Performance Optimization of Long Haul High Bit Rate Optical Fiber System with Dispersion Compensating Fiber

Vineet Mubai[1], A. K. Jaiswal[2], Mukesh Kumar[3], Rohini Saxena[4], Neelesh Agrawal[5]

[1]PG Student, [2]Professor & H.O.D, [3, 4, 5]Assistant Professor (ECE, Deptt.)

[1, 2, 3, 4, 5] Department of Electronics and Communication Engineering, SHIATS-DU, ALLAHABAD

ABSTRACT

In this paper the comparison of the performance characteristic of pre and post compensation is done to reduce the chromatic compensation. The transmission behavior of return-to-zero (RZ) and non return-to-zero is compared numerically and experimentally. Data at the rate of 10 Gb/s were transmitted over 2000-km standard single-mode fiber using an alternative compensation scheme in a recirculation loop with more than 100 km amplifier spacing. The pre-compensation and post-compensation scheme is proposed using DCF to reduce the chromatic dispersion at the transmitter end. This method improves the Q-factor in single wavelength of 1550 nm.

Keywords-*BER, Dispersion Compensation, Dispersion Compensating Fiber, Fiber transmission, NRZ Modulation, RZ Modulation, Single Mode Fiber*.

I. INTRODUCTION

Single-mode fiber (SMF) network are subject to stringent limitations in fiber length due to the linear chromatic dispersion when the high capacity fiber optic transmission system is operated at 1.55µm [1]. Passive dispersion compensation using dispersion compensating fibers (DCF) is one of the most powerful approaches to overcome this limitation and has been investigated intensively during the past few years [1]-[3].

One of the most promising methods of installing high capacity all-optical network on the already existing SMF base is the use of dispersion compensating fiber so as to reduce or compensate for the dispersion slope directly. Reverse dispersion fiber and an inline dispersion slope compensator with arrayed waveguides (AWGs) and DCFs can be used to achieve this compensation of dispersion.

To date network design is aiming to achieve SMF amplifier spacing above $z_{z=}$ 100 km in order to reduce the number of repeater stations. Higher input powers are required due to these extended lengths of SMF sections, thus increasing the effect of nonlinearities [2], [4].

Work has been carried out for Pre-compensation and post-compensation of chromatic dispersion at the transmitter end. This has brought in improved Q-factor and results the BER in the desired range in single wavelength. Data at the rate of 10-Gb/s is transmitted using NRZ and RZ transmission over 2000-km SMF with increased amplifier spacing of more than 100 km in a recirculation loop [5], [6] has been demonstrated experimentally and system behavior has been explained by numerical simulations. As it is obvious from theory that for higher data rates return-to-zero (RZ) modulation format is better than that to NRZ, hence the transmission of a 10-Gb/s RZ data signal through the transmission line and comparison of the performance to the NRZ system has been done.

The RZ pulse occupies just a part of the bit slot, so it has a duty cycle smaller than 1 and a broad spectrum. The RZ signal has amplitude between adjacent 1's returns to zero. A RZ signal has spectrum peak power twice the larger than that of the NRZ signal with the same average power. The main characteristic of RZ modulated signals is a relatively broad optical spectrum, resulting in a reduced dispersion tolerance and a reduced spectral efficiency. The RZ pulse shape enables an increased robustness to fiber nonlinear effects. The RZ performs better than NRZ because the energy is confined in the center of each bit-slot in the case of RZ case and thus more differential group delay (DGD) is required before the energy leaks out the bit-slot to result in inter-symbol interference.

II. EXPERIMENTAL SETUP

The experiments are performed in a recirculation span (Fig 1 and Fig 2) in which there is PRBS generator with the 10Gbps bit rate and pattern length also a continuous wave laser source has been used to generate carrier wave at 1550 nm wavelength.

Machzehnder modulation as an external modulator is used and 80 km single mode fiber (SMF) having positive dispersion coefficient is used with total dispersion of +1358 ps/nm/km In order to compensate the transmitting fiber dispersion we inserted DCF 20 km with negative dispersion slope of -67.69ps/nm/km. An EDFA amplifier is also used with 30GHz bandwidth in the system.

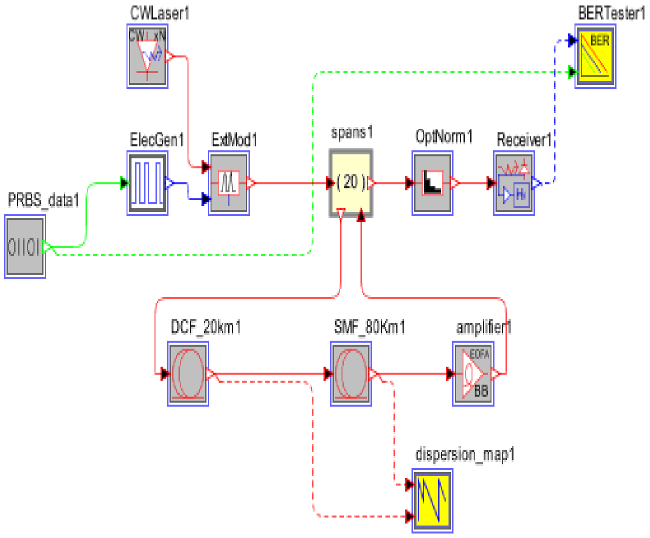

Fig. 1 Pre-compensation of chromatic dispersion

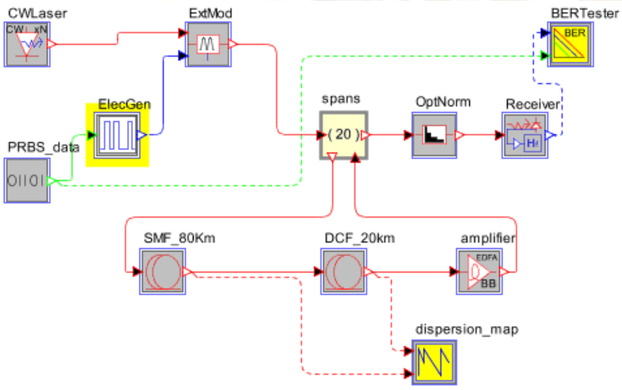

Fig. 2 Post-compensation of chromatic dispersion

III. EXPERIMENTAL RESULT

In the pre-compensation scheme, total negative dispersion generated by DCF is -1358 ps/nm/km, which is compensated through 80 km SMF of positive dispersion slope. BER is measured at data packets after 20 round trips corresponding to 2000 km SMF length. In the case of NRZ, at very low power 0.5mW the Q-factor is 16.16dB and at 1mW power level the Q-factor becomes 14.76dB which is below the desired value of 15.56dB. Also by the numerical simulation, it thus enable us to achieve BER<10^{-9}. For RZ modulation format on the other hand, at 1mW power the Q-factor has maximum value of 22.31dB and BER is 2.792×10^{-39}. As we increase the power above 1mW, Q-factor decreases.

In post compensation DCF reduces the dispersion which is generated by the 80 km SMF. In this compensation scheme, NRZ modulation is applicable below 2mW signal power to get the desired range of BER and Q factor but RZ modulation has a large range of signal power. Hence at 10mW power Q-factor is 16.077dB for RZ modulation and BER is 9.709×10^{-11}, which is appropriate for optical communication.

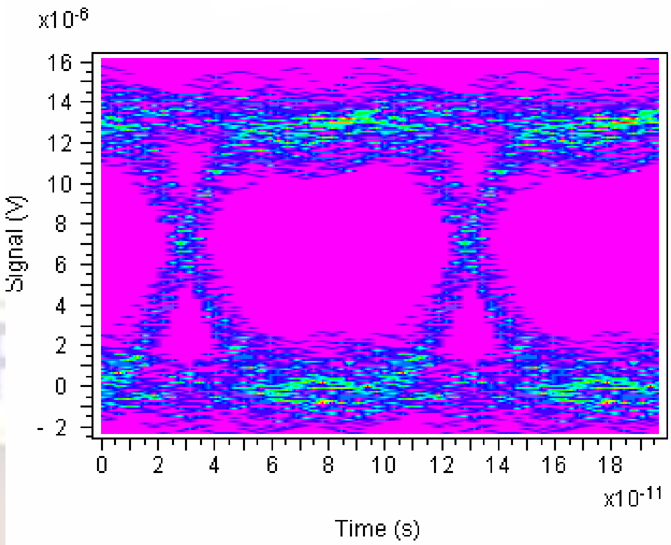

Fig 3 Eye diagram of post-compensation of chromatic dispersion with NRZ

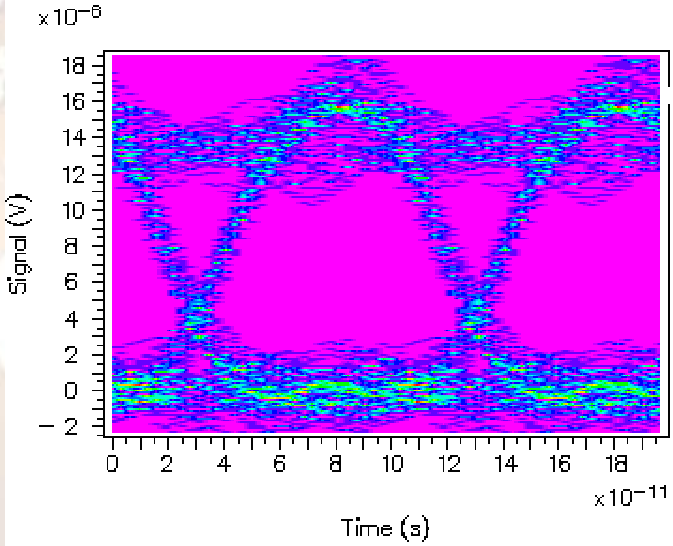

Fig. 4 Eye diagram of pre compensation of chromatic dispersion with NRZ

Figure 3 shows the eye diagram of post-compensation of chromatic dispersion with NRZ modulation. This figure has been taken at 1 mW power. At the time of maximum eye opening, sampling of the signal is best, that is the transmission of signal will be error free. In this transmission system, the eye opening is best at the time of signal transmission. The width of the eye opening defines the time interval over which the received signal can be sampled without error from intersymbol interference.

In pre-compensation of the same transmission system, the eye diagram as shown in Figure 4 contains some distortion in the signal. Some noise seen in the diagram and eye opening is also less in this as compared to the post compensation of chromatic dispersion.

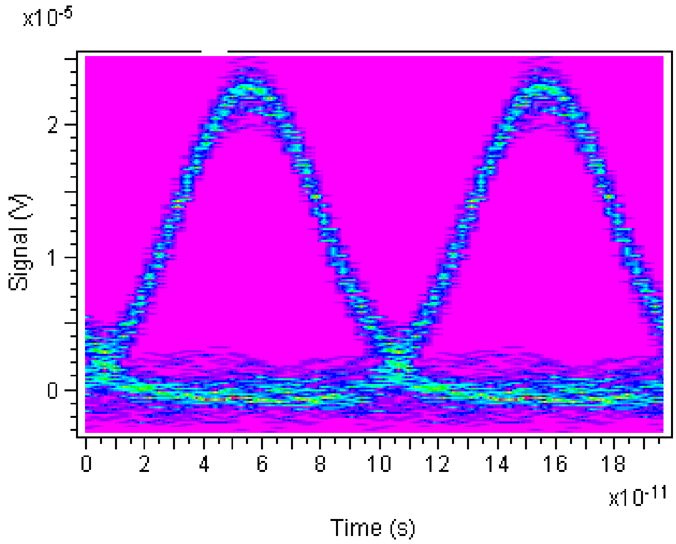

Fig. 5 Eye diagram of post compensation of chromatic dispersion with RZ modulation

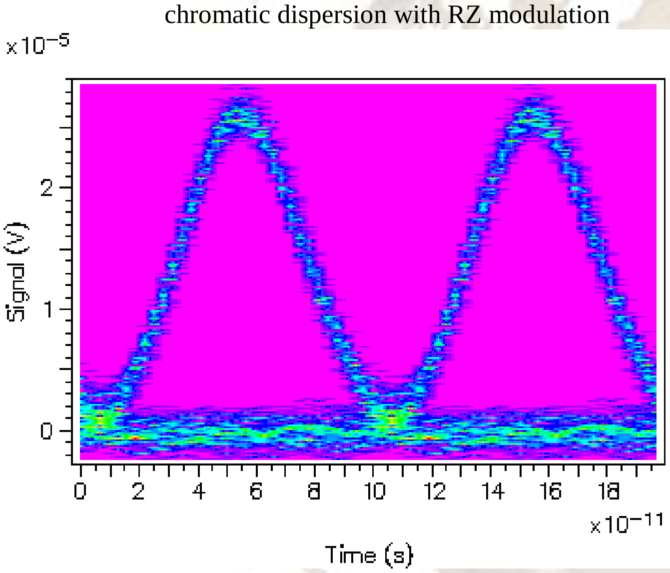

Fig. 6 Eye diagram of pre compensation of chromatic dispersion with RZ

On the transmission of RZ signal in post compensation scheme, BER is find very low as compared to desired system BER (10^{-9} to 10^{-12}) and also the quality factor is very high as compare to desired quality factor (15 to 17) of the system. From figure 5 and figure 6 it is clear that the eye opening is very poor at the time of transmission.
From the analysis of eye diagram NRZ modulation is better perform in the post compensation of the chromatic dispersion as compared to the RZ modulation format.

On the transmission of RZ signal in pre compensation technique, the eye opening of the system is very less as compared to the NRZ modulation format. BER is very low as compare to desired value of the system and also Q (dB) is very high as compared to desired value of system value.

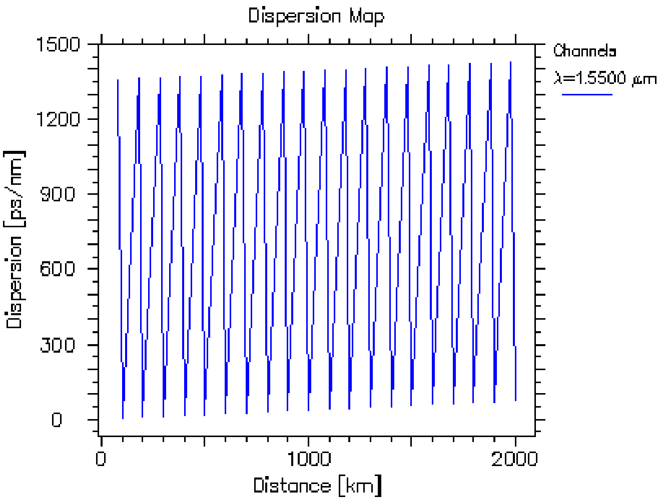

Fig. 7 Dispersion map in the Post Compensation of the Chromatic Dispersion

Figure 7 shows the dispersion map for the post compensation scheme in which it is clear that the total dispersion created after the 80 km SMF is 1368 ps/nm/km and then after passing it through the 20 km DCF the dispersion reduces towards zero. The received signal is then amplified by the EDFA (erbium doped fiber amplifier) and then it is transmitted to next 100 km span [7].

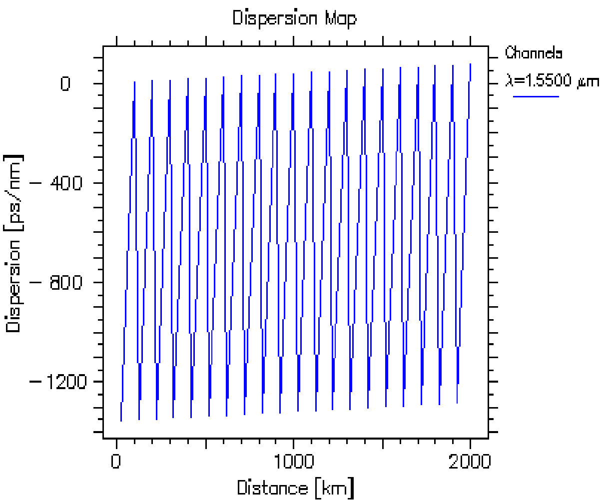

Fig. 8 Dispersion map for Pre-Compensation of Chromatic Dispersion

In Figure 8, dispersion map of the pre compensation scheme is shown, from which it is evident that the total dispersion passes through the 20 km DCF reduces the dispersion towards -1200 ps/nm/km. Then the total dispersion created after the

80 km SMF is 1368 ps/nm/km which compensates the dispersion through the DCF towards zero. The received signal is then amplified by the EDFA (erbium doped fiber amplifier) and transmitted over the next 100 km span.

IV. CONCLUSION

10 Gb/s data transmission over 2000-km SMF at 1.55 µm with more than 100 km amplifier spacing with an alternating dispersion compensation scheme in a recirculation span is demonstrated experimentally.

At 10Gbps bit rate, 1550 nm wavelength pre-compensation is better than the post compensation. In the Pre compensation Q-factor and BER improves as compared to the post compensation. Also it has been analyzed and investigated that the NRZ Modulation is better than the RZ modulation although in the RZ modulation, for large power we get the BER less than 10^{-9}, which is suitable for optical communication at 1550 nm wavelength.

REFERENCES

[1] D. Breuer, K. Ennser, and K. Petermann , *"Comparison of NRZ- and RZ modulation format for 40 Gb/s TDM standard-fiber systems,"* presented at ECOC'96, Oslo, Norway, vol. 2, 1996, paper TuD.3.3..

[2] D. Breuer, K. J¨urgensen, F. K¨uppers, A. Mattheus, I. Gabitov, and S. K. Turitsyn, *"Optimal schemes for dispersion compensation of standard monomode fiber based links," Opt. Commun.*, vol. 140, pp. 15–18, July15, 1997.

[3] D. M. Rothnie and J. E. Midwinter, *"Improved standard fiber performance by positioning the dispersion compensating fiber," Electron. Lett.*, vol. 32, no. 20, pp. 1907–1908, Sept. 1996.

[4] N. Smith, F.M. Knox, N.J. Doran, K.J. Blow, I. Bennion, Electron. Lett. 32 (1996) 55.

[5] N. Kikuchi, S. Sasaki, and K. Sekine, *"10 Gb/s dispersion-compensated transmission over 2245km conventional fibers in a recirculatiing loop," Electron. Lett.*, vol. 31, no. 5, pp. 375–377, Mar. 1995.

[6] N. Kikuchi and S. Sasaki, *"Fiber nonlinearity in dispersion-compensated conventional fiber transmission," Electron. Lett.*, vol. 32, no. 6, pp. 570–572, Mar. 1996.

[7] S. Artigaud, M. Chbat, P. Nouchi, F. Chiquet, D. Bayart, L. Hamon, A. Pitel, F. Goudeseune, P. Bousselet, J.-L. Beylat,Electron. Lett. 32(1996) 1389.

Vineet Mubai was born in Allahabad, U.P, India in 1984. He received B.Tech from the department of Electronics and Communication from B.B.S College of Engineering and Technology, Allahabad in 2006. He is perusing M.Tech from the Department of Electronics and Communication Engineering from S.H.I.A.T.S, Allahabad. His main research interest includes Optical Fiber Communication System.
Email-ec.mvineet@gmail.com,
Mobile:+91-9695063167

Prof. Arvind Kumar Jaiswal was born in 1942. He is M.Sc in Science and M.Sc (Tech.) in Electronic and Radio Engineering from Allahabad University. He has 33 years of industry experience and 10 years of teaching experience. Prof. A.K Jaiswal is working as Professor and Head of Electronics and Communication department in SHIATS-DU, Allahabad. He guided many Undergraduates and Post Graduates Students in their projects and Research work. He has 3 publications on various platforms. His research interests includes Optical Fiber Communication and Control Systems.
Email: arvind.jaiswal@shiats.edu.in

Mukesh Kumar is working as a Asst. Prof. in the Department of Electronics & Communication Engineering in SHIATS, Allahabad. He received his M.Tech. Degree in Advanced Communication System Engineering from SHIATS, Allahabad in 2010. His research is focused on Signal processing, Wireless Sensor Network and Computer Networks ,Microwave Engineering, as well as Optical fiber communication.
Email-mukesh044@gmail.com,
Mobile:+91-9935966111

Rohini Saxena is working as a Asst. Prof. in the Department of Electronics & Communication Engineering in SHIATS, Allahabad. She received her Degree of M.Tech in Advanced Communication

System Engineering from SHIATS-DU, Allahabad in 2009. Her research is focused on Digital Communication, Microwave Engineering, Wireless Sensor Network and Computer Networks and Mobile communication.
Email-rohini.saxena@gmail.com,
Mobile:+91-9208548881

Neelesh Agrawal is working as a Asst. Prof. in the Department of Electronics & Communication Engineering in SHIATS, Allahabad. He received his M.Tech. Degree in Advanced Communication System Engineering from SHIATS-DU, Allahabad in 2009. His research is focused on Signal Processing, Microwave Engineering, Wireless Sensor Network and Computer Networks, Mobile communication and Optical Communication.
Email- agrawalneelesh@gmail.com