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Chromatic Dispersion Compensation by Cascaded FB Gunder Duobinary Modulation

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ABSTRACT: In this paper, we propose a dispersion compensation model to minimize the chromatic dispersion to enhance system performance. The proposed model is based on applying the duobinary (DB) modulation scheme on 4 - stages of cascaded identical apodized uniform fiber Bragg grating (FBG). Different apodization functions are tested to determine the one that provides the best performance. 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, Cascaded Apodized Uniform FBG, 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 (DCF) 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 work is to enhance the performance of chromatic dispersion compensation in a standard single mode optical fiber. To achieve this, we propose a model of four-stages cascaded identical apodized UFBGs with DB modulation format. The model is evaluated in terms of Q-factor and BER. In the beginning, the most common apodization functions are investigated to determine the best function. Then, we examine different FBG connection schemes (i.e., pre, post and symmetrical schemes). Finally, DB modulation format is compared with MDB and NRZ modulation formats. Optisystem 17.0 is used to simulate and evaluate 10 Gbps single channel optical fiber communication system

.II. APODIZED UNIFORM FBG (AUFBG)

FBGs have emerged as an important element, mostly in optical fiber communications, especially in long haul networks. The reflectivity of FBG has sidelobes, which can be minimized by applying different index profiles, called as apodization[5]. The DB modulation scheme is an effective scheme which can increase the spectral efficiency 12(R. Kaur et al. 2014). In view of spectral efficiency and chromatic dispersion tolerance, DB modulation scheme outperforms the NRZ scheme. Due to the increased bandwidth requirement for high bit rates long haul optical fiber communication systems, 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 [6]

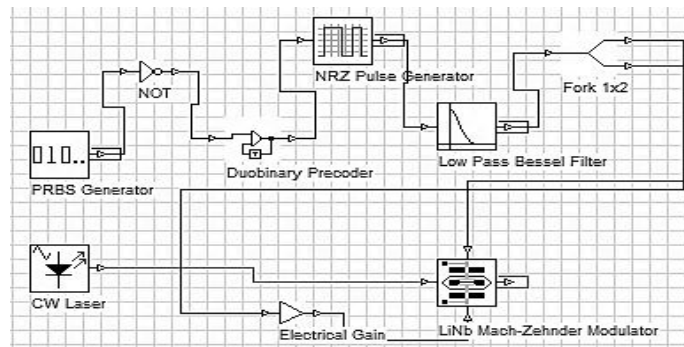


Fig. 1 Duobinary transmitter

The main idea of chromatic dispersion compensation by FBG in optical fiber communication system is inserting a wavelength-dependent time delay. The time delay, $\tau(\lambda)$ for each wavelength along the AUFBG can be obtained.

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.

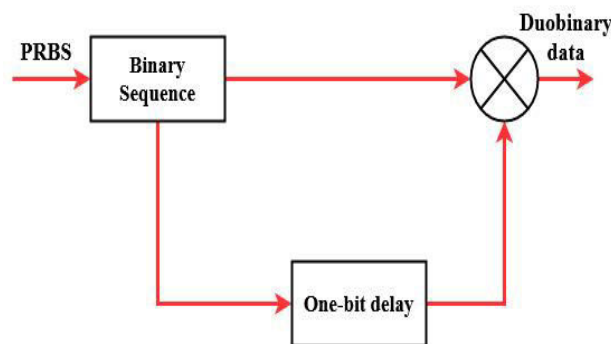


Fig. 2 Basic principle of DB format

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

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

Where T is the pulse width.

IV. PROPOSED MODEL

We propose a model to achieve the aim of this study which is the chromatic dispersion compensation in single mode optical fiber [10]. The proposed model is based on applying DB modulation scheme on 4-stages of cascaded identical AFBGs. Each stage of the proposed model is connected to a standard optical circulator. The input signal enters the first stage and the reflected signal is connected to the input of the second stage, and so on. The reflected signal of the last stage is considered as the output of the cascaded AFBGs [11].

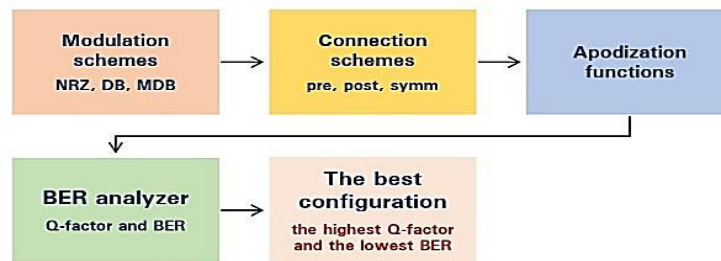


Fig. 3 Proposed model block diagram

V. 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.

AUBG	
Grating length (mm)	5
Wavelength (nm)	1553.6
Effective refractive index	1.45
Induced refractive index	10 ⁻⁴
SSMF	
Reference wavelength (nm)	1553.6
Length (km)	100
Attenuation (dB/km)	0.2
Dispersion (ps/nm.km)	17
WDM link	
Input power (dBm)	0
Bit rate (Gbps)	10
EDFA gain (dB)	40
EDFA noise figure (dB)	4
PIN photodetector responsivity (A/W)	1
PIN photodetector dark current (nA)	30
Bessel filter cutoff frequency	0.75 × bit rate

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

Table 1 Simulation parameters

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.

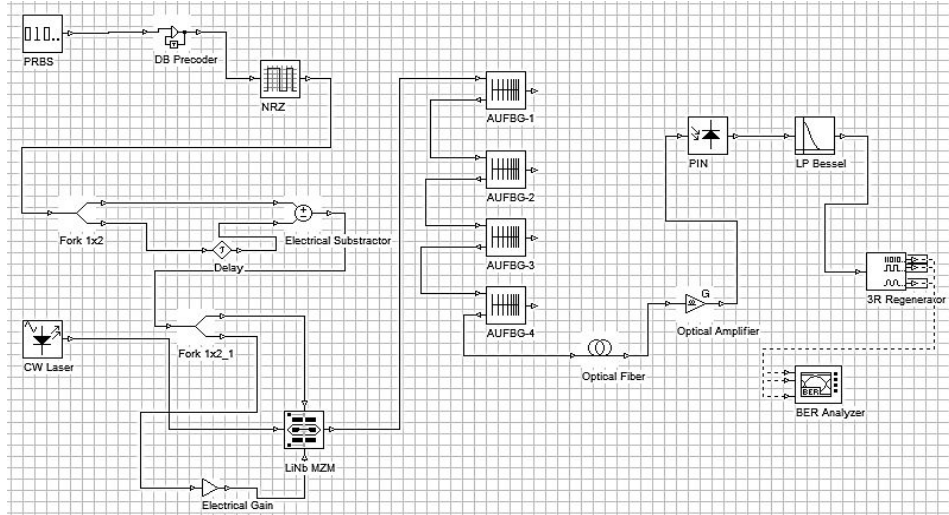


Fig. 5 Pre-compensation scheme.

Figure 6 displays the obtained results of this case.

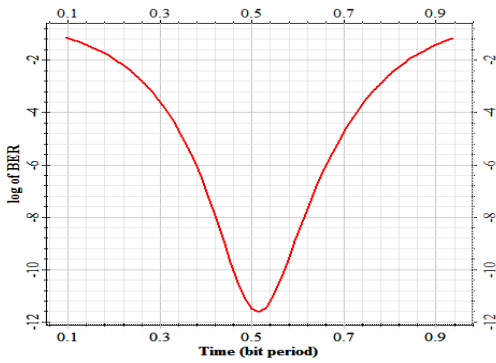


Fig. 6(a) BER of pre-compensation scheme.

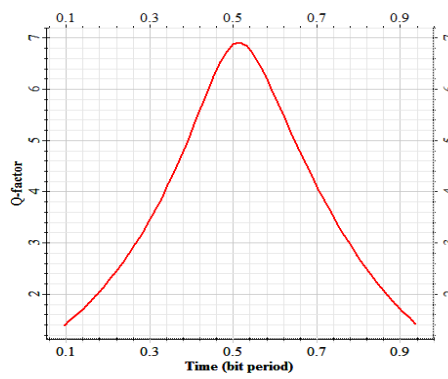


Fig. 6(b) Q-factor of pre-compensation scheme.

The results are exciting the minimum operational criteria with a Q-factor of 8.9 and a BER of 1.4×10^{-12}

B.Post-compensation scheme

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

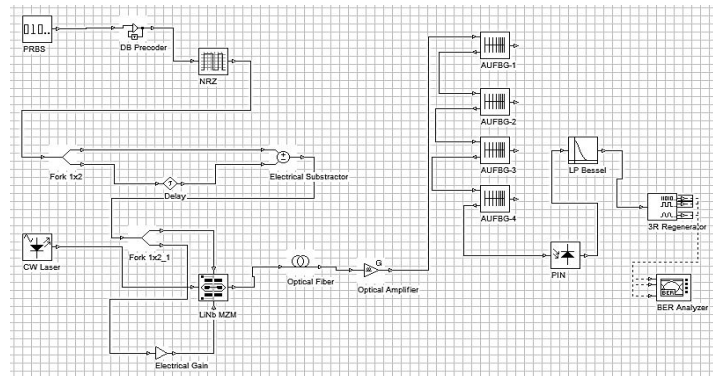


Fig. 7 Post-compensation scheme

C.Symmetrical compensation scheme

The symmetrical compensation scheme is illustrated in Fig 8.

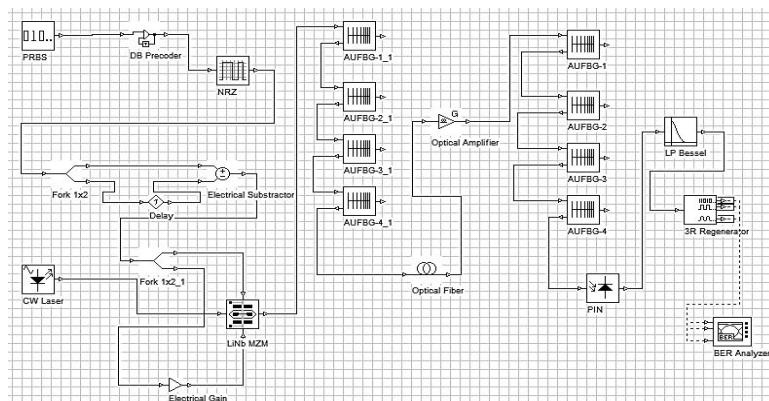


Fig. 8 Symmetrical compensation scheme.

Figure 9 illustrates the results of the symmetrical scheme.

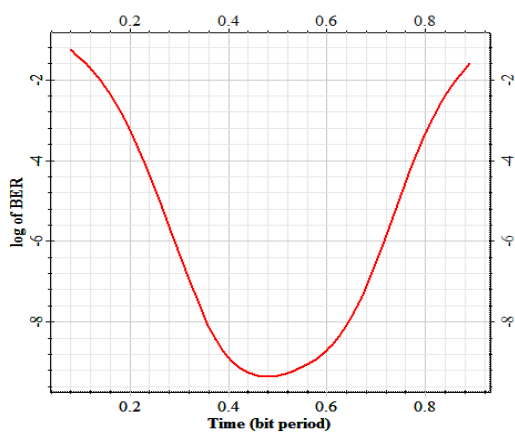


Fig. 9(a) BER of symmetrical scheme.

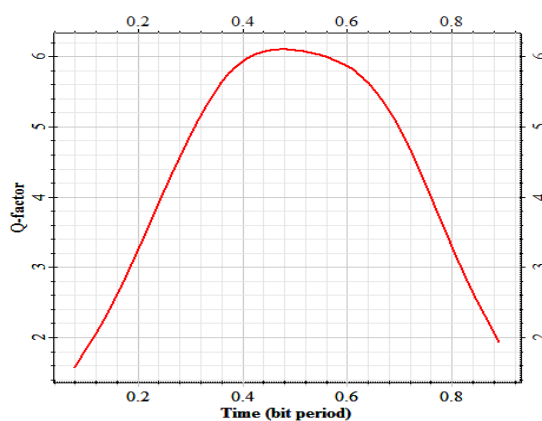


Fig. 9(b) Q-factor of symmetrical scheme.

The scheme achieves acceptable results with a Q-factor of 6.2 and a BER of 8.4×10^{-11} .

D. Summarized results

As mentioned above, all cases in NRZ modulation do not meet the operational requirements and the output signal is totally lost. Also, in MDB modulation the results do not meet the operational requirements but the output signal is not totally lost. We note that all connection schemes in DB modulation meet the operational requirements. It provides the maximum reasonable results in pre connection scheme with tanh apodization function, where Q-factor = 8.964 and BER = 1.3×10^{-19}

TABLE 2 Summarized results of the proposed model

Connection scheme	Apodization function	Q-Factor	BER
	Tanh	6.386	8.44×10^{-11}
	Hamming	2.681	0.00339
	Raised Cosine	2.675	0.00351
	Raised Sine	2.73	0.00303
	Sinc	2.679	0.00343

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 8.9 and a BER of 1.4×10^{-12} . The percentage of improvement in the system performance over the related work is about 99%.

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