

DWDM System Simulation of Design for Different Channel Spacing using PDCF & PSMF

Harsimranjit Kaur*, Harminder Kaur** and Jagjit Kaur***

*Student M.Tech ECE GNDEC, Ludhiana

**Assistant Professor, Department of Electronics and Communication Engineering

harminder12@yahoo.com

***Assistant Professor, Guru Nanak Dev Engineering College, Ludhiana, Punjab

j.jagjeet@ymail.com

Abstract: The multichannel DWDM system is designed for different dispersion compensation techniques to achieve high capacity. The obligation for the network bandwidth is large in present scenario due to the expansion in multimedia traffic. DWDM improvement is a challenging technique in present time to meet this demand. By comparing different modulation formats it is observed that MDRZ (Modified Duo-binary Return to Zero) is best than CSRZ and DRZ. As a result, it is used for high data rate DWDM system. The PDCF (Pumped Dispersion Compensating Fiber) and PSMF (Pumped Single Mode Fiber) are used in dispersion compensating techniques for 64×20 Gbps DWDM system. The results of three compensation methods have been compared for 200GHz and 100GHz channel spacing in term of bit error rate and Quality factor. It is observed that 100 GHz channel spacing is used to achieve maximum coverage distance and symmetrical compensation show best results as compared to Pre- and Post - compensation.

Keywords: DWDM, Pumped dispersion compensating fiber, Pumped single mode fiber, MDRZ, Channel spacing, BER, Q-value.

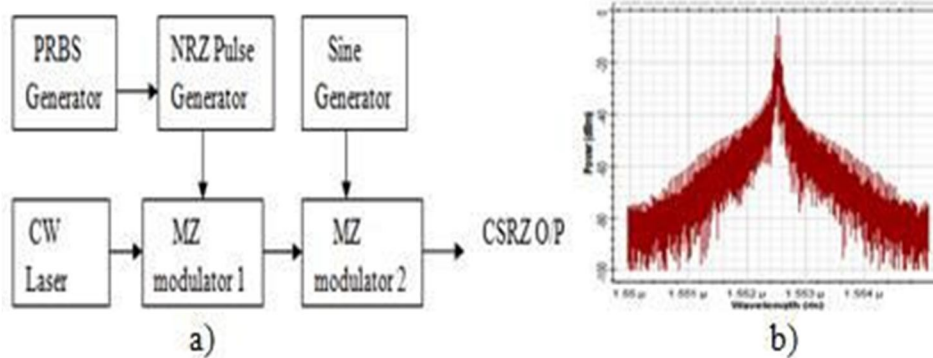
Introduction

With hybrid optical amplifier, DWDM is the key technology for escalating the transmission capacity in an optical fiber networks. The recent efforts of research and enlargement are aiming at increasing the total capacity of medium and long - haul optical transmission systems. To achieve dense wavelength division multiplexing (DWDM) systems with high spectral efficiency, it is necessary to work at high bit rates. [1] For DWDM system in which the information rate is greater than 10 Gbps, the lethal effects of dispersion and nonlinearity be required to manage to achieve communication over any significant distance. The dispersion management is a key technique which keeps the dispersion low by suppressing the nonlinear effects. In the optical communication for long distance transmission, the optical amplifiers play a major role and eliminate the costly conversions from optical to electrical signal and vice versa. In recent times, the hybrid optical amplifiers improved the bandwidth [2] and increase the coverage distance. [3]. The various optical effects such as chromatic dispersion limited the performance of the system. The utilization of power and dispersion compensated fiber (DCF) is the main scheme to improve the already installed links of SMF. To compensate the positive dispersion for large lengths of common fiber the high value of negative dispersion is used. Singh et al. [4] investigated pre-, post- and symmetrical compensation techniques for different position of SOA in fiber link. By increasing the signal input power it has been observed that the Post- compensation is superior to others. Randhawa et al. [5] have compared different dispersion mapping techniques in the presence of fiber nonlinearities in 10 and 40 Gbps carrier-suppressed return to zero (CSRZ) systems. It has been observed that the hybrid-compensation is the best in dispersion mapping. The BER is reduced to more amount by using hybrid compensation which is produced due to the fiber nonlinearities. Singh et al. [6] evaluated the performance of 64×10 Gbps and 96×10 Gbps DWDM system with hybrid optical amplifier for different modulation formats, and investigate that RZ modulation format provides good results as compared to NRZ and DPSK. Tiwari et al. [7] achieved dispersion and power compensation in parallel by using pumped dispersion compensating fiber means Raman amplification has been done by using counter pumped DCF (PDCF).

Different Modulation Formats

2.1 Carrier-suppressed Return-to-Zero (CSRZ) format Fig.1 (a) shows the representation of the simulation setup for CSRZ modulation format. This signal is generated by passing the NRZ signal to the first MZM and then applied to the phase modulator driven by a sine wave generator at the frequency equal to half the bit rate. Therefore, a phase shift of π , among any two adjacent bits is introduced. As a result of this, the central peak at the carrier frequency is suppressed as shown in the

Fig.1 (b). It has high tolerance to the mixed effect of self phase modulation (SPM) and group velocity dispersion (GVD). It has also narrower pedestal shape of the optical spectrum than the conventional RZ format.



Duo-binary Return-to-Zero (DRZ)

format Fig.2 (a) shows the representation of the simulation setup for DRZ modulation format. The duo binary is generated by first creating an NRZ duo binary signal using a duo binary precoder, a duo binary pulse generator and NRZ generator. The generator impels the first MZM and then attached this modulator with a second modulator that is driven by a sinusoidal electrical signal with the frequency of 20 GHz, phase -90° . The duo binary precoder used is composed of an Exclusive-OR gate with a delayed feedback path. DRZ formats are very attractive, as its optical modulation bandwidth can be compressed to the data bit rate B, which is half-bandwidth of the NRZ format $2B$ as revealed in Fig.2 (b). 2.3 Modified Duo-binary Return to Zero (MDRZ) format Fig.3 (a) shows the representation of the simulation setup for MDRZ modulation format. MDRZ is generated by first creating an NRZ duobinary signal using a delay-and-subtract circuit that drives the first MZM and then concatenating this modulator with a second modulator that is driven by a sinusoidal electrical signal with the frequency of 10 GHz and phase -90° . Fig.3 (b) shows the optical spectrum of MDRZ setup which is a carrier suppressed duo-binary signal. Fig.3 a) Schematic of MDRZ modulation format b) MDRZ optical spectrum By comparing these modulation formats it has been found that MDRZ is the best among these. The proposed optimized modulation format has narrower bandwidth compared to other schemes and also the dispersion tolerance is high. Thus, makes it possible to attain very high capacity for long distance transmission. Therefore, for multichannel DWDM system design the MDRZ modulation format is used. 3. SIMULATION SETUP DWDM system setup of 64 channels each of 20 Gbps data rate using MDRZ modulation format are multiplexed through WDM using 200 GHz, 100 GHz and 50 GHz channel spacing. Opti system 11 is used to design the desired simulation set up. In the communication channel the different compensation techniques Pre-, Post- and symmetrical compensations are used using PDCF & PSMF. The Fig. 4 shows the performance of three different power and dispersion compensation techniques.

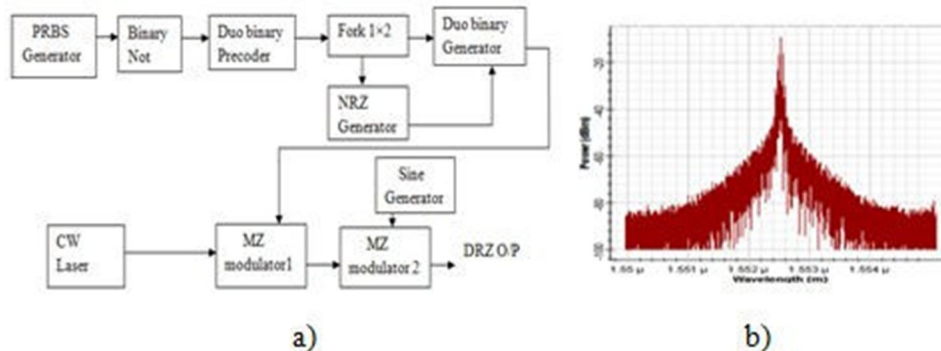


Fig.2 a) Schematic of DRZ modulation format b) DRZ optical spectrum

Modified Duo-binary Return to Zero (MDRZ) format

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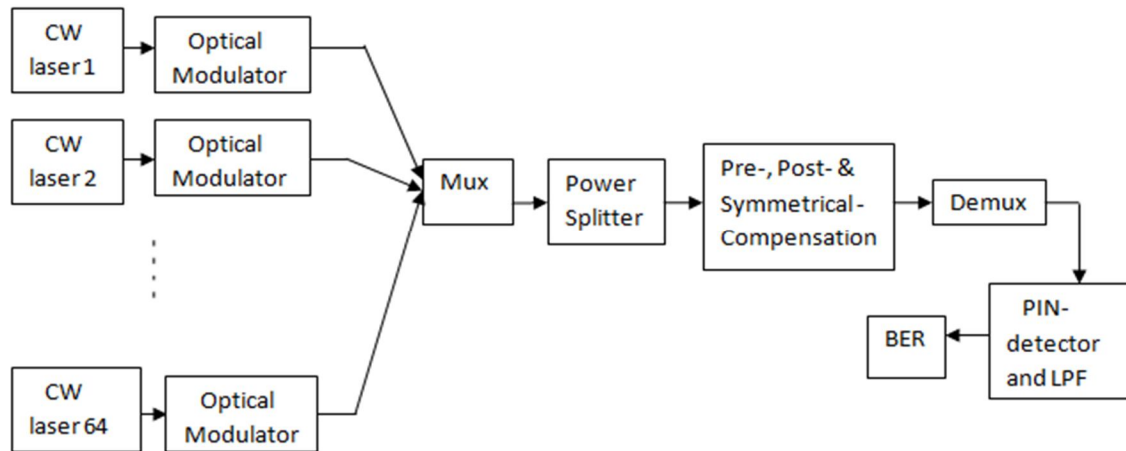


Fig.4. Schematic of simulation setups for different compensation techniques

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Simulation Setup

DWDM system setup of 64 channels each of 20 Gbps data rate using MDRZ modulation format are multiplexed through WDM using 200 GHz, 100 GHz channel spacing. Opti system 11 is used to design the desired simulation set up. In the communication channel the different compensation techniques Pre-, Post- and symmetrical compensations are used using PDCF & PSMF. The Fig. 4 shows the performance of three different power and dispersion compensation techniques.

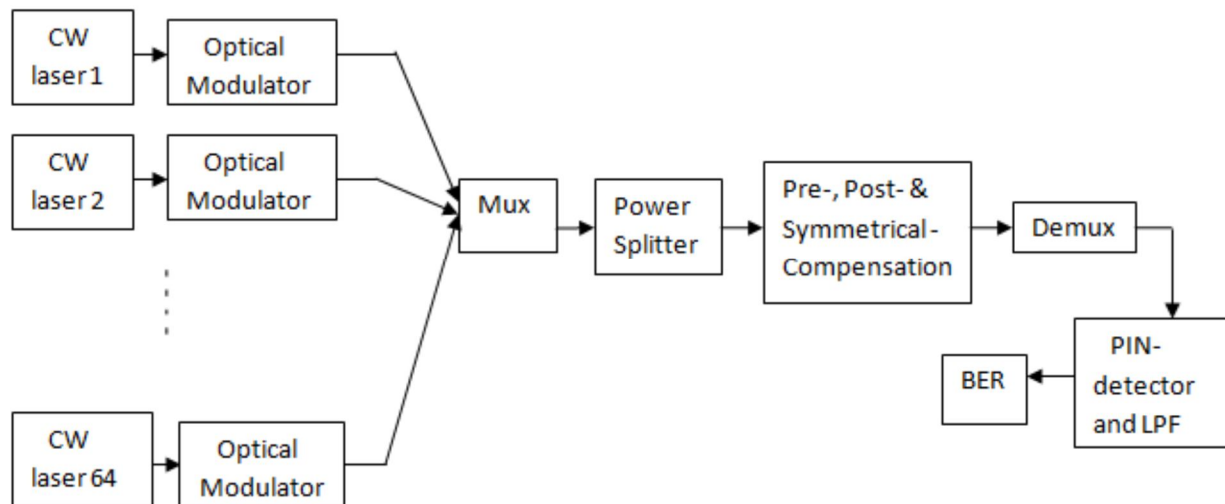


Fig.4 Schematic of simulation setups for different compensation techniques

Using pre-, post- and hybrid-compensations three fiber links are provided as shown in Fig. 5. The optical communication system is pre-amplified in the pre-compensation, and dispersion compensated by the PDCF of negative dispersion against the pumped SMF (PSMF), as shown in Fig. 5(a). In the post-compensation, as shown in Fig. 5 (b) the optical communication system is post amplified and dispersion compensated by the PDCF of negative dispersion against the PSMF. The optical communication system is symmetrically amplified and compensated by two PDCF of negative dispersion against the PSMF for symmetrical compensation, as shown in Fig.

5(c). Using PSMF and PDCF the Raman amplification has been achieved.

Table 1 Simulation parameters of the setup

Parameter	Value
Bit rate	20Gbps
Number of channels	64
DWDM channel spacing	200, 100 and 50 GHz
Capacity	64 ×20 Gbps
Sequence length	64
Samples/bit	256
Distance	70 Km ×N spans
Input power	4 mw

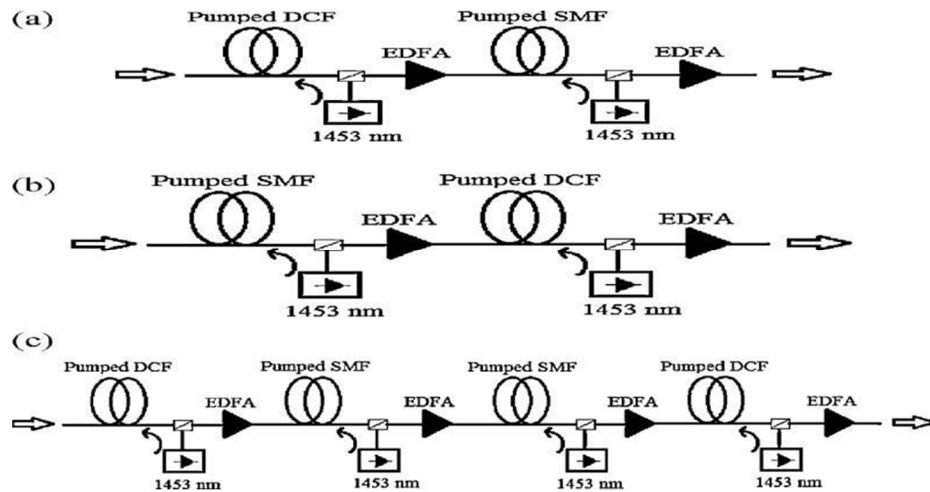


Fig.5(a) Pre-, (b) post- and (c) symmetrical compensation techniques for 64 channel DWDM system

Table 2 Parameters of PSMF and PDCF

Parameter	PSMF	PDCF
Length(Km)	60	10
Operating temperature (K)	300	300
Pump type	Counter-propagate	Counter-propagate
Pump wavelength(nm)	1453	1453
Pump power(mW)	1000	200
Dispersion ps/nm/km)	16	-96

64 × 20 Gbps DWDM system set up using 200 GHz channel spacing

The proposed system consists of a transmitter, the communication channel and an optical receiver. Transmitter consists of 64-channels, optical modulator and optical multiplexer. The frequency range used for this set up is (186.7–199.3) THz, with centre frequency of 193.1 THz using the adjacent channel spacing of 200 GHz. The fibers used in this simulation set up are PDCF (pumped dispersion compensated fiber) and PSMF (pumped single mode fiber). The different parameters for the simulation set up are shown in Table 1 and the parameters for the PDCF and PSMF are shown in Table 2. The fiber link is designed suitably, so that the first-order dispersion is compensated exactly ($D = 0$) that is, $DSSMFLSSMF = DDCFLDCF$.

stands for first-order dispersion and L stands for length of the respective fiber. DCF is the dispersion compensating fiber. The erbium doped fiber amplifier (EDFA) is used for compensating the linear loss and its noise figure is kept constant (6 dB). The signal is launched over N spans of fiber of 70 km (60 km-PSMF + 10 km-PDCF) each. The model is simulated for different dispersion compensation techniques. At the receiver, the signal is conceded through optical demultiplexer, detected by PIN detector, filtered and applied to BER analyzer. The dark current and responsivity of the PIN diode is taken as 10 nA and 1 A/W respectively. 3R regenerator is used to generate an electrical signal, connected directly to the BER analyzer which is used to visualize the graphs and results such as eye diagram, eye opening, and Q value. The total capacity of the 64 channels, 20 Gbps data rate DWDM system is 1.28 Tbps.

64 × 20 Gbps DWDM system set up using 100 GHz channel spacing

This setup is designed same as described for 200 GHz spacing setup but it includes extra Gaussian band-pass filters at transmitter and receiver end for each channel. The frequency range used for 100 GHz channel spacing is from (190 – 196.3) THz, with centre frequency of 193.1 THz for the adjacent channel spacing of 100 GHz. The fibers used in this simulation set up are PDCF (pumped dispersion compensated fiber) and PSMF (pumped single mode fiber). In this simulation set up the Gaussian band-pass filters at transmitter and receiver end for each channel are used. The Gaussian filter is considered here to minimize the group delay, hence minimizes the rise and fall time of the input signal. The band width of the filter considered is 84 GHz and 42.33 GHz for channel spacing of 100 as its practical availability. The Gaussian filter is used because for 100 GHz channel spacing there will be FWM (Four wave mixing) or intermixing of signals which produces the distortion in channels. The performance of the proposed setup is analyzed in terms of BER, Q factor, eye penalty and eye opening.

Results and Discussion

Comparisons of CSRZ, DRZ and MDRZ modulation formats

The various modulation formats CSRZ, DRZ and MDRZ are compared with each other. The Fig. 6 shows the comparison of modulation formats at various input power for a particular distance. It is observed that MDRZ is the optimized modulation format as it shows the maximum Q – factor as compared to CSRZ and DRZ. From Fig. 6 it is also observed that when the input power is too low or too high, the performance of the system deteriorates, because too low input power is not sufficient to drive the components and too high input power causes the non-linearity in the fiber.

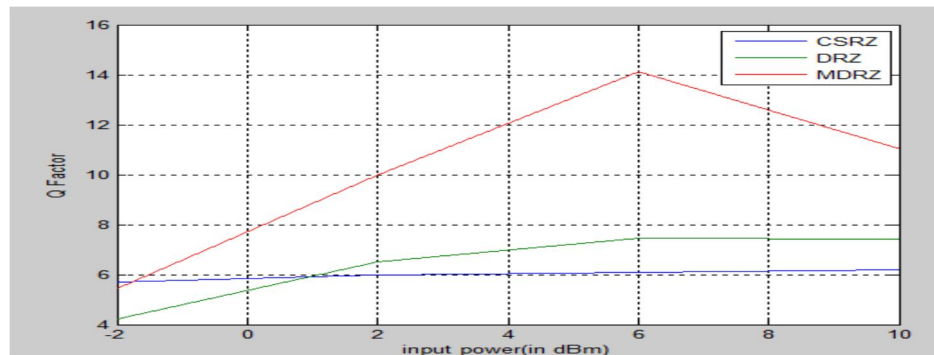


Fig.6 Comparisons of CSRZ, DRZ and MDRZ

Results of 64 × 20 Gbps DWDM System using 200 GHz Channel Spacing

The proposed setup is simulated for three different i.e. Pre-, Post- and Symmetrical compensation techniques using MDRZ (Modified Duo-binary Return to zero) modulation format for a distance of 70 km for single span using 4 mw input power. The 64 channels using 20 Gbps bit rate for 200 GHz channel spacing have the frequency range from 186.7 THz – 199.3 THz with center frequency of 193.1 THz.

Results for Pre-Compensation Technique

The total distance covered using Precompensation technique is 420 Km. It is observed that the eye penalty is high for end channels (channel nos. 1 and 64) comparing to central channel (channel no. 32). Fig. 7.1 shows the eye diagrams and Q-value for the Pre-compensation using MDRZ system at 420 km for input power level of 4 mw for channel no.1, channel no.32 and channel no.64. It is observed that the eye is clear at centre channel comparing to end channel. It is because of the non-linear characteristic of the fiber that is the FWM effect, which is prominent for end channels comparing to centre channel. For a coverage distance of 420 km, it is observed that the Q-value of the center channel is 12.6099 and BER is 8.12548e-037.

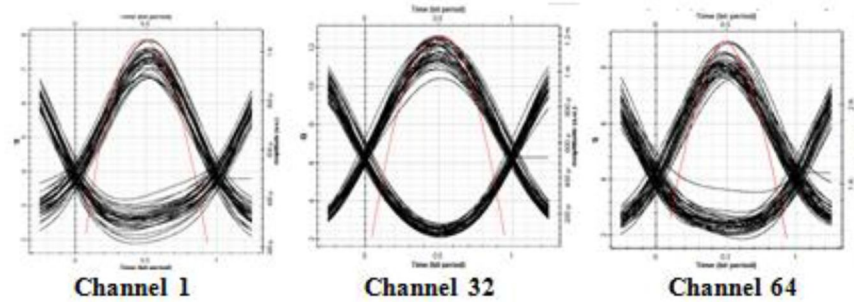


Fig.7.1 EYE Diagrams of Pre-compensation for a) channel 1 b) channel 32 c) channel 64

Results for Post-Compensation Technique The parameters for the Post-compensation technique are same as that used for Pre-compensation technique. The Post-compensation is also used to cover a distance of 420 Km. The maximum Q-factor is 11.1939 and minimum BER is 3.5707×10^{-32} for central channel. The eye diagrams for channel no.1, 32 and 64 are shown in Fig. 7.2 and it is observed that eye is open widest for central channel.

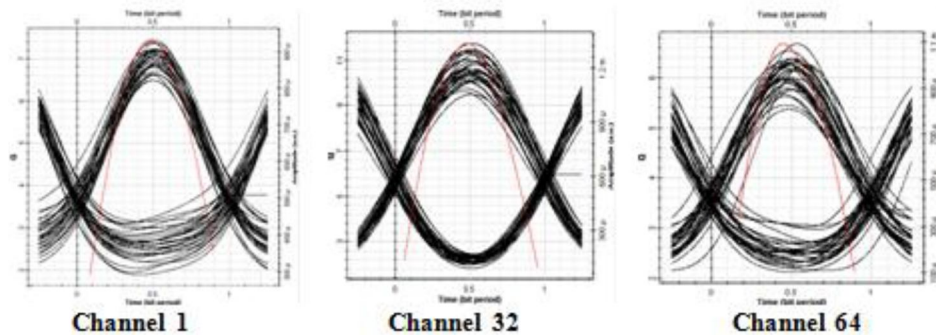


Fig.7.2 EYE Diagrams of Post compensation for a) channel 1 b) channel 32 c) channel 64

Results for Symmetrical-Compensation Technique

The parameters for the Symmetrical-compensation technique are same as that used for Pre-and Postcompensation techniques except that Length of PDCF= 20 Km, PSMF=120 Km for single span and by using Symmetrical-compensation the total distance of 560 Km (no. of loops = 4) can be covered. The maximum Q-factor is 10.9884 and minimum BER is 1.6529×10^{-28} for symmetrical compensation. The eye diagrams for channel no.1, 32 and 64 are shown in Fig. 7.3 and it is observed that eye is open widest for central channel for a coverage distance of 560 Km.

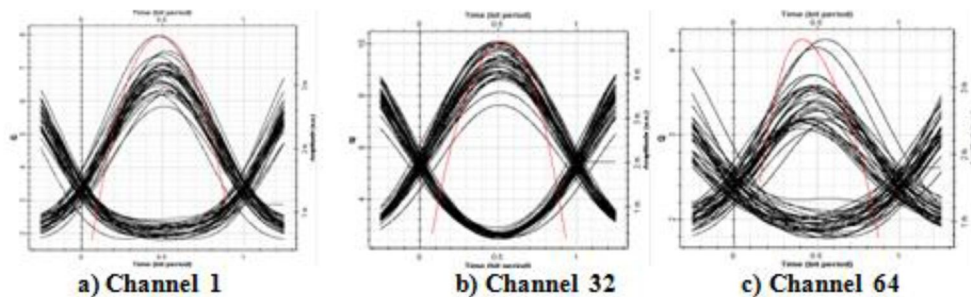


Fig.7.3 EYE Diagrams of Symmetrical compensation for a) channel 1 b) channel 32 c) channel 64

Results of 64×20 Gbps DWDM System using 100 GHz Channel Spacing

The setup used for 64×20 Gbps DWDM system using 100 GHz channel spacing is same as that used for 200 GHz channel spacing but here the frequency range is from 190 THz – 196.3 THz with channel spacing of 100 GHz and Gaussian optical filter of 84 GHz bandwidth as its practical availability are used at both the transmitter and receiver

end for each channel. Gaussian optical filters are used to minimize the group delay, therefore minimize the rise and fall time of the input signal. Fig. 8 (a) shows the Optical Spectrum for the first channel of frequency 190 THz and Fig. 8 (b) shows the Optical Spectrum of Gaussian filter for the same channel. This spectrum shows that the output is a carrier suppressed duo-binary signal.

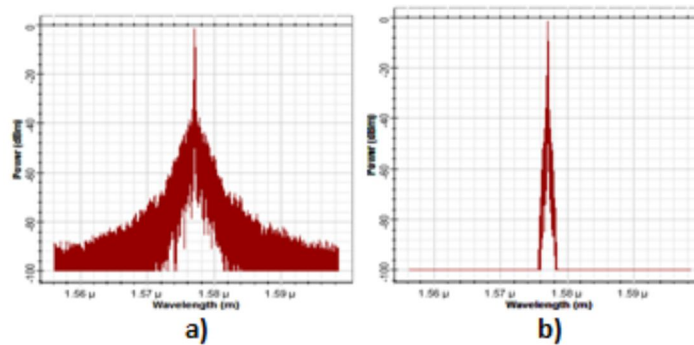


Fig.8 Optical Spectrum of a) first channel b) Gaussian filter

Results for Pre-Compensation Technique The distance covered using Pre-compensation technique for 100 GHz channel spacing is 700 Km using 10 number of loops. The maximum Q factor is 10.6527 and minimum BER is 7.99188×10^{-27} for Pre-compensation. The eye diagrams for channel no. 1, 32 and 64 are shown in Fig. 8.1.

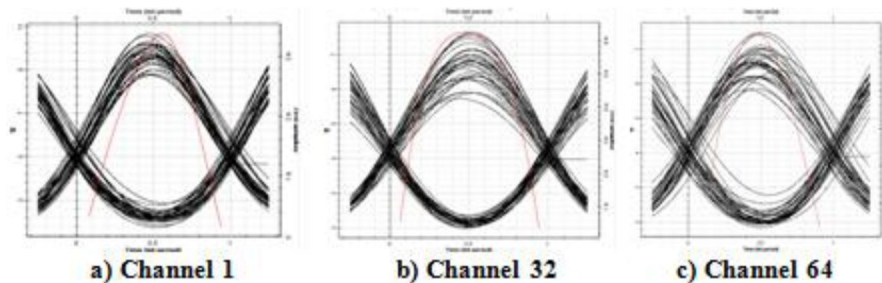


Fig.8.1 EYE Diagrams of Pre-compensation for a) channel 1 b) channel 32 c) channel 64

Results for Post-Compensation Technique

The parameters used for Post-compensation technique are same as that of Pre-compensation, but the numbers of loops are extended up to 11. Hence total distance covered by Post compensation technique is 770 Km. The maximum Q-factor is 9.80459 and minimum BER is 4.81358×10^{-23} for Post-compensation. The eye diagrams for channel no. 1, 32 and 64 are shown in Fig. 8.2.

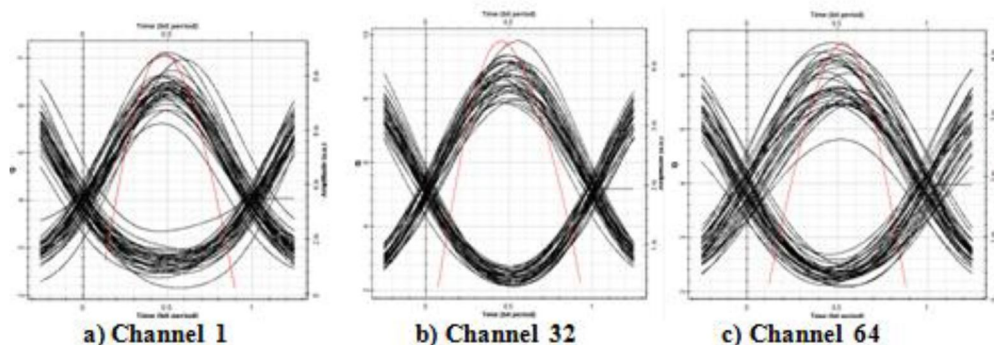


Fig.8.2 EYE Diagrams of Post compensation for a) channel 1 b) channel 32 c) channel 64

Results for Symmetrical-Compensation Technique

The parameters used for Symmetrical compensation technique are same as that of Pre compensation except the length of PDCF = 20 Km and PSMF = 120 Km, and the number of loops used are 6 for symmetrical compensation. Hence total distance covered by Symmetrical compensation technique is 840 Km. The maximum Q- factor is 7.96883 and minimum BER is 7.07918×10^{-16} for Post- compensation. The eye diagrams for channel no. 1, 32 and 64 are shown in Fig. 8.3. Therefore, it is observed that Symmetrical compensation is used for long – haul communication as it is used to cover more distance as compared to other compensation techniques.

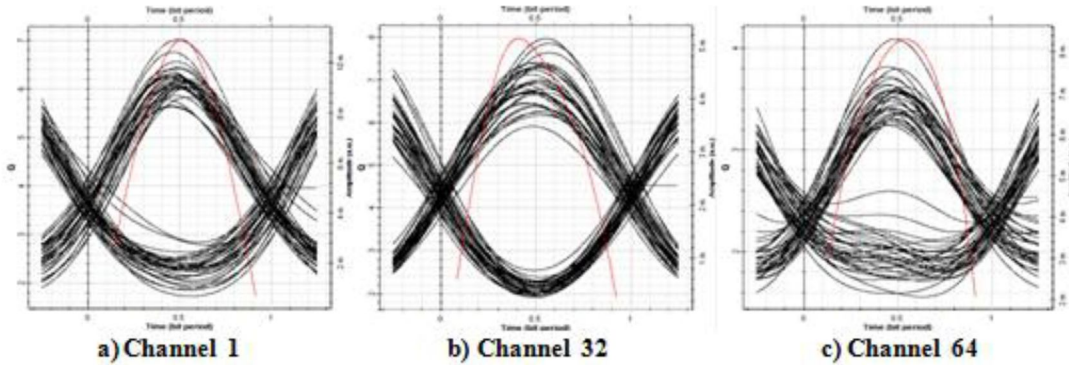
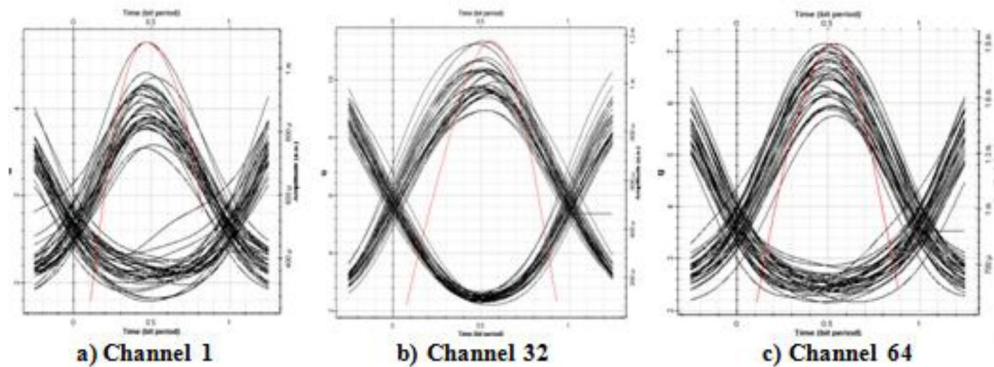


Fig.8.3 EYE Diagrams of Symmetrical compensation for a) channel 1 b) channel 32 c) channel 64



The maximum Q- factor achieved using Post – compensation technique is 11.3308 and minimum BER is 3.59094×10^{-30} for the central channel.

Fig.8.4 EYE Diagrams of Post - compensation for a) channel 1 b) channel 32 c) channel 64

The parameters used for Symmetricalcompensation technique are same as that of Precompensation except the length of PDCF = 20 Km and PSMF = 120 Km, and to achieve a distance of 420 Km the number of loops used are 3. The maximum Q- factor achieved using Symmetrical – compensation technique is 13.2948 and minimum BER is 1.0123×10^{-40} for the central channel. It is observed that as the Q- factor is high for the central channels, the eye opening is widest for these as compared to the end channels.

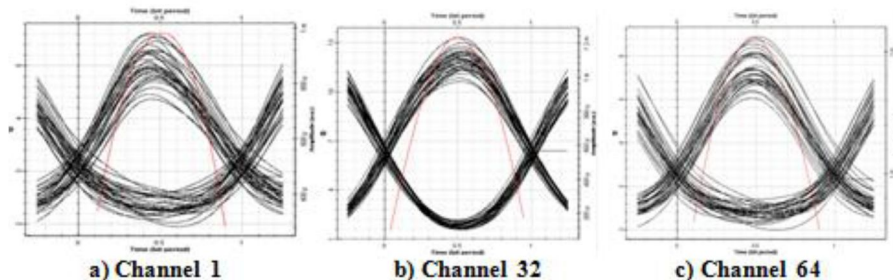


Fig.8.5 EYE Diagrams of Symmetrical compensation for a) channel 1 b) channel 32 c) channel 64

The Fig.9 shows the graph for the Comparison of BER for Pre-, Post- and Symmetrical compensation technique for 50 GHz Channel spacing at a distance of 420 Km.

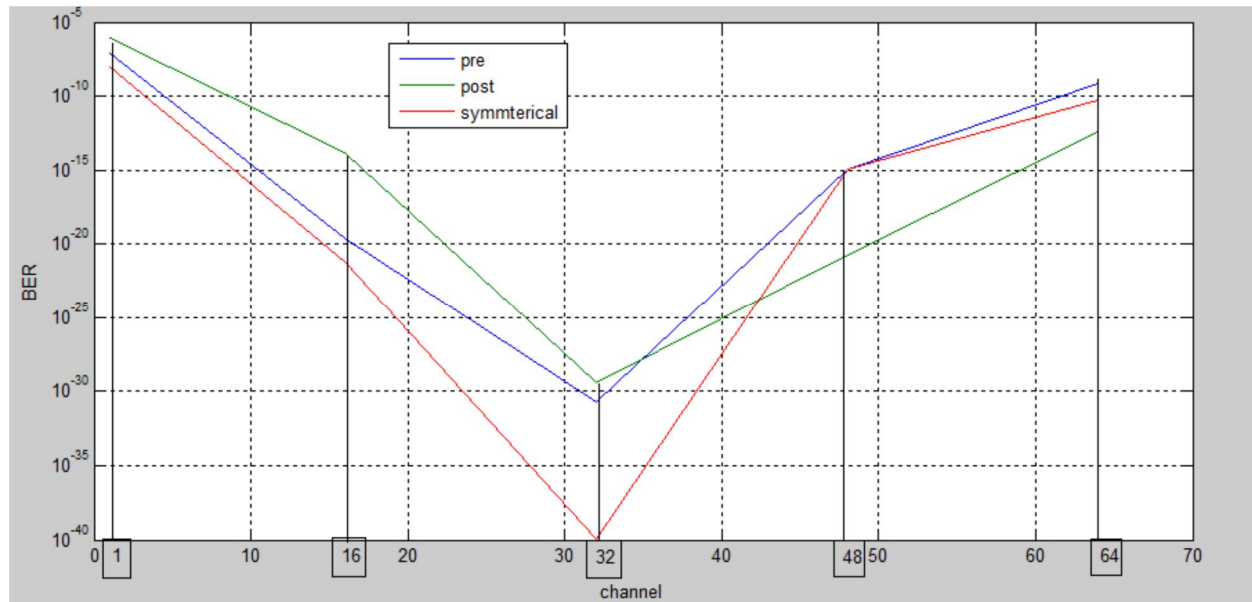


Fig.9 Graph for the Comparison of BER for different compensation techniques

It is observed that the center channel frequency have maximum Q – factor and minimum BER as compared to end channels. Also the symmetrical – compensation shows the better results as compared to Pre- and Post- compensation techniques for a distance of 420 Km.

Conclusion

In this Paper the Capacity of the DWDM network is increased in Tera bits per second by using 64×20 Gbps DWDM system. The optimized modulation format which is used to achieve high data rate is MDRZ (Modified Duo-binary Return to Zero). PDCF & PSMF are used for different Compensation techniques to increase the coverage distance. The different channel spacing are used to achieve the maximum coverage distance. By using 200 GHz channel spacing the maximum coverage distance achieved is 560 Km. As for 200 GHz channel spacing the system is simulated without Gaussian optical filters, so it is cost effective and simple. It is observed that by using 100 GHz channel spacing the symmetrical compensation is used for long – haul communication and covered a distance up to 840 Km using Gaussian optical filters for each channel. Therefore, it is concluded that as the channel spacing is decreased there will be intermixing of channels; hence the coverage distance will be decreased.

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