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Third Order Dispersion Compensation in 40Gbps Single Channel System under Different Modulation Formats

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***Abstract* -- In this paper, a single channel 40Gbps Dispersion compensation system with 600 km distance is presented. Analysis of third order dispersion is done using dispersion compensating fiber with single mode fiber. The dispersion effect is analyzed under different modulation formats like RZ, NRZ, and NRZ-DPSK. After compensation of group velocity dispersion, the effect of third order dispersion is observed by varying the third order dispersion co-efficient. The quality factor is observed at each value of the third order dispersion co-efficient. It is observed that NRZ-DPSK has better performance in case of dispersion compensation as compared to NRZ and RZ modulation formats on input power of 0dBm. Compensation of third order dispersion results improvement in Q-factor.**

***Index Terms*- Return to Zero(RZ), Non Return to Zero(NRZ), Differential Phase Shift Keying (DPSK), Amplitude Shift keying(ASK), Erbium Doped Fiber Amplifier(EDFA), Dispersion Compensation, Dispersion Compensating Fiber(DCF), Group Velocity Dispersion (GVD), Third Order Dispersion (TOD), Quality Factor.**

I. INTRODUCTION

In modern era, applications and services in telecommunication field are growing at very rapid pace. The rising demand makes it necessary to improve telecommunication networks for higher speed and bandwidth requirements. Fiber optics communication system is more suitable for high speed and bandwidth as compared to conventional networks. But, performance of fiber optics communication system is affected due to dispersion.

Dispersion is the major factor which affects the performance of optical fiber communication system. It is basically chromatic dispersion or group velocity dispersion which effects the pulse width i.e. pulse broadening. The pulse broadening takes place at long distance in optical fiber communication system. At lower data rate group velocity dispersion affects the system but at high data rate third order dispersion also comes into picture. So, to improve quality of signal third order dispersion compensation is required. Third order dispersion affects the system less as compared to second order dispersion but compensation will give better results. In case of higher order dispersion, the effect becomes negligible but increases with increase in bit rate. [1-2]

II. DISPERSION COMPENSATION TECHNIQUE

Dispersion compensating fiber is an easy and efficient way to upgrade installed links made of single mode fiber. Performance degradation in optical communication system is because of group velocity dispersion, Kerr nonlinearity, and accumulation of amplified spontaneous emission noise due to periodic amplification. Because of the nonlinear nature of propagation, system performance depends on the power levels at the input of different types of fibers, on the position of the DCF and on the amount of dispersion. There are basically three types namely-pre, post and symmetrical compensation schemes where

the DCF is placed before, after the SMF or symmetrically across the SMF. A DCF should have low insertion loss, low polarization mode dispersion and low optical nonlinearity and also it should have large chromatic dispersion coefficient to minimize the size of a DCF. Smaller size of the DCF is preferable [6-7]. By placing one DCF with negative dispersion after a SMF with positive dispersion, the net dispersion should be zero.

$$D_{SMF} \times L_{SMF} + D_{DCF} \times L_{DCF} = 0 \quad (1)$$

Where D_{SMF} and L_{SMF} are dispersion coefficient and length of single mode fiber (SMF) respectively and D_{DCF} and L_{DCF} are dispersion coefficient and length of dispersion compensating fiber (DCF) respectively. Compensation is done by three different methods depending on the position of the DCF:

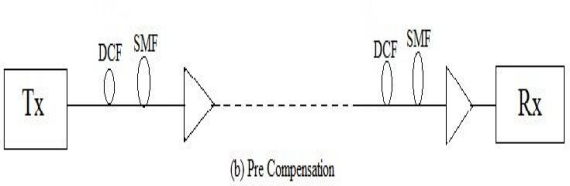
i. Pre-Compensation
ii. Post Compensation
iii. Symmetrical Compensation

Pre-Compensation: In this Compensation scheme, the dispersion compensating fiber of negative dispersion is placed before the standard fiber to compensate positive dispersion of the standard fiber.

Post-Compensation: In this Compensation scheme, the dispersion compensating fiber of negative dispersion is placed after the standard fiber to compensate positive dispersion of the standard fiber.

Symmetrical-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 the standard

fiber [8]. These compensation schemes are represents in fig. 1.



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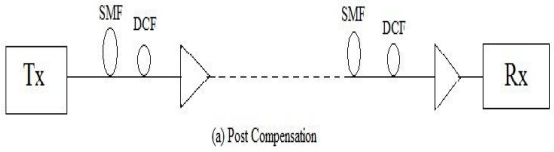

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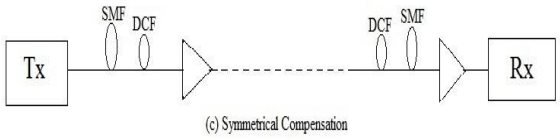

1(c)

Fig.1 Pre, Post and Symmetrical compensation schemes

III. MODULATION FORMAT

The optical signal can be generated by different modulation formats. The modulation formats used are NRZ, RZ and NRZ-DPSK. NRZ and RZ are comes under the category of ASK modulation scheme and NRZ- DPSK is type of PSK modulation scheme.

A. NRZ Modulation Format

NRZ modulation format is intensity modulated format. It is simplest format where pulse sends for entire bit period. NRZ format has low electrical bandwidth as compared to RZ modulation format. It has narrow spectral width so dispersion tolerance is better [9]. Transmitter for NRZ modulation format is shown in fig.2. From this figure PRBS is used to generate random data sequence. Then NRZ format is implemented on binary data and it is modulated with optical signal having frequency 193.1 THz

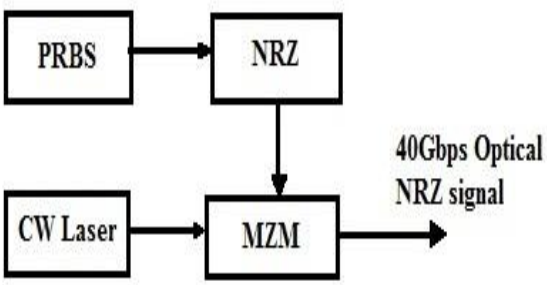

Fig.2 NRZ Transmitter

B. RZ Modulation Format

In RZ modulation format power is available for a fraction of bit duration. No pulse sends for low signal. At same average power RZ has twice peak power as compared to NRZ. RZ modulation format consists of large bandwidth as compared to NRZ format. The dispersion tolerance is less due to broad spectral width.[1][9].

C. NRZ-DPSK Modulation Format

NRZ-DPSK format comes under the category of Phase shift keying modulation scheme. In this format NRZ and DPSK are combined.

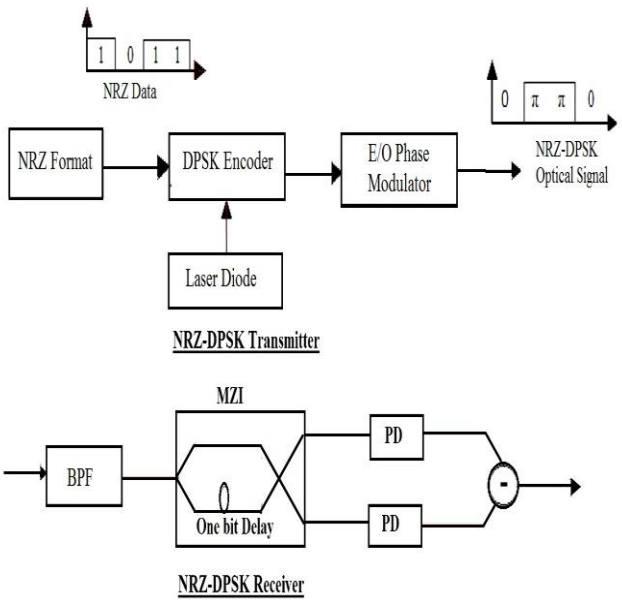

Fig.3 DPSK Transmitter and Receiver

As shown in fig.3, the output of NRZ is encoded by DPSK encoder. DPSK encoded signal operates the electro-optic phase modulator and produce optical signal. One bit MZI co-relates the each bit with immediate bit at receiver. When bits are same, it will add and give high signal. If not same there is phase shift of π takes place which results low signal. DPSK signal is received by balanced detection in which two photo detectors are used. The photo current of photo diodes is combined which improves the sensitivity of receiver [3].

IV. SYSTEM DESIGN AND SIMULATION

OPTISYSTEM 7.0 simulator is used for simulation. It provides an identical environment as practical realization of optical fiber communication system. It is an innovative optical communication system simulation package that designs, tasks and optimizes virtually any type of optical link in the physical layer of broad spectrum of optical networks.

In this work, a single channel 40Gbps dispersion compensated system is designed with 600 km distance and analyzed the dispersion effect up to third order. The performance has been analyzed with different modulation formats i.e. NRZ, RZ and NRZ-DPSK. In transmitter section, PRBS generator is used to generate random binary sequence which is treated as a digital input data. Different modulation formats are applied to digital data and is modulated by optical signal, which is generated by CW laser operating at 193.1THz and 0dB of power. But, NRZ-DPSK transmitter consists of DPSK encoder which encode the NRZ modulated signal.[1][9].

Table.1 Fiber parameters under different modulation format

Modulation Format at 40Gbps with Compensation Schemes	Parameters of Single Mode Fiber						
	D (ps/km.nm)	Slope (ps/km.nm^2)	β_2(ps^2/km)	β_3(ps^3/km)	Wave Length(nm)	Input Power (mW)	Atten Uation (dB/km)
RZ Pre	20	0.07	6	17	1550	1	22
RZ Post	7	0-07	25	23	1550	1	22
RZ Symmetrical	21	0.05	13	21	1550	1	22
NRZ Pre	4	0.085	4	25	1550	1	22
NRZ Post	3	0.075	1	25	1550	1	22
NRZ Symmetrical	1	0.03	4	1	1550	1	22
NRZ-DPSK Pre	4	0.075	13	1	1550	1	22
NRZ-DPSK Post	3	0.075	1	0.1	1550	1	22
NRZ-DPSK Symmetrical	17	0.075	17	13	1550	1	22

In fiber section, single mode fiber of 50km and dispersion compensating fiber of 10km are implemented in fiber span along with EDFA. This span is repeated 10 times to cover distance of 600km. Position of DCF is decided under compensation schemes like pre, post, symmetrical compensation. The parameters are selected to compensate group velocity dispersion and third order dispersion as given in Table 1.

V. RESULTS AND DISCUSSION

The observation has been carried out by varying the fiber parameters as mentioned in table 1.. First of all, second order dispersion is compensated by selecting appropriate value of dispersion parameter i.e. β_2. Then, third order dispersion is analyzed by varying the dispersion co-efficient β_3. It is observed that, the value of Quality factor further increases with compensation of third order dispersion. Table 2 shows the Q-factor for different modulation formats under compensation schemes. By third order dispersion, the value of Q-factor in RZ modulation format is increased up to 18.38 with post compensation. In case of NRZ modulation format, the value of Q-factor is increased up to 19.39 with symmetrical compensation. In case of NRZ-DPSK modulation format, the maximum value of Q-factor i.e. 20.86 is achieved by third order dispersion compensation with post compensation. This value is maximized among other formats under pre, post and symmetrical compensation.

It is observed that NRZ-DPSK modulation format is performed better in pre, post and symmetrical compensation schemes as compared to NRZ and RZ modulation format. The effect of third order dispersion is less as compared to second order dispersion, but it has some improvement in performance at high bit rate. In fig.3 (a), it is noted that, RZ post compensation has better Q-factor as compared to other. The maximum value of Q-factor is observed at β_3 equal to 23.

Table.2 Q-Factor with Third order dispersion compensation using different modulation formats. (Input power- 0 dBm, Distance- 600 km, Data rate – 40Gbps)

Compensation Schemes	Q-Factor in RZ Format	Q-Factor in NRZ Format	Q-Factor in DPSK Format
Pre Compensation	17.7567	13.2827	20.2211
Post Compensation	18.3820	16.5722	20.8686
Symmetrical Compensation	17.6002	19.3944	19.5167

Pre compensation has least value of Q-factor among others. In NRZ modulation format, symmetrical compensation has better Q-factor. The maximum value of Q-factor reaches to 19.36 at value of β_3 around 1 as observed in fig.3 (b). In case of NRZ-DPSK format, the maximum value of Q-factor i.e. 20.86 is observed with post compensation as shown in fig.3(c). The value of Q-factor is highest in pre, post, and symmetrical compensation with NRZ-DPSK format as observed in graphs.

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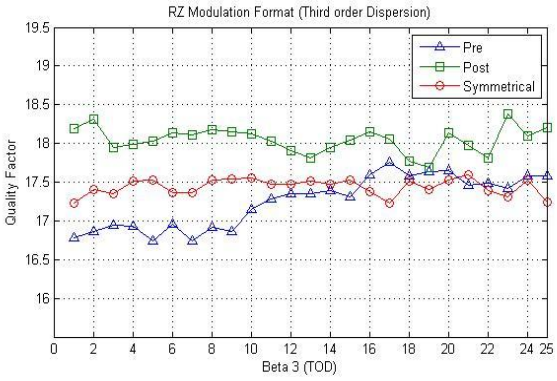

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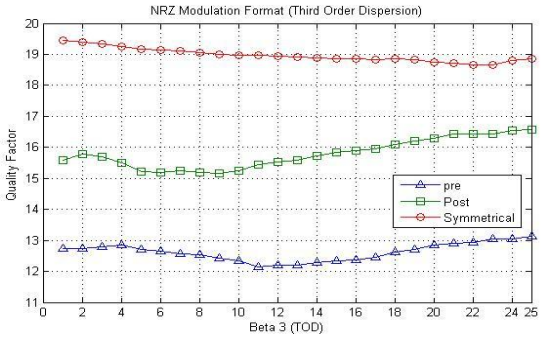

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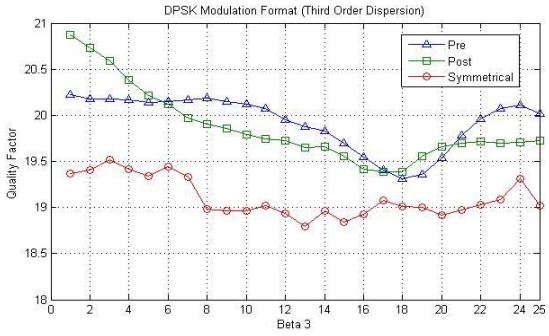


3(c)

Fig.3 Q-Factor vs. β_3 (TOD) with different modulation formats, Input power- 0dBm, Distance-600km, Data rate- 40Gbps : (a) RZ Format, (b) NRZ Format, (c) DPSK Format.

In the next case, the graph is plotted between Q-factor and input power of laser. The value of input power is increased from -10dBm to 0dBm and Q-factor is measured at each value in NRZ-DPSK format as shown in fig.4. The quality factor increases as input power increases, but at high positive power, Q-factor again decreases. In this graph, the value of Q-factor is minimum at -10dB and increases with increase in power up to 0dBm. In this system, the results are observed at 0dBm but, low power can be used up to acceptable Q-factor.

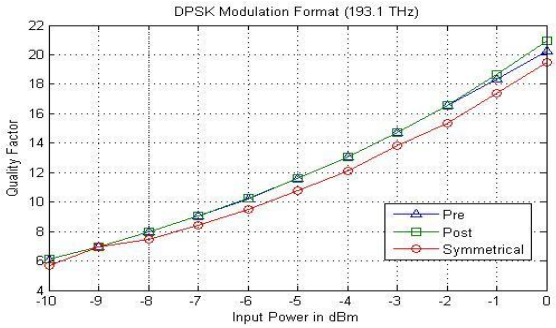
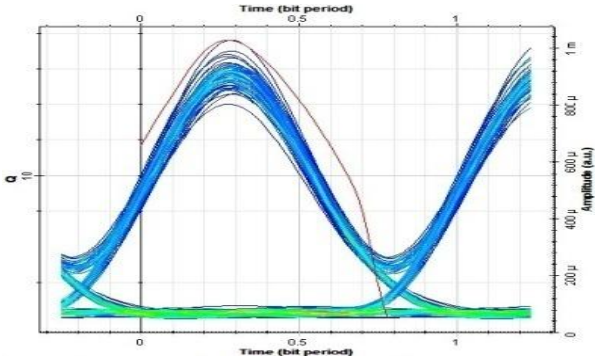
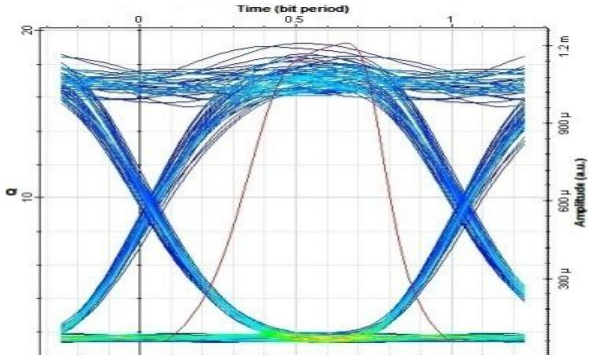


Fig.4 Q-Factor vs. Input power in DPSK, Distance- 600km, Data rate- 40Gbps

The fig.5 shows eye diagrams for three modulation formats with post compensation. Maximum is the opening of eye diagram, better is the performance of communication system. The results show that NRZ-DPSK format has better eye opening as compared to RZ and NRZ format with post compensation.



5(a)



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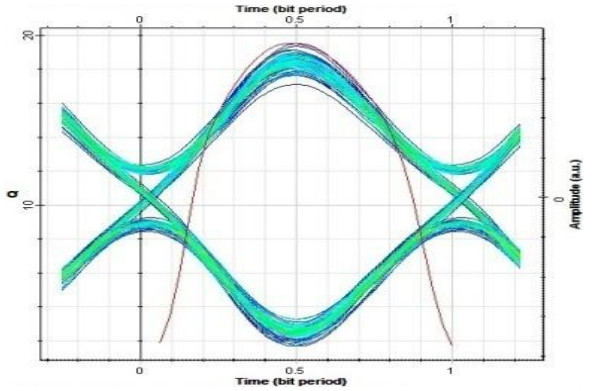

5(c)

Fig.6 Eye diagram for (a) RZ (b) NRZ (c) DPSK modulation format with symmetrical compensation

IV. CONCLUSION

It is concluded that NRZ-DPSK modulation format gives more acceptable Q-factor as compared to ASK based modulation formats when both group velocity and third order dispersion effects are considered. The system has been investigated to evaluate its performance for pre, post and symmetrical compensation schemes under NRZ, RZ, and NRZ-DPSK format. It is found that NRZ-DPSK with post compensation is outperformed among others. Therefore, the performance of optical communication system is improved by compensation of higher order dispersion.

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