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Chromatic Dispersion Compensation by DCF under Duobinary Modulation Format

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ABSTRACT:The aim of this paper is to enhance chromatic dispersion compensation in Standard Single Mode Fiber (SSMF). To achieve this, a dispersion compensation model is proposed. The proposed model is based on Dispersion Compensation Fiber (DCF) under Duobinary (DB) modulation format in pre-compensation scheme. To evaluate the performance of the proposed model, a comparative study is conducted based on the connection scheme (i.e. pre, post and symmetrical connection schemes). For simulation, the proposed model is connected in a 10 Gbps WDM transmission system at a distance of 110 km under a set of predefined operating parameters. Optisystem is used for simulation in terms of Quality factor (Q-factor) and Bit Error Rate (BER). The three connection schemes of the proposed model have good and acceptable results. The proposed model in pre-connection scheme has the best obtained results compared to the other schemes, with a Q-factor of 6.9 and BER of 2.4×10^{-12} . The percentage of improvement in the system performance over the related work is about 99%.

KEYWORDS:Chromatic Dispersion Compensation, Dispersion Compensation Fiber DCF, Duobinary Modulation, Wavelength Division Multiplexing.

I. INTRODUCTION

The transmission performance of optical fiber communication system is based on the optimal design of optical fiber. In optical fiber transmission system, the key objective is to increase the transmission distance and bit rate. Hence, the transmission characteristics of optical fiber should be investigated. Attenuation and chromatic dispersion are the major propagation problems that affect the system performance. With the development of optical amplifier, such as erbium doped fiber amplifier (EDFA), the chromatic dispersion became the main propagation problem [1].

Chromatic dispersion occurs as a result of the group velocity delay (GVD). Where, different wavelengths have different velocities. Therefore, the propagated pulse is broadened and successive symbols are overlapped. This overlapping is called intersymbol interference (ISI), which increase the bit error rate in the received signal. Also, dispersion has a great impact on the transmission bit rate and transmission distance[2]. Therefore, in high speed long haul optical fiber communication systems, we have to compensate for chromatic dispersion. Among different dispersion compensation techniques, the dispersion compensating fibers (DCFs) is notably useful.

In DCF, the large negative chromatic dispersion coefficient of DCF is considered a perfect solution to compensate for the positive dispersion of the standard single mode fiber (SSMF) [3].

Also, chromatic dispersion in optical fiber communication systems is affected by the used optical modulation format. Where, the using of suitable and efficient modulation format leads to maximizing the spectral efficiency and improve tolerance to chromatic dispersion. Therefore, advanced modulation formats such as duobinary (DB) modulation has been used [3].

The aim of this study is to enhance the performance of chromatic dispersion compensation in a SSMF A compensation model that consists of DCF in different compensation schemes under DB modulation format is proposed. For simulation, the proposed compensation model is connected in a WDM transmission system with 10 Gbps transmission rate. The Q-factor and BER are used as measurements for the system performance with help of Optisystem [4].

The remainder of this paper is organized as follows. Section 2 explains compensation techniques using DCF. The DB modulation format is illustrated in Sec. 3. The proposed model is discussed in Sec. 4. Section 5 displays and discusses the simulation results. Section 6 is devoted to the main conclusions.

II. DISPERSION COMPENSATION USING DCF

The DCF is an efficient chromatic dispersion compensation technique used with SSMF. The idea behind DCF is to concatenate an SSMF with a DCF whose dispersion-length product is the additive inverse of that of the SSMF, hence reducing the overall chromatic dispersion of SSMF.

In DWDM systems DCF is used along with SSMF. A few hundred meters to a kilometer of DCF can be used to compensate for dispersion over tens of kilometers of the fiber length[5]. As products of DCF are more mature, stable, not easily affected by temperature, wide bandwidth, DCF has become a most useful method of dispersion compensation and has been extensively studied. Therefore, the DCF has a higher negative dispersion coefficient around -85 ps/nm-km fibers can be linked to the SMF having positive dispersion coefficient of 17 ps/nm-km to compensate the dispersion effect as shown in Fig 1[6]

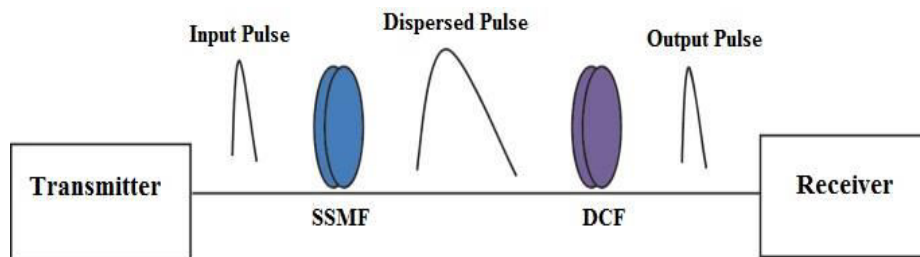


Fig. 1 DCF basic principle

The equivalent-wavelength dependent-dispersion that exemplifies the concatenated SSMF-DCF fiber link can be given by

$$D_{eq}(\lambda)=[RD_{SSMF}(\lambda)+D_{DCF}(\lambda)]/(1+R) \quad (1)$$

where R is the length ratio between SSMF and DCF, D_{SSMF} and D_{DCF} are the dispersions of the SSMF and the DCF, respectively.

From Eq. 1, given D_{eq} as zero fulfills the ideal compensation condition, and $R=L_{SSMF}/L_{DCF}$, the formula would be

$$D_{SSMF}L_{SSMF}+D_{DCF}L_{DCF}=0 \quad (2)$$

Where L_{SSMF} and L_{DCF} are the lengths of the SSMF and the DCF, respectively. This rule can be applied by introducing the calculated DCF to the communication system[7]

III.RELATED WORK

Duobinary transmission technology was studied by Lender in the 1960's as a means of transmitting binary data into an electrical cable with high frequency cut off characteristic. Recently, the technology has been applied to high speed optical transmission systems to avoid the waveform distortion due to chromatic dispersion. The optical signals have a narrower spectrum bandwidth than conventional signals and higher tolerance against chromatic dispersion. Duobinary modulation scheme is an effective scheme which can increase the spectral efficiency [8]. In view of spectral efficiency and chromatic dispersion tolerance, duobinary modulation scheme outperform NRZ scheme. Due to the increased bandwidth requirement for high bit rates long haul optical fiber communication systems duobinary scheme became a

significant modulation scheme. The main idea behind DB modulation format is the addition of the input sequence and a one-bit delayed version of the same sequence[9]. Figure 2 shows the basic principle of DB format.

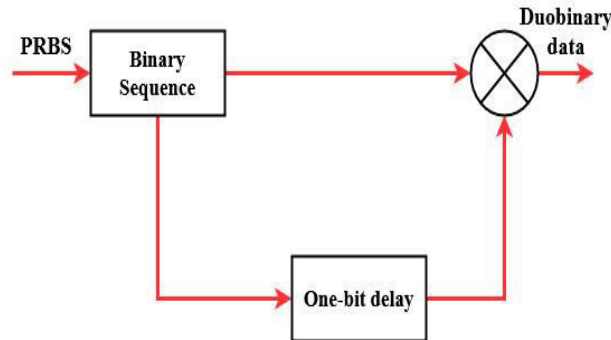


Fig. 2 Basic principle of DB format

The duobinary signal has two intensity levels ON and OFF. The ON state signal can have one of the two optical phases 0 and π . This state is represented by “1” and “-1” in the DB signal. While the OFF state has only one logic state “0”. The original signal can be recovered by inverting the directly detected signal, so a direct detection PIN photo detector is used [10]. The pulse form of the Duobinary format is

$$x(t) = \text{sinc}\left(\frac{t}{T}\right) + \text{sinc}\left(\frac{t-T}{T}\right) \quad (3)$$

Where T is the pulse width.

V. PROPOSED MODEL

To achieve the aim of this study, a chromatic dispersion compensation model in a SSMF is proposed. The proposed model is based on applying DB modulation scheme on a DCF compensation module in different compensation schemes. Figure 3 illustrates the block diagram of the proposed model in the pre-compensation scheme [11].

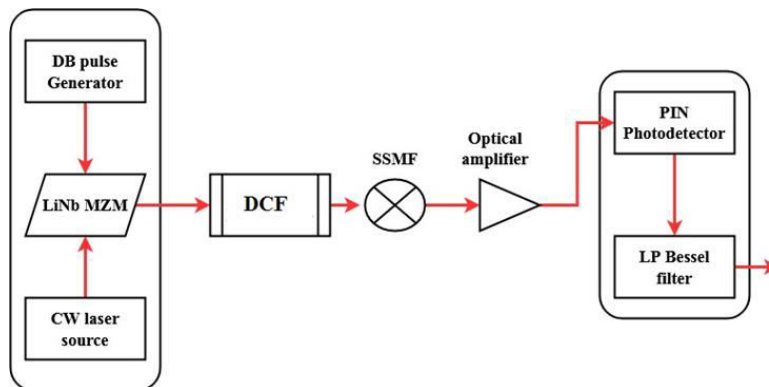


Fig. 3 Proposed model block diagram



IV.SIMULATION RESULTS AND DISCUSSION

The evaluation of the proposed model is performed through a comparative study in terms of Q-factor and BER. This study includes three cases based on which connection schemes (i.e. pre, post or symmetrical compensation scheme) is used[12]. The procedure of this comparative study is illustrated in Fig. 4.

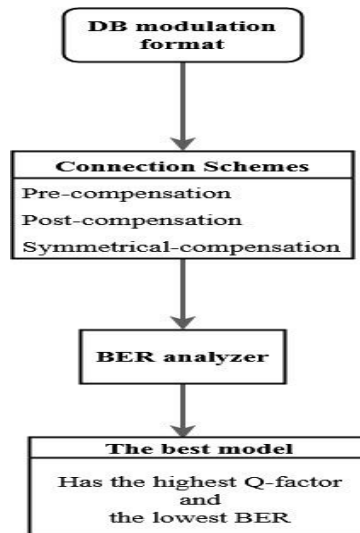


Fig. 4 Comparison study procedure

For simulation by Optisystem, the used simulation parameters shown in Table 1.

Table 1 Simulation parameters

DCF	
length (km)	10
Wavelength (nm)	1553.6
Dispersion	-80
Attenuation	0.5
Dispersion slope	-0.3
SSMF	
Reference wavelength (nm)	1553.6
Length (km)	110
Attenuation (dB/km)	0.2
Dispersion (ps/nm.km)	17
WDM link	
Input power (dBm)	0
Bit rate (Gbps)	10
EDFA gain (dB)	20
EDFA noise figure (dB)	4
PIN photodetectorresponsivity (A/W)	1
PIN photodetector dark current (nA)	30
Bessel filter cutoff frequency	0.75×bit rate

The acceptable model is that meets the minimum operational requirements in terms of Q-factor > 6 and BER < 10⁻⁹

A. Pre-compensation scheme

The basic structure of the pre-compensation scheme is displayed in Fig. 5.

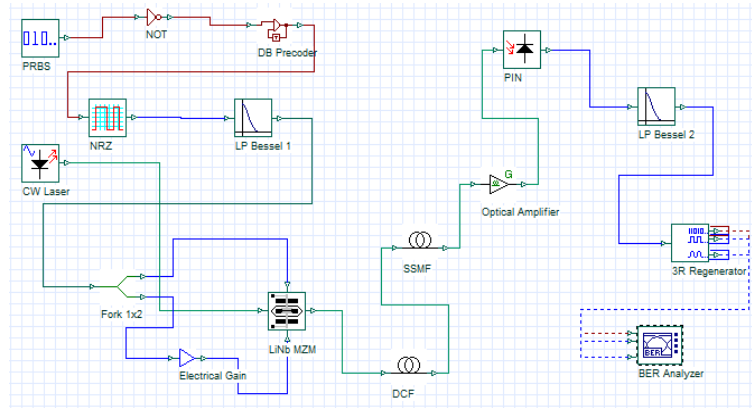


Fig. 5 Pre-compensation scheme.

Figure 6 displays the obtained results of this case.

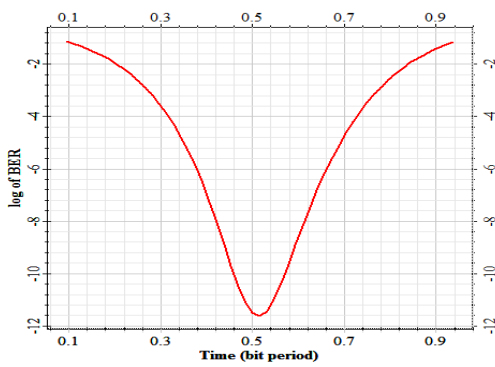


Fig. 6(a) BER of pre-compensation scheme.

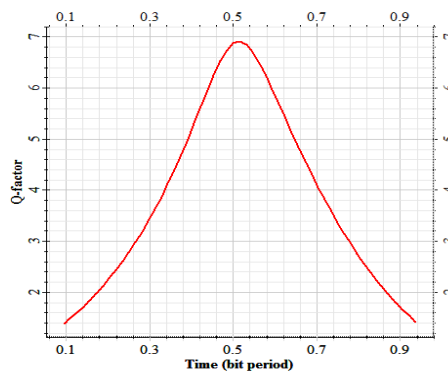


Fig. 6(b) Q-factor of pre-compensation scheme.

The results are exciting the minimum operational criteria with a Q-factor of 6.9 and a BER of 2.4×10^{-12}

B. Post-compensation scheme

Figure 7 illustrates the basic structure of the post-compensation scheme.

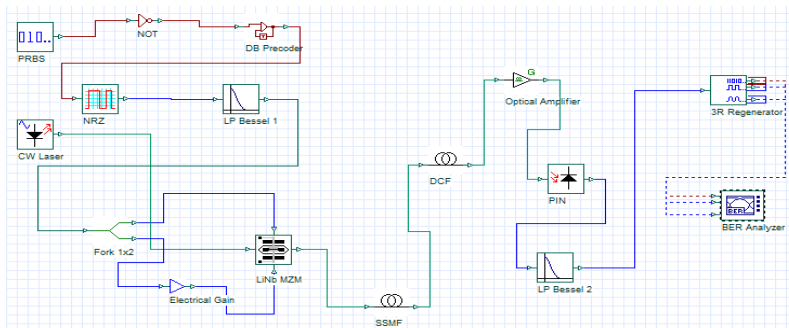


Fig. 7 Post-compensation scheme

C.Symmetrical compensation scheme

The symmetrical compensation scheme is illustrated in Fig 8.

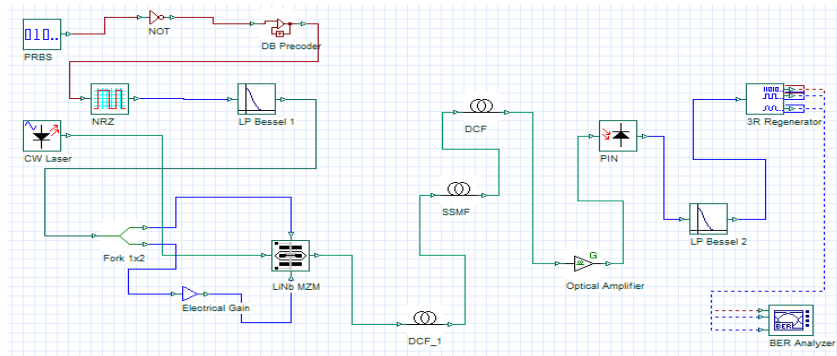


Fig. 8 Symmetrical compensation scheme.

Figure 9 illustrates the results of the symmetrical scheme.

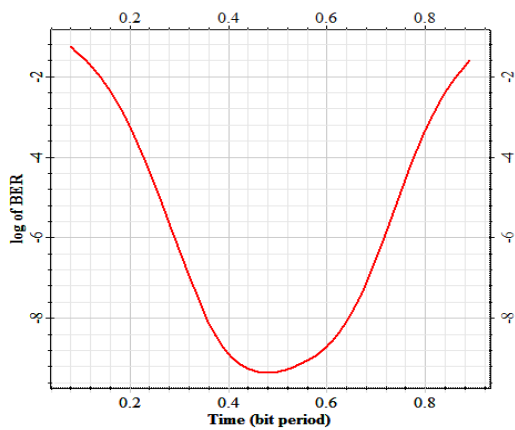


Fig. 9(a) BER of symmetrical scheme.

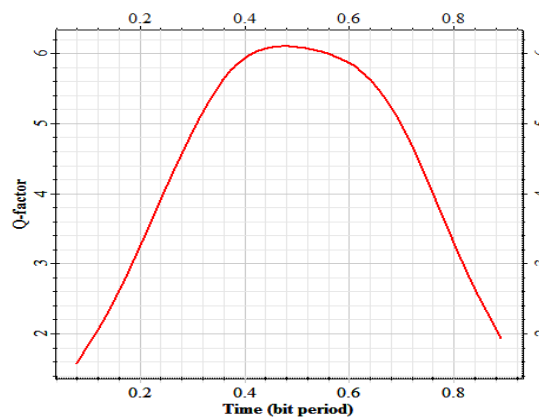


Fig. 9(b) Q-factor of symmetrical scheme.

The scheme achieves acceptable results with a Q-factor of 6.1 and a BER of 4.4×10^{-10} .

D. Summarized results

As mentioned above, all the connection schemes meet the minimum operational requirements. It attains the maximum obtained results in the case of pre-connection scheme, where Q-factor = 6.9 and BER = 2.4×10^{-12} . Table 2 summarizes the obtained results, Q-factor and BER, for the proposed model in three connection schemes.

TABLE 2 Summarized results of the proposed model.

Connection scheme	Q-factor	BER
Pre-connection	6.9	2.4×10^{-12}
Post-connection	6.8	4.7×10^{-12}
Symmetrical-connection	6.1	4.4×10^{-10}



V. CONCLUSIONS

In this paper, we proposed a DCF based chromatic dispersion compensation model under DB modulation format. The proposed model is evaluated by Optisystem in terms of Q-factor and BER under predefined simulation parameters. A 10 Gbps WDM transmission system is simulated at distance of 110 km. A comparative study is performed based on the connection schemes. It is found that DB modulation scheme in pre-compensation scheme provides the best results: Q-factor of 6.9 and a BER of 2.4×10^{-12} . The percentage of improvement in the system performance over the related work is about 99%.

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