International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 5, May 2013)

# An Improved Methodology for Dispersion Compensation and Synchronization in Optical Fiber Communication Networks

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***Abstract*****-- We consider that Optical communication network offers very high potential bandwidth and flexibility In terms of high bit-rate transmission. However, their performance slows down due to some parameter like dispersion, attenuation, scattering and unsynchronized bit pattern. In long haul application, dispersion is the main parameter which needs to be compensated in order to provide high level of reliability of service (ROS). Fiber Braggs Grating (FBG) is one of the most widely used element to compensate it, however its performance slows down with the increase in distance. In this paper we proposed a method for dispersion compensation which offers much better performance than FBG compensation. This method offers almost negligible dispersion and very high value of synchronization by reducing jitter portion in the Eye diagram. This method also offers very high value of Q-factor, SNR and Reduced BER in long haul optical communication networks.**

***Keywords*****-- Intermodal dispersion, reliability of service, PMD, DCF, Q-factor, BER, Threshold Value, Eye-Height**

## I. Introduction

Intermodal dispersion is not a significant problem in single mode fiber based system, where it is absent. However, PMD is the main limitation that confines the optical fiber transmission from utilizing the bandwidth efficiency. This Dispersion is the main parameter which needs to be compensated for faithful signal transmission and Fiber Bragg's Grating is one of the solution to compensate it, but only up to a certain level Fig.(1) illustrates the idea behind the dispersion compensation technique, where the SMF is used followed by DCF. Here the value of dispersion coefficient$\beta_2$ is calculated in terms of $\beta_1$ (dispersion coefficient of SMF) in such a manner, so that after a certain distance the total first order or chromatic dispersion must be zero. This management scheme can be repeated over entire length of total transmission distance. An EDFA can regenerate weak signal but it makes the dispersion worse. Since the dispersion effect accumulates over the multiple amplifier stages therefore the current task of optical fiber communication system design is to solve the fiber dispersion problem especially due to PMD.

There are many techniques demonstrated for PMD compensation in both the optical domain and electrical domain. Early strategies to reduce the PMD were focused on reducing the intrinsic PMD of fiber by altering manufacturing process.

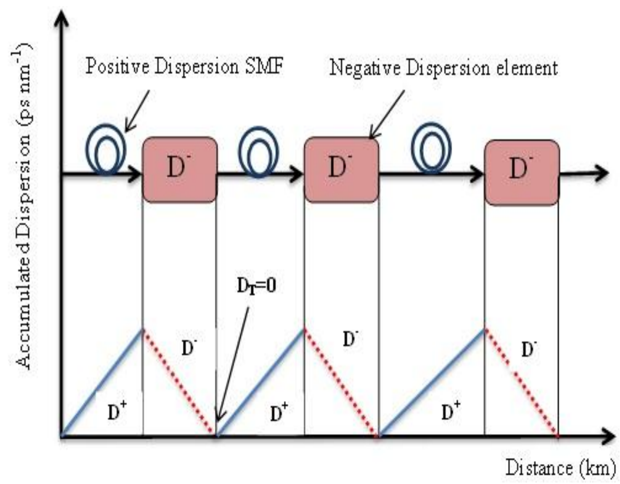


**Figure 1: An illustration of DCF technique**

This leads to low and stable values of PMD in the new generation of single mode fiber being manufactured. The complex impulse baseband impulse response is the backbone to construct the simulation of optical fiber channel. Gaussian noise signals are also added to represent the thermal noise in the channel at the front end of receiver. An Improved methodology for Dispersion Compensation is discussed in this work, which offers much better performance compared to FBG compensation in long haul Optical Fiber Networks.

## II. Simulation Setup

The Simulation model of transmitter and Receiver for optical fiber Communication is implemented on "OPTISYSTEM-11.0" software. A dispersion compensated fiber is used before the SMF. The total length of fiber channel remains same, however it is segmented in the ratio of 1:5 i.e. 17 km DCF and 83 km SMF.

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The parameters for DCF are reference wavelength 1550 nm, attenuation 0.6 dB/km, dispersion -80 ps/nm/km, dispersion slope 0.21 ps/nm$^2$/km, $\beta_2$= -20 ps$^2$/km, Differential group delay 3 ps/km, PMD coefficient 0.5 ps/km, mean scatter section 50 m, scattering section dispersion 100 m, maximum nonlinear phase shit 5 mrad, lower calculation limit 1200 nm, upper calculation limit 1700 nm, effective area 30 um$^2$, $n_2$= 3e-020 m$^2$/w, Raman self-shift time 1 = 14.2 fs, Raman self-shit time 2 = 3 fs, fract. Raman contribution 0.18 and orthogonal Raman factor 0.75.

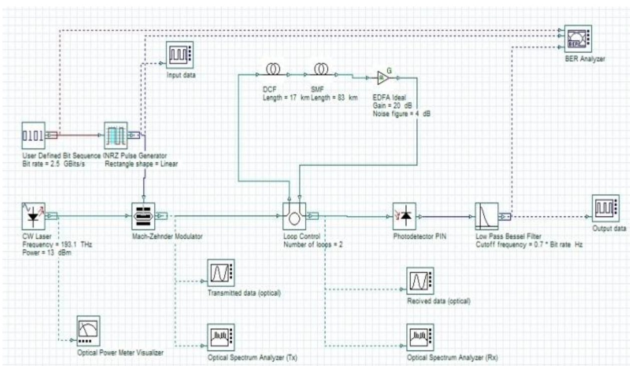


**Figure2: Simulation Model for DCF Dispersion Compensation Technique**.

We took the sequence generator with sequence=10101100, Bit rate 2.5 Gbps. NRZ pulse generator have maximum amplitude of 1 a.u. and both Rise and Fall time are 0.05 bit. A CW laser is taken as a optical source having frequency value of 193.1 THz with sweep power level 13 dBm. MZM have the Excitation ratio 30 dB and symmetry factor -1. The loop control system has 2 loops. The PIN photo detector have the Responsbity 1 A/W and Dark current 10 nA the down sampling rate is 800 GHz for the central frequency 193.1 THz considering thermal noise 2.048e-023 W/Hz. The Random seed index is 11 with the filter sample rate 5 GHz. A forth order low pass Bessel filter is connected at the output having 100 dB depth and sweep value of Cut frequency “0.7×Bit rate” Hz. An Ideal EDFA is considered having Gain and Noise figure of 20 dB, 4 dB respectively with power and saturation power level of 10 dBm, the noise BW is 13 THz and noise bins spacing is 125 GHz. For center frequency of 193.4 THz. SMF have the reference wavelength of 1550 nm with attenuation 0.25 dB/km, Dispersion 16 ps/nm/km and dispersion slope 0.08 ps/nm$^2$/km with $\beta_2$=-20 ps$^2$/km and $\beta_3$=0 ps$^2$/km.

Differential group delay for PMD is taken 0.2 ps/km with the PMD coefficient of 0.5 ps/km. Fig.(3) represents the simulation setup arrangement for long haul optical transmission networks, where we increased the distance of OFC Channel , and tested that whether the proposed compensation technique holds the performance characteristics better to FBG compensation or not. We have not changed the parameters of any other block as discussed earlier, however only the communication distance is increased approximately three times as compared to the previous model. The channel consist two SMF each having 120 km length, two DCF having 24 km length, there EDFA gain similar to previous one, and one EDFA with reduced gain of 13 dB

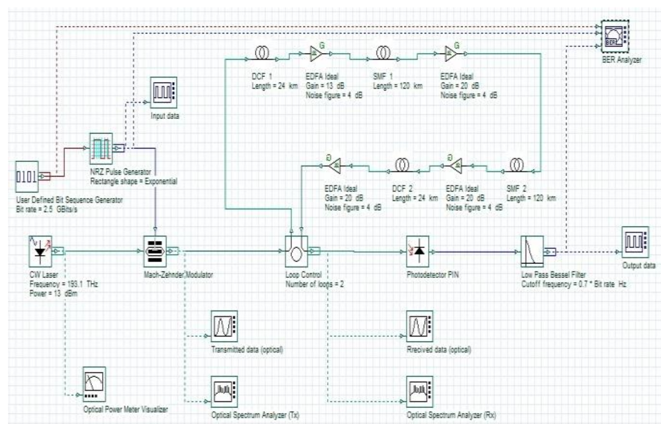


**Figure3: DCF Compensation Technique Simulation Model for long haul network**.

## III. RECIVED SEQUENCE PATTERN

From the simulation results it has been observed that even though the distance is increased three times, yet the performance parameters (Q-factor, BER, Threshold Value, Eye-Height and Received sequence) possess better value compared to FBG compensation technique. Thus the proposed technique is quite good for long haul communication networks.To calculate the probability of error, we need to establish the noise statistics and compute the probability that the noise level at any given sampling point pushes the signal to the wrong side of the threshold for a 1 or 0 transmitted.

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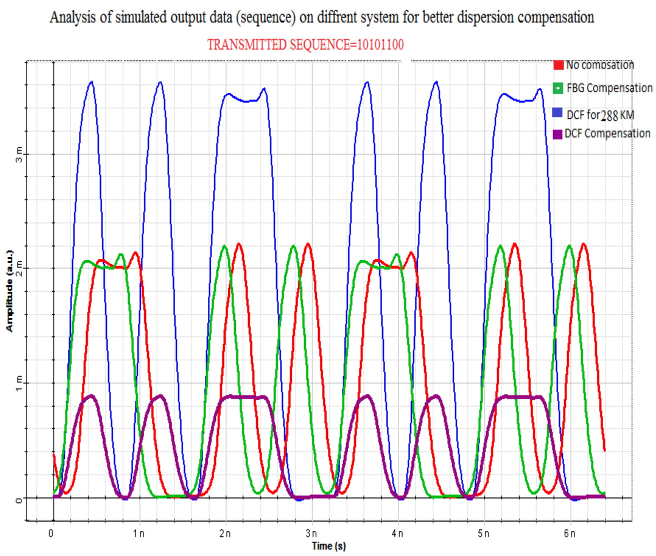


**Figure 4: Analysis of simulated output sequence on different systems for better dispersion compensation**

Fig.(4) illustrates the amount of dispersion occurred in the channel during signal transmission. Here the simulated plot of proposed dispersion compensation method for different length of fiber is plotted along with the FBG compensation output, and it can be clearly observed that, though the sequence for all the systems is transmitted at the same time yet reaching at the destination at different-different time, for no compensation pulses are more broadened (ending at 6.5 ns), for FBG it sis ending at 6.4 ns offering better performance but for the case of DCF compensation it it is ending at 6.0 ns for both 100 km and 288 km, which represents that DCF technique offers much better performance than FBG technique for dispersion management even for long haul networks also.

## IV. Q-FACTOR ANALYSIS

BER is the function of system quality factor Q. the quality factor is an electrical domain measure of ratio of separation between digital states to the noise associated with the state. Q-factor decides the performance of system parameter such as accumulated optical noise generated by optical amplifiers, polarization dependent losses and polarization mode dispersion occurred in the cannel in long haul transmission.

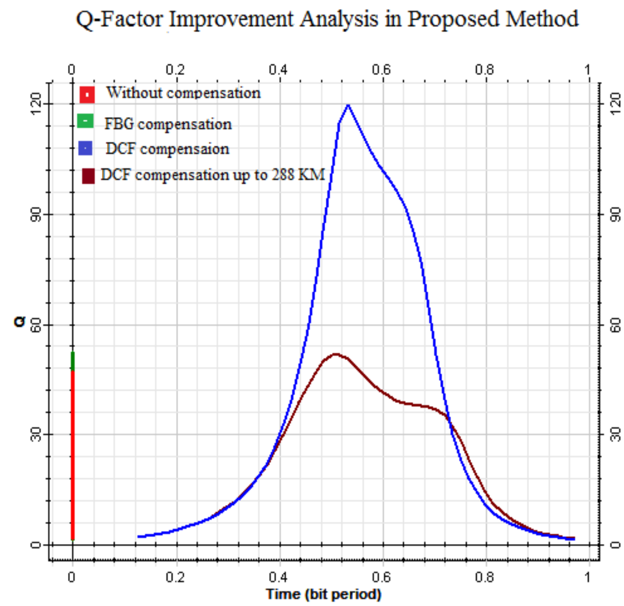


**Figure 5: Q-factor analysis of simulated data for different techniques**

It can be observed from fig.(5) that the value of Q-factor is 46.9078 without any compensation, However it offers slightly improved value 52.541 for FBG compensation method. While for proposed DCF method it comes out 119.745 which is much higher than previous one. This method is verified for thee times longer channel length and it is observed that even for such large distance the value of Q-factor comes out 51.7991 which is approximately same as FBG method with smaller distance. i.e. DCF method offers better Q-factor value for long haul OFC Networks.

## V. BER ANALYSIS

The bit error rate (BER) is the most significant performance parameter of any digital communications system. It is a measure of the probability that any given bit will have been received in error. For example a standard maximum bit error rate specified for many systems is $10^{-10}$. This means that the receiver is allowed to generate a maximum of 1 error in every $10^{10}$ bits of information transmitted or, putting it another way, the probability that any received bit is in error is $10^{-10}$. The different simulated parameters for different systems are listed in table (1) in support of quality transmission, which will offer the better bandwidth utilization with high level of signal reliability and quality with increased SNR in the transmission channel.

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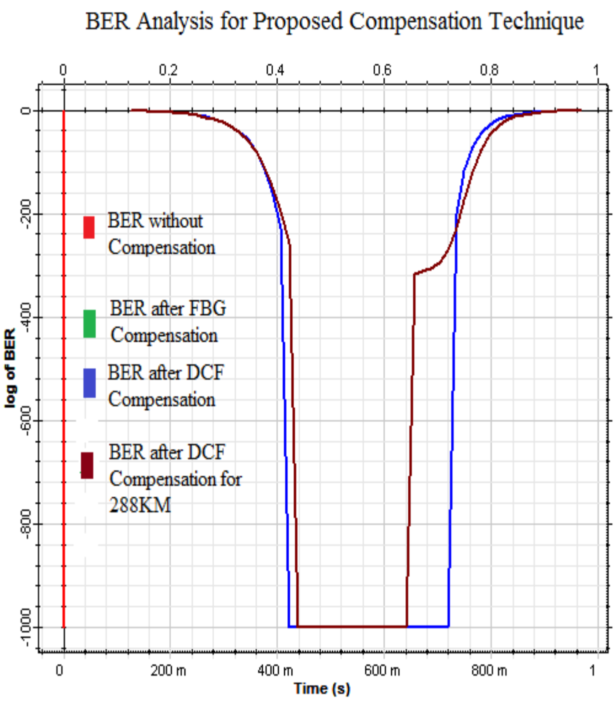


**Figure 6: BER analysis for obtained simulated data**

Fig.(6) shows the plot of MIN BER data for different methods, simulated systems offers log BER=-1000 for the time, 163-193 ps for no compensation, 156-200 ps for FBG compensation, 421.875-718.75 ms for DCF compensation and 437.5-640.625 for long haul DCF system. Thus it can be stated that DCF technique offers much better BER in optical system. It can also be noted here that this method offers MIN BER value for longer time which ultimately will result in better spectrum for this channel.

**TABLE 1**
**Simulated values of different parameters for different compensation methods**

| Technique/ Parameter | No Compensation | FBG Compensation | DCF Technique | DCF for long distance |
|---|---|---|---|---|
| Q-factor | 46.9078 | 52.541 | 119.745 | 51.7997 |
| MIN BER | 0 | 0 | 0 | 0 |
| Eye-Height | 0.00191449 | 0.00191978 | 0.00085787 | 0.00333959 |
| Threshold value | 0.00119569 | 0.00110904 | 0.00033168 | 0.00098500 |
| Decision Inst. | 0.390625 | 0.390625 | 0.421875 | 0.4375 |

## VI. Hight And Threshold Pattern

In a digital optical telecommunications receiver, the incident signals are sampled in the centre of the bit period and the sampled level is compared to a threshold to determine the presence of a one or zero. With threshold detection of this nature errors arise when noise in the system pulls a one signal level below threshold at the sampling point and pushes a zero above threshold.

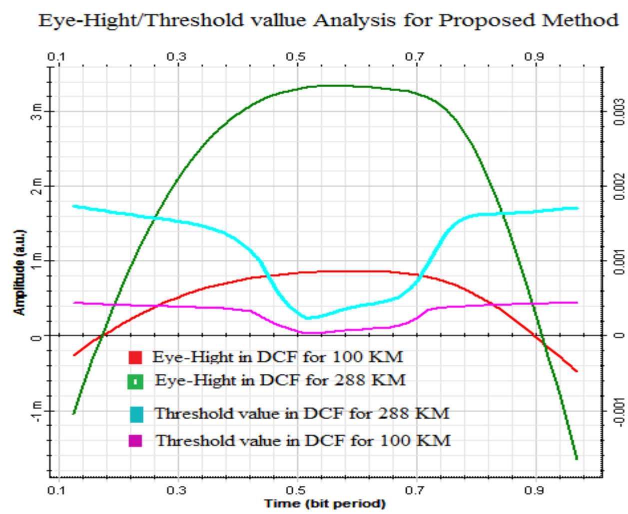


**Figure 7: Threshold vale vs. Eye-height analysis on different systems**

Fig.(7) shows that the threshold value is more than 50% of Eye-height at some instant of time which will result in increased number of errors at that time instant. However for the case of DCF method it is always less than 50% of Eye-height, this condition holds good even for increased channel length. From here it can be concluded that DCF method offers better Height and Threshold values.

## VII. Spectrum Analysis

Bandwidth of an optical fiber determines the data rate. The mechanism that limits a fiber's bandwidth is known as dispersion. Dispersion is the spreading of the optical pulses as they travel down the fiber. Optical spectrum analyzers (OSA) can divide a light-wave signal into its constituent wavelengths.

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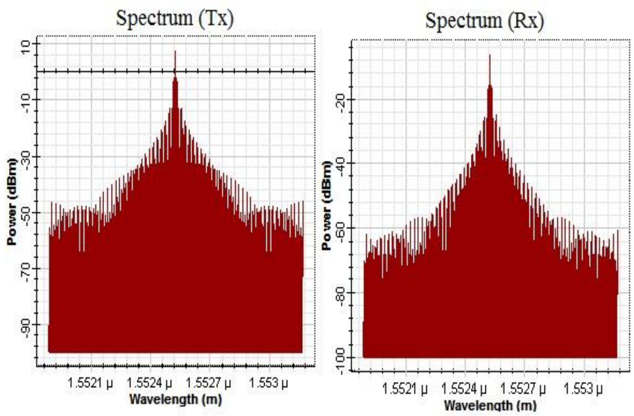


**Figure 8: Analysis of Transmitted and Received spectrum for proposed method**

This means that it is possible to see the spectral profile of the signal over a certain wavelength range.. The profile is graphically displayed, with wavelength on the Vertical axis and power on the Horizontal axis. In this way, the many signals combined on a single fiber in a dense wavelength division multiplexing (DWDM) system can be taken apart to perform per-channel analysis of the optical signal and its spectral interaction with the other wavelengths The transmitted and Received spectrums are shown in fig.(8) for DCF system which shows that spectrum does not decreases due to other nonlinear effects as they were in the FBG method thus, DCF method offers better frequency spectrum for wavelength routed channels.

## VIII. Eye Diagram Analysis

The eye diagram is also a common indicator of performance in digital transmission systems. The eye diagram is an oscilloscope display of a digital signal, repetitively sampled to get a good representation of its behaviour. In a radio system, the point of measurement may be prior to the modulator in a transmitter, or following the demodulator in a receiver, depending on which portion of the system requires examination.

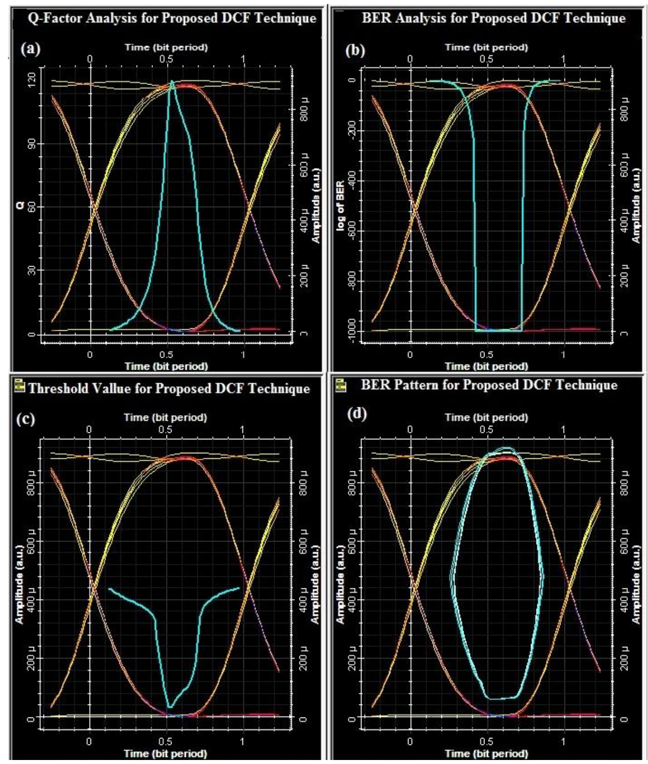


**Figure 9: Eye diagram analysis with reference to (a) Q-factor (b) MIN BER (C)Threshold value (d) BER Pattern**

The eye diagram can also be used to examine signal integrity in a purely digital system—such as fiber optic transmission, network cables or on a circuit board. Fig.(9) shows the analysis for obtained result and it can be observed that this system offers reduced jitter present here which indicate that the SNR is very high in the channel and also shows improved value of synchronization, better threshold value, improved BER pattern for all five iterations, which indicate that DCF method offers reduced dispersion and improved synchronization in long haul OFC Networks.

## IX. CONCLUSION

In this work, improved methodology for dispersion compensation in long haul network is discussed. This method offers improved value of performance parameters such as Q-FACTOR, MIN BER and THRESHOLD value compared to FBG compensation technique. During the analysis of simulation result it is also observed that BER pattern is much better than other available methods for dispersion compensation. Eye diagram shows better value of THRESHOLD and HIGHT which alternatively results in reduced jitter and improved synchronization in Optical Fiber Communication Networks. Proposed method is also verified for three times longer channel length; and observed that even for such long distance, synchronization does not lost and offers negligible dispersion in the channel. The proposed method can be implemented on OFDM networks with the two powerful methods namely window synchronization and offset frequency synchronization for better synchronization. DSP analysis for this method results in complete illumination of ISI and ICI present in the received signal for long haul optical fiber communication networks.

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