm

4. CONCLUSION

In this paper, a detailed investigation of High speed dispersion compensated DWDM system of different optical pulses at 10Gbps using pre-, post- and symmetric-DCF techniques is reported at varied values of laser line-width. To achieve acceptable BER and to reduce power penalty required to compensate the dispersion impact in the high speed DWDM system, it is recommended to use symmetric- and post-DCF schemes for all the simulated optical pulses rather than using pre-DCF scheme together with deployment of lasers of low laser line-width. It is also observed that the intermediate channels are more sensitive to dispersion degradations than that of side-channels. Further, RZ- and RZ soliton- optical pulses perform better than NRZ optical pulse. Both the optical pulses require less optical power at receiver sensitivity with low eye closure as compare to NRZ optical pulse. The conclusion is drawn on the basis of computation of Q-parameter, required optical power at receiver sensitivity and eye closure.

5. REFERENCES

[1] A.H. Gnauck, S.K. Korotky, J.J. Veselka, J. Nagpal, C.T. Kemmerer, W.J. Minford and D.T. Moser, IEEE Photonics Technology Letters, Volume 3, Issue 10, 1991.

[2] C.D. Poole, J.M. Wieserfed, D.J. DiGiovanni and A.M. Vengsarkar, Journal of Light wave Technology, Volume 12, Issue 10, 1994.

[3] A.J. Antos and D.K. Smith, Journal of Light wave Technology, Volume 12, Issue 10, 1994.

[4]A.K. Sharma, R.K. Sinha and R.A. Agarwala, Optik, Volume 111, Issue 7, 2000.

[5] C. Peuchere T, N. Hanik, R. Freund, L. Molle and P. Jeppesen, IEEE Photonics Technology Letters, Volume 12, Issue 8, 2000.

[6] Manjit Sngh , Ajay K. Sharma and R.S. Kaler, " Investigation on order and width of RZ super Gaussion pulse in pre-,post-and symmetrical-dispersion compensated 10Gb/s optical communication system using standard and dispersion compensating Fiber", Optik, volume 121, Issue 7 , pp. 609-616, 2010.

[7] Manoj kumar, Ajay K. Sharma, T.S.Kamal and Jagjit Malhotra, "Comparative investigation and suitability of various data formats for 10Gb/s optical soliton transmission links at different chirps", Optik, Volume 120, Issue 7, pp. 330-336, 2009.

.

[8] R.S.Kaler A.K. Sharma, T.S. Kamal, " Compression of pre -, post and symmetrical-dispersion compensation schemes for 10Gb/s NRZ links using standard and dispersion compensated Fibers", Optics Communication Volume 209, pp. 107-123, 2002.

[9] Juanjuan Yan, Minghua Chen, Shizhong Xie, and Bingkun Zhou, "Performance compression of standards FEC in 40 Gbps optical transmission system with NRZ, RZ and CSRZ modulation Formats", Optics Communication, Volume 231, Issue 16, pp. 175-180, 2004

[10] Aihan Yin, Li-Li, Xinliang Zhang," Analysis of modulation formats in 40 Gbps optical communication system", Optik, Volume 121, Issue 17, pp. 1550-1557, 2010

[11] Peter M Krummrich, "Advance modulation formats for more robust optical transmission system", AEU-International Journal of Electronic and Communication, Volume 61, Issue 3, pp. 141-146, 2007

[12] K.Tajima, L.M.Washio, Opt.Lett.10 (9) (1985) 460.

[13] T.L. Koch, R.C. Alferness, J. Lightwave Technol. LT-3(1985) 800

[14] R.S. Kaler, T.S. Kamal, A.K. Sharma, S.K. Arya, R.A. Aggarwala, J.Fiber Integrated Opt.21 (3) (2002) 193