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AN IMPROVED APPROACH FOR DISPERSION COMPENSATION BASED ON CHIRPED FBG AND DECISION FEEDBACK EQUALIZER FOR DWDM SYSTEM

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Abstract

Optical fiber is one of the fastest and reliable means of communication because of their high data carrying capacity and less loss in transmission signals. A number of techniques are used in the optical fibers to transmit data from sender to receiver end in an effective way. But the optical signals get degraded while travelling longer distances due to various factors such as dispersion, attenuation etc. that lead to overlapping of optical signals. These parameters directly affect the efficiency of optical fiber in DWDM communication systems. Various techniques such as DCF, FBG etc. were proposed by various researchers to reduce the effect of dispersion in DWDM systems but these systems also had some limitations that need to be addressed. In this paper, a novel technique is presented in which FBG and DFE are combined in order to overcome the dispersion, attenuation and other non-linear factors. Along with this, DRZ modulation technique is applied to enhance the performance of the proposed system in terms of Q-factor, Min BER by varying the channel length (30km to 150km) and input power (0dBm to 20 dBm) of the fiber links. The proposed FBG-DFE model is simulated and analyzed in the Optisystem and results obtained are compared with the traditional DCF-FBG models in terms Q-factor and bit error rate to validate the effectiveness and stability of the proposed approach.

Keywords: Optical communication, BER reduction, FBG, Optical Modulation schemes, Fiber grating, etc.

Introduction

The optical fiber communication is one of the fastest means of communication that changed our day-to-day life in several ways. Optical fiber earned huge success in optical communication technology due to their low loss in transmission [1]. Basically, the main goal of an optical system is to regulate the optical light source. The optical fiber communication system and the microwave system, differ from each other at the frequency range of carrier wave. The frequency range at which the optical fiber carrier operates is around 200 THz. Whereas, the frequency range of the microwave carrier is around 1GHz [2]. The features of the optical fiber transmission can be determined by various factors such as attenuation, dispersion and other non-linear effects [3]. In optical transmission high data rate can be accomplished through pre, post and symmetric DCF compensation techniques along with the MDRZ encoding format and Fiber Bragg Grating (FBG) at the rate of 40 Gbps [4]. But, the ability of the optical fiber system is reduced by dispersion and loss during the transmission.

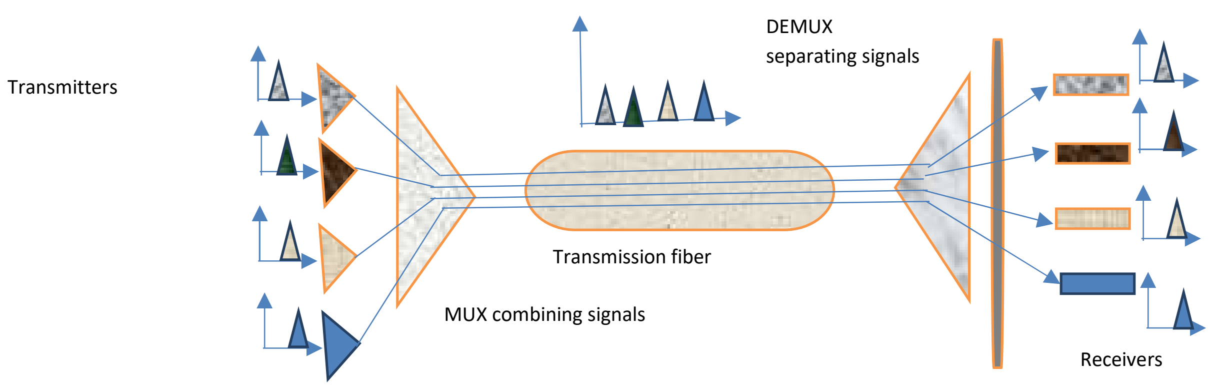

Fig 1.1 Represents the basic Dense wavelength Division multiplexing (DWDM) transmission system

With the help of MDRZ modulation techniques the dispersion in the optical fiber communication can be minimized because the bandwidth of the MDRZ is narrower than duobinary Division multiplexing (DRZ). Another technique called as Dense Wavelength Division Multiplexing (DWDM) is used that can increase the capacity of the optical fiber and decrease dispersion [5].

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There are two ways of enhancing the capability of the system. One is by enhancing the data rate and the other is by enhancing the number of channels [6]. When data rate is enhanced, it may lead to restriction of the electronics used and when number of channels is enhanced, lower channel spacing is required. This results in increase in the non-linear effects, transmission loss and dispersion in DWDM systems [7]. The non-linear effects rise when there is any enhancement in the data rate, power level or channel which lowers the speed, length of link and flexibility of channels in the system [8]. With the help of erbium doped fiber amplifier (EDFA) transmission loss and various non-linear effects may be minimized by operating on appropriate power levels [9]. The Figure 1.2, represents the working principle of EDFA system.

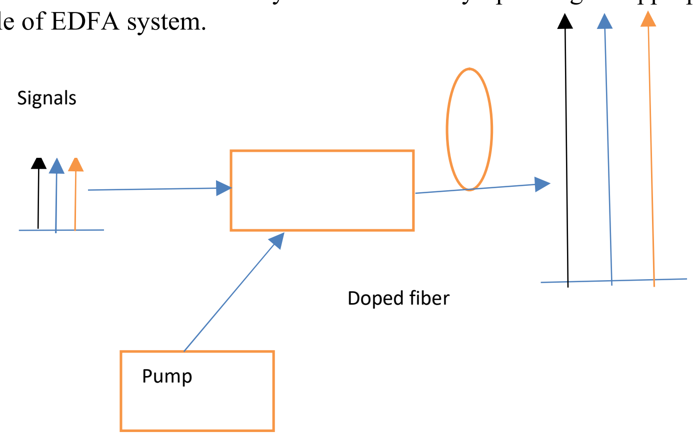
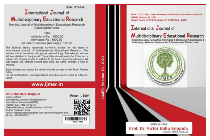


Fig 1.2: Working principle of EDFA system

To resolve the problem of dispersion in the optical fiber communication, number of methods were proposed which are broadly classified into three categories- Pre-distortion compensation that's used at the transmitter end, post-distortion that's used at the receiver end and the inline-compensation that's used in the channel. These methods usually use DCF, EDC, FBG, optical phase conjugation (OPC) and many other techniques [10]. Among all these techniques, Dispersion compensation fiber (DCF) is widely used as its simple, easy to use, authentic and provides easy upgradation to previously deployed fiber links [11]. But there are some drawbacks in DCF as well such as increase in non-linear effects and cost of optical fiber links. Therefore, an alternative approach is needed that can decrease the non-linear effects, cost of fiber links, insertion loss and spatial dimensions [12]. In addition to these functionalities, new features like dispersion tunability should also be addressed. To satisfy the above needs the Fiber Bragg Grating (FBG) and Dispersion compensator (DC) were introduced that is considered as the most flexible and well-developed method [13]. Basically, Fiber Bragg Grating (FBG) comprises of the optical fiber whose refractive index is varying with the direction of propagation. Each and every grating portion represents different wavelength thus producing delays at different times. This process reduces the dispersion as well as narrows the pulse of the fiber communication links and that's the reason why FBGs are mostly used in optical communication fiber links and optical sensors [14]. In addition to this various other method were proposed by various researchers that are described in the next section.

Related Work

A number of researches have been done in order to overcome different problems such as dispersion, non-linear effects etc. in DWDM systems. Among them some of the works are analyzed here: **M.L. Meena, Raj Kumar Gupta, [15],** proposed 8 channels DWDM optical transmission system by utilizing 2 dispersion compensation approaches. **M.L. Meena and Deepika Meena [16**], also proposed a novel model of 4-channel DWDM optical transmission system with dispersion mitigation approaches. The mechanism of dispersion compensation restricts the transmitted signals pulse broadening effect. **V Sathya, et al. [17],** proposed approach focused on dispersion and compensation approaches of it, on the DWDM networks. To overcome the dispersion, different compensation approaches such as FBG, DCF and EDC were used. **Chiranjit Ghosh, Vishnu Priye, [18],** proposed the dispersion compensation approach utilizing least number of CFBGs to transmit the signal of 20Gbps in 24 WDM channels with channel spacing of 0.4 nm. **A. Sangeetha, et al., [19],** demonstrated the usage of Fractionally-Spaced, Symbol-Spaced Decision Feedback Equalizers (FS-DFE, SS-DFE) utilizing LMS (Least Mean Square) algorithm and Highest Probability Sequence Estimator to compensate accrued CD and PMD over 5000 km of maximum distance in 100 Gbps DD-OFDM (Direct Detection Orthogonal Frequency Division Multiplexing) system. **Anu Sheetal, et al., [20],** performed a 40 Gb/s long haul DWDM system with mega high capacity up to 1.28 Tb/s, for CSRZ (carrier-suppressed return-to-zero), duobinary RZ (DRZ) and modified DRZ (MDRZ) modulation formats. **FadilPaloi, et al., [21],** used the standard SMF and DCF in which DCF has been utilized as loss compensator in RoF (Radio-Over-Fibre) systems. The integration of pre, post and symmetrical fiber reparation approaches was done so that dispersion in a fiber can overcome. **T.Sabapathi, R. Gowri**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Manohari [22], presented the Deterministic Differential Group Delay (DDGD) approach to overcome PMD in single channel, and wavelength independent PMF (Polarization Maintaining Fiber) approach for PMD compensation in multichannel. **Simranjit Singh, R.S. Kaler, [23],** examined the pre-, post-, symmetrical dispersion and power compensation for 96 channels × 10 Gbps NRZ DWDM system utilizing pumped DCF (PDCF) and pumped SMF (PSMF). **Haoran Cheng, et al. [24],** introduced the fiber nonlinear effects in high speed DWDM systems by implementing time–space duality theory- based fractional Fourier transform (FRFT). Prior to being implemented in fiber links, the pre-distortion of modulated optical pulses was performed by an FRFT module.

From the literature survey conducted, it is analyzed that currently DWDM systems provide an increasing data carrying ability and are efficient in utilizing the fiber networks as well. The transmission in the optical DWDM systems mainly gets affected when the different wavelength signals overlap each other while travelling longer distances. This causes the broadening of pulse that causes dispersion and losses in transmitted signals which lead to an error signal at receiver end. To overcome the dispersion issue, number of techniques was proposed. Among these techniques linear Chirped Fiber Bragg Grating (CFBG) and dispersion compensation fiber (DCF) schemes having EDFA amplifier were considered as efficient in order to overcome the dispersion in DWDM systems. However, it consists of various limitations such as use of simple RZ modulation format, dispersion compensation fiber etc. due to which it become inefficient and need to be improved. Hence, it became compulsory to update the existing system in order to eliminate the above-mentioned limitations. Inspired from these findings the proposed model in this paper is proposed to overcome the dispersion problem in DWDM systems. The detailed description of the proposed model is given in the next section.

Proposed Work

In order to address various limitations such as high cost, complexity etc. in the traditional systems, a hybrid approach based on chirped Fiber Bragg grating (CFBG) and Decision Feedback Equalizer (DFE) is proposed. In the proposed approach DFE is used instead of DCF because DFE is cost-effective as well as less complex. Furthermore, in traditional systems less numbers of users were considered which is not sufficient enough according to increasing demand. This issue is also addressed in the proposed system in which the number of users is increased so that it can meet the increasing demand. Moreover, the conventional system was designed using simple RZ modulation format which consists of various drawbacks that leads to inefficient results. Therefore, in order to increase the efficiency of the proposed model DRZ modulation technique which inherits some advanced features of the CSRZ and DPSK modulation techniques is applied. Every mark in DRZ signals has a 180-degree phase shift from its nearest mark. This feature significantly reduces inter-symbol interference and thus overcomes the elevation of an isolated zero level occurring in CSRZ signals, providing better dispersion tolerance. Furthermore, to make the DRZ signals more resilient to the non-linear effects, complete carrier suppression along with the additional suppression of side peaks is used in the spectra. In addition to this, only one Mach-Zehnder (MZ) modulator is used to generate DRZ signals. This not only lowers the cost but also reduces the complexity and improves the reliability of a DRZ transmitter, hence improving performance of an optical fiber communication system. All these advantages make DRZ one of the most cost-effective solutions for high-capacity long-haul transmission.

Simulation setup

The proposed model is simulated and tested in the Optisystem software with different parameters and modules along with their specific values which are mentioned in the Table 1 below:

Table 1: Simulation factors with details of used components and their values

Sr. No.	Components	Values
1	Input Data rate	10Gbps
2	Line coder type	DRZ
3	CW Laser Power	10 dBm
4	Mach-Zehnder Modulator (Extinction ratio)	50 dB
5	SMF length	30-150 km
6	EDFA Gain	25 db
7	FBG frequency	193.1 THz
8	Receiver	Photo detector
9	Equalizer type	Electronic
10	Low Pass Filter type	Gaussian filter

The main contribution of the proposed scheme is that it utilized DRZ scheme in place of traditional RZ. As the system designed is for WDM, there are number of transmitter modules followed by the multiplexer. Each transmitter in the proposed model is

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utilizing the concept of DRZ modulation in which signals are generated, boosted by a sine wave generator and modulated by MZ modulator with CW laser having frequency of 193.1 THz as shown in figure 1.3. Then the boosted and modulated signals are transmitted through DWDM multiplexer. Once the signal is multiplexed, single mode fiber is used to transmit the signal. At the receiver end, EDFA amplifier is used to amplify the received signals in order to maintain and boost its amplification. As the main objective of the proposed scheme is to compensate the dispersion, after amplification Fiber Bragg Grating (FBG) is utilized. The role of FBG is that it reflects only single wavelength for compensating the dispersion. Furthermore, a DWDM demultiplexer is used at the receiver end in order to split the optical signal into different channels. The output of the de-multiplexer is given to pin photo detector followed by low pass Gaussian filter. In addition to this, a Decision feedback Equalizer (DFE) is used to equalize the frequency notches by pole insertion. For performance analysis dual port WDM analyzer and eye diagram analyzer is used in the proposed DWDM system. The performance of the proposed system is analyzed and compared with the traditional RZ and DCF techniques under different parameters which are described in the next section.

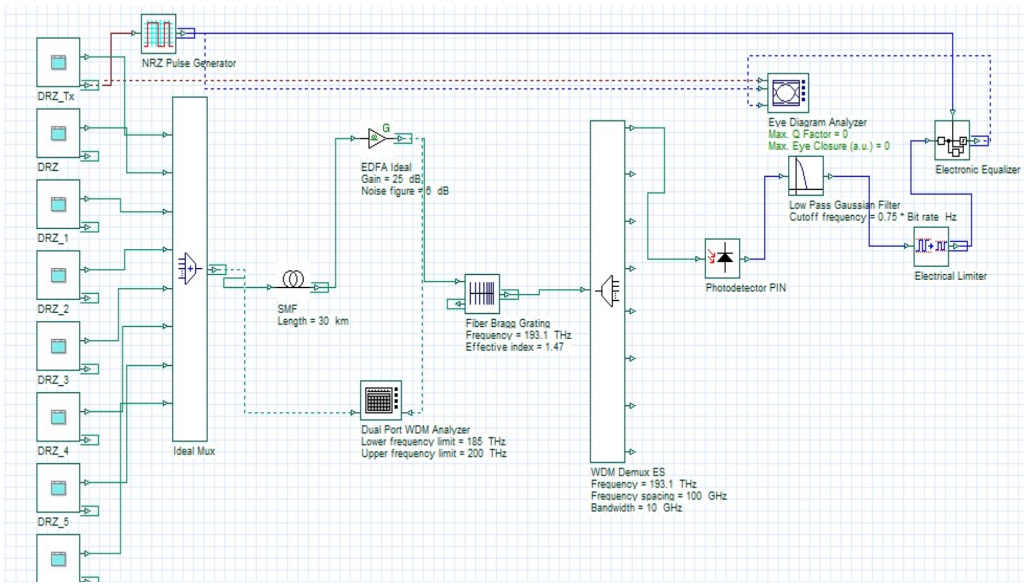


Fig 1.3 Proposed simulated WDM system

Results and Discussion

The proposed advanced DWDM system for reducing dispersion in the optical signals is tested and analyzed in the optisystem software in terms of Q-factor and Min Ber by varying length and power of optical fiber links. The simulation results are then analyzed and compared with the traditional methods and are discussed in this section.

Performance evaluation

The performance of the proposed DWDM system is analyzed in terms of the Q-factor by varying the length of the fiber from 30km to 150Km. Figure 1.4 represents the effect on Q-factor by changing the fiber length. The graph has two curves one is given by blue color which represents the Q-factor of the proposed FBG-DEF system while aso range color represents the traditional DCF-FBG approach. From the graph, it is observed that with the increase in fiber length, Q-factor is reducing in the proposed system FBG-DEF system while the Q-factor is increasing in the traditional DCF-FBG system with the increase in the fiber length.

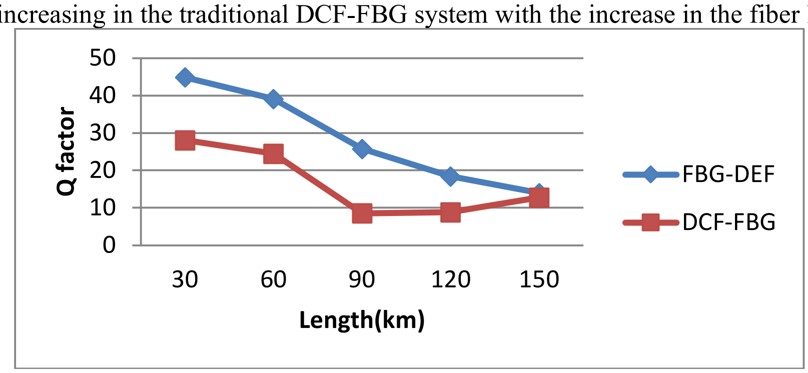
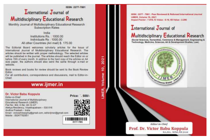


Fig 1.4: Comparison of Q-factor for varying fiber length



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The simulation results show that the value of Q-factor of the proposed model at 30Km fiber length is 44.92 while as it was 28.11 for traditional model. Similarly, when the length is changed to 60, 90, 120 and 150 the Q-factor achieved are 39.09, 25.79, 18.42 and 13.98 for proposed FBG-DEF system and 24.46, 8.57, 8.83 and 12.74 for traditional system respectively.

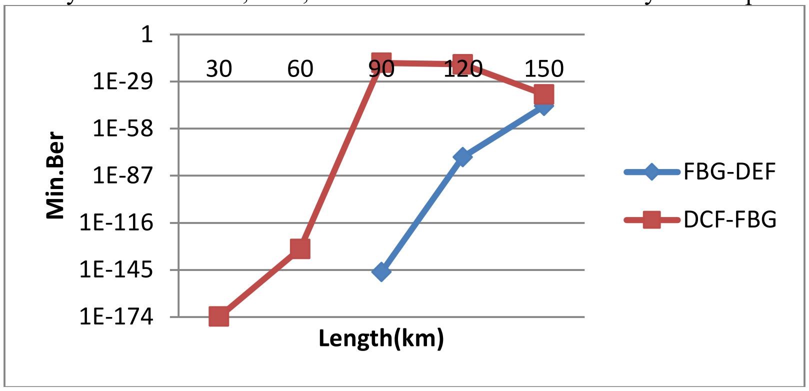

Fig 1.5: Comparison of Min. BER for varying fiber length

The performance of the proposed FBG-DEF system was further analyzed in terms of the MinBer value while varying the fiber length as shown in figure 1.5. The blue line represents performance of the proposed model while as the orange line represents the performance of the traditional system. The values of Min. BER at 30, 60, 90, 120 and 150 Km of fiber length of proposed scheme are 0, 0, 5.38E-147, 3.81E-76 and 1.00E-44, where as in traditional system these were 2.09E-174, 9.14E-133, 3.80E-18, 4.18E-19 and 1.63E-37 respectively.

In addition to this, the performance of the proposed FBG-DEF systems is analyzed in terms of Q-factor and Min. Ber by varying the input power.

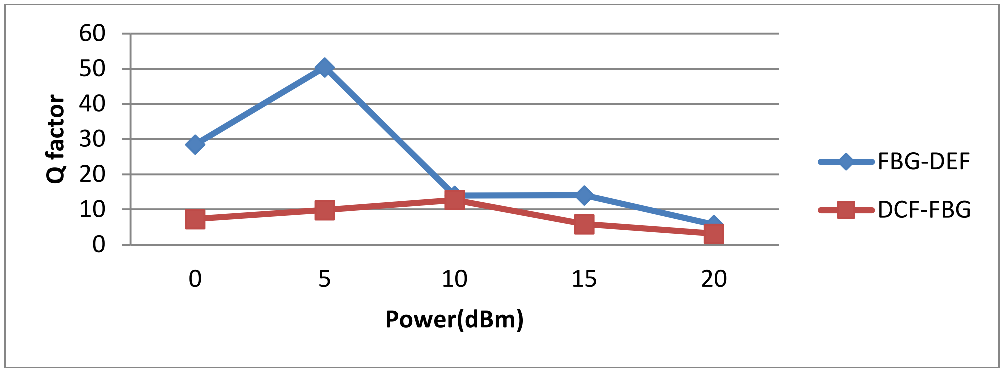

Fig 1.6: Comparison of Q-factor for varying Power (dBm)

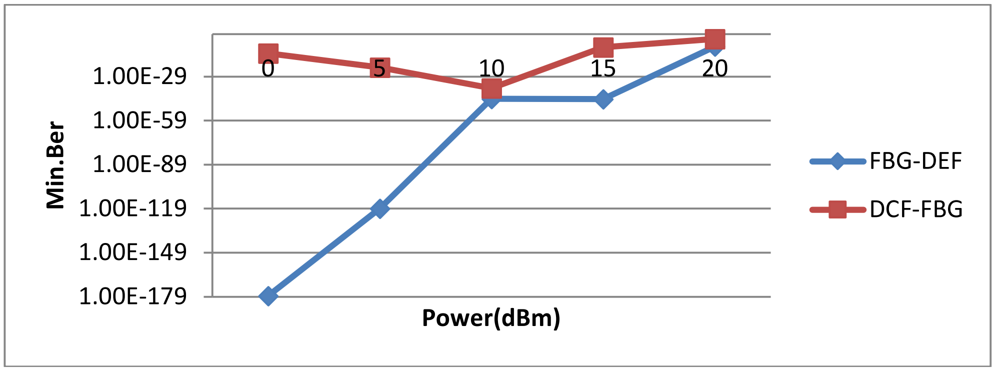

Fig 1.7: Comparison of Min. BER for varying Power (dBm)

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Figure 1.6 represents the effect of increasing input power on Q-factor in proposed and traditional schemes. The Input power is in dBm and its values are varying from 0 dBm to 20 dBm, and the Q-factor of proposed scheme which is represented through blue color line are 28.51, 50.46, 13.98, 14.01 and 5.71 at 0, 5, 10, 15 and 20 dBm power respectively while as in traditional approach (orange line) the value of the Q-factor at 0, 5, 10, 15 and 20 dBm are 7.32, 9.89, 12.74, 5.88 and 3.17 respectively. As the values of Q-factor are more in the proposed scheme this represents that the proposed scheme is better even after changing the input power.

Figure 1.7 depicts the min. BER of proposed scheme (blue line) and orange line depicts the Min. Ber of the traditional approach. The value of Ber at input Power of 0, 5, 10, 15 and 20 dBm are 3.95E-179, 1.25E-119, 1.00E-44, 6.04E-45 and 4.91E-09 respectively for proposed scheme while as the value of Ber at 0, 5, 10, 15 and 20 dBm are 8.16E-14, 1.93E-23, 1.63E-37, 1.35E-09 and 6.00E-04 respectively in traditional model. From the graph it is observed that the values are almost negligible and near to zero in proposed FBG-DEF model, which shows that the proposed scheme is capable to provide better signal at receiver end with least error.

Conclusion

Optical fiber communication is considered as one of the fastest means of communication due to their low losses and huge data carrying capacity in transmissions. But, the ability of the optical fiber system is reduced by various factors such as dispersion, attenuation, non-linear effects etc. which directly effects the efficiency and effectiveness of the optical fiber systems. In order to remove dispersion and other effecting parameters from the optical signal a number of modulation techniques such as DRZ, MDRZ, DWDM etc. were already proposed by various researchers. The problem with the existing models was that these models were not efficient enough and used simple modulation techniques. To overcome the limitations of the existing methods, a technique is implemented that is based on the FBG and DRZ strategies with an electrical equalization and EDFA amplification technique to reduce dispersion from the optical signals. The proposed FBG-DFE model was simulated and analyzed in the Opti-system software in terms of Q-factor and Bit Error Rate (BER) by varying channel length (km) and input power (dBm) of optical fiber links. The simulation results of the proposed FBG-DFE model are then compared with the traditional DCF-FBG model and it was analyzed that the proposed model outperformed the conventional DCF-FBG model in terms of Q-factor and BER values. Hence, the proposed FBG-DFE model comes out to be efficient and reliable when compared to the traditional models.

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