Engineering and Technology Journal Vol. 36, Part A, No. 5, 2018

DOI: http://dx.doi.org/10.30684/etj.36.5A.6

Hussein A. Mahmood

Department of communications Engineering, College of Engineering, University of Diyala, Diyala, Iraq
hussein.ahmed8282@gmail.com

Received on: 30/04/2017
Accepted on: 20/07/2017

DCF with FBG for Dispersion Compensation in Optical Fiber Link at Various Bit Rates using Duobinary Modulation Format

Abstract- *Dispersion is one of the very important parameters that effect on the performance of optical fiber communication systems. It causes pulse broadening, limiting of transmission distance and the number of channels on optical fiber link and low Bit rate. Dispersion compensation fiber (DCF) based on Fiber Bragg Grating (FBG) is widespread used in the dispersion compensation scheme. In this work, the proposed dispersion compensation fiber is included (pre – post–symmetrical) schemes with Fiber Bragg Grating and duo-binary modulation format. These are at various bit rates (10 Gbit/s, 20 Gbit/s, 30 Gbit/s and 40 Gbit/s) and different input laser power from (0 dBm to 10 dBm) for 200 Km distance. Optisystem software version 10 is used to design simulation model. Q- factor and BER are two parameters which used to evaluate the performance analysis of the system, we concluded that, the symmetrical compensation techniques is better than others compensation schemes when the Q factor is 52.977 and bit rate is equal 0, these at 10 Gbit/s and 10 dBm transmitted power.*

Keywords- *Dispersion compensation fiber, Fiber Bragg Grating, duo-binary modulation, Bit Error Rate, Q- factor.*

How to cite this article: H.A. Mahmood, "DCF with FBG for Dispersion Compensation in Optical Fiber Link at Various Bit Rates using Duobinary Modulation Format," *Engineering and Technology Journal*, Vol. 36, Part A, No. 5, pp. 514-519, 2018.

1. Introduction

First of all, Optical fiber communication systems are used to transmit information with a form of optical signal through an optical fiber by using high carrier frequency to another point [1]. The light signal is used as an electromagnetic carrier wave through the fiber optic communication system that is employed the optical fiber for information transmission. The signal is modulated to transfer the information from the source to destination [2]. Generally, the fiber-optic construction involve three main parts in optical fiber communication systems, which are light source that converts electrical signal into corresponding optical signal, optical fiber which is a section as a transmission medium and the last unit is light detector that converts the optical signal into electrical signal at the receiver part [3]. Chromatic dispersion is an occurrence can be minimized by two techniques first is by reducing the line width of laser and operating near to zero dispersion wave length in fiber-optics [4]. The chromatic dispersion is made for the purpose of dependency of the group refractive index on wavelength. As a result, it created a time expansion in propagated signals travelling at various velocities through optical fiber [5]. The chromatic dispersion (D) is measured in ps / nm.km and can be calculated by [6]

$$D = \frac{d}{d\lambda}\left(\frac{1}{v_g}\right) = -\frac{2\pi c}{\lambda^2}\beta_2 \qquad (1)$$

Where: (λ) is the operative wavelength, (vg) is the group velocity, (c) is the velocity of optical signal and (β_2) is the group velocity dispersion (GVD) according to the equation:-

$$\beta_2 = \frac{d^2\beta}{d\omega^2} \qquad (2)$$

Where: (ω) is the angular frequency [7]. Recently, many techniques are used for compensated dispersion in optical fiber communication systems generally defined: dispersion compensation fiber, fiber Bragg grating, imaged phased array and planar waveguide technology [8]. Dispersion compensating fiber (DCF) is a simple and efficient method to make efficient installed links of single mode fiber. It has negative group velocity dispersion from (-70) to (-90) ps/nm.km. This is used to compensate dispersion connected with a standard single mode fiber, which shows positive group velocity dispersion at the laser wavelength source of 1.55 μm. Then the optical light signal is broadened through moved inside the fiber-optic and compressed in the telecommunication fiber [9].

$$D_1L_1 + D_2L_2 = 0 \quad (3)$$

Where: D_1 and L_1 are dispersion and length of single mode fiber SMF, D_2 and L_2 are dispersion and length of dispersion compensation fiber DCF [10]. In addition to used DCF, the FBG periodic structure is consummate to compensate group velocity dispersion at many differences of the wavelength. Therefore, FBG has the priority-favored solution for group velocity dispersion [7]. FBG is a dynamic dispersion compensator lengthways of the fiber reflective index outline differs linearly with regard to the method of area writing on the fiber core. The grating assembly reflected the incident wavelength signals reliant upon the Bragg wavelength [11]. According to the grating period and the actual refractive index, the optical light reflection wavelength will spread a greater distance inside the fiber Bragg grating before the light is reflected [12]. Due to the same reason, the smaller light wavelength will propagate a shorter distance inside the grating before reflection. Therefore, the light broadening because of the group velocity dispersion in standard single mode fiber is compacted by travelling signal inside Fiber Bragg Grating [13]. Where, this is the basic features of Fiber Bragg Gratings. The reflected wavelength (λ_B) that is specified as the Bragg wavelength, which is assumed by the mathematical definition:

$$\lambda_B = 2n_{eff}\Lambda \quad (4)$$

Where: n is the effective refractive index that has the influence of the directed mode in the core's fiber, and Λ is the grating length area. This mathematical relationship is represented the finishing appearance of the optical signal to be reflected through a Fiber Bragg Grating [14]. The performance analyzed optical communications systems are effect respect to optical modulation techniques [15]. In addition to the configurations transmission setups of NRZ and RZ, other different modulation techniques are explored to enhancement performance analysis systems [16]. Figure 1 is shown the configuration of Duobinary transmitter. Its signal is generated by based of a NRZ from Duobinary pre coder [17]. In addition, the method is easy to generate, design and implement because of its low ghostly line width and high allowance to chromatic dispersion to enhance spatial efficiency and to decrease the sensitivity to nonlinear effects [18]. In this work, the simulation of performance analysis Duobinary modulation format with high-speed data rate (10 Gbit/s, 20 Gbit/s, 30 Gbit/s and 40 Gbit/s), these are at different input laser power from (1 dBm to 10 dBm) are used to transmit data rate. Three dispersion compensation fiber models namely, pre, post and symmetrical with Fiber Bragg Grating in a 200 km distance optical fiber link. The simulation result is analyzed according to parameters Q-factor and BER for each and every case. In section 2 simulation setup is shown for three schemes. In section 3 the simulation results are shown for all cases. In section 4 ultimate observation our work is given.

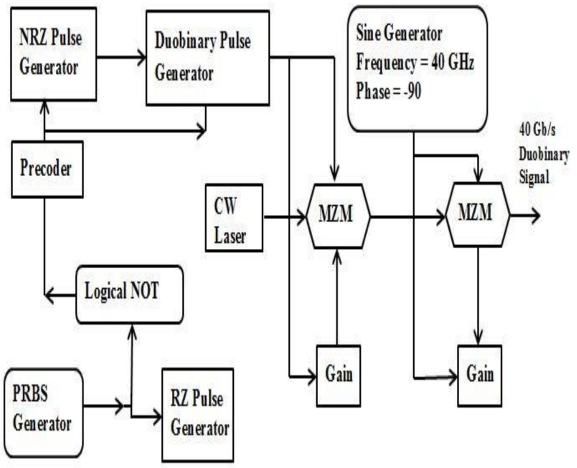


Figure 1: Block diagram of duo-binary transmitter

2. Simulation Setup

The Simulation parameters are listed in Table 1. The proposed system is involved of a transmitter section, optical fiber channel and optical receiver section as shown in Figure 2. This system is simulated and designed using "OPTISYSTEM 10" software. The transmitter is involved of a PRBS generator, CW laser and duo-binary data modulator. The PRBS is used to generate pseudo bit sequences at the various bit rates (10 Gbit/s, 20 Gbit/s, 30 Gbit/s and 40 Gbit/s). The emission frequency of CW laser is 193.1 THz and different power from (1 dBm to 10 dBm). The extermination value of MZM is used at 30 dB. The optical signal is entered to optical channel. The fiber parameters are indicated in Table 2. FBG parameters are listed in Table 3. Three different types of dispersion compensation techniques (pre, post and symmetrical) are proposed and analyzed excluded DCF with FBG in optical fiber link. Optical amplifier (10 dB) with noise figure of (6 dB) is joined after (DCF) and (20 dB) joined after (SMF), their gain used to compensate fiber losses. Figure 2(a) shows the pre compensation scheme where a (DCF) of 20 km is used before (SMF) of 200 km distance, these with FBG to compensated dispersion. Figure 2(b) shows the post compensation scheme where a (DCF) of 20 km is used after (SMF) of 200 km distance. Figure 2(c) is shown the symmetrical compensation scheme, 20 km (DCF) used between the (SMF) of 100 km.

The receiver involves of two parts, the first part is PIN photo detector to convert optical signal to electrical signal and the other is Bessel low pass filter. The optical signal is detected through PIN photodiode whose operating wavelength is 1550 nm, responsively [A/W] equals one and dark current is 0.1 nA. The BER analyzer is joined after the filter to show graphs and analysis the values of Q- factor, min BER and eye diagram.

Table .1: Simulation Parameters

Parameters	Value
Bit rate G bit/s	10,20,30 and 40
Sequence length	64
Samples / bit	256
Central frequency (THz)	193.1

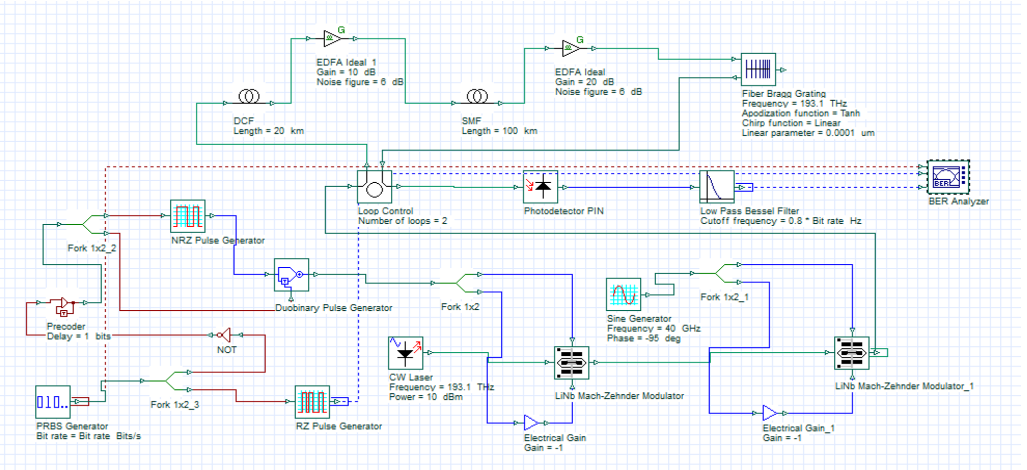
\

Table .2: Fiber Parameters

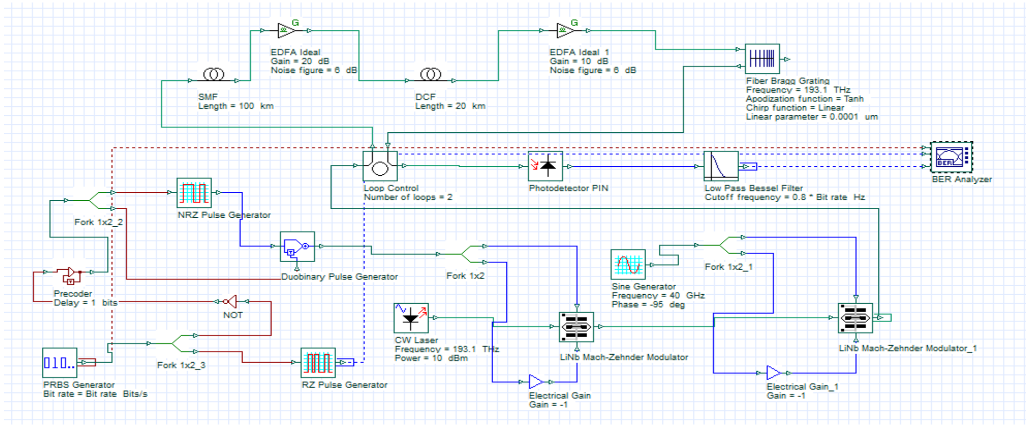
Parameters	Single Mode Fiber	Dispersion Compensation Fiber
Length (km)	200	20
Dispersion (ps/nm/km)	17	-85
Dispersion slope (ps/nm^2/km)	0.075	-0.3
Attenuation	0.2	0.6

Table .3: FBG parameters

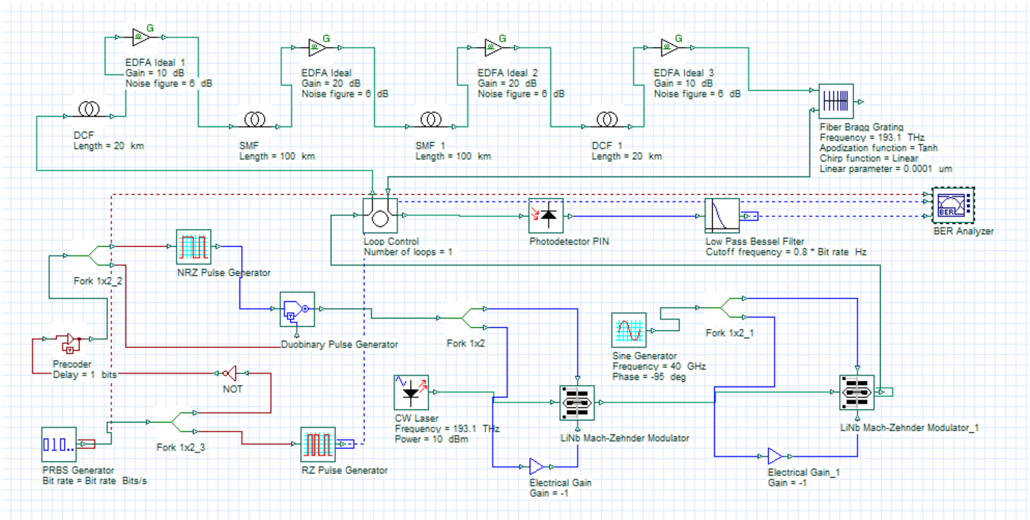
parameters	Value
Frequency (THz)	193.1
Length of grating (mm)	2
Apodization function	Tanh
Chirp function	Linear



(a) pre scheme



(b) post scheme



(c) symmetrical scheme

Figure 2: The simulation setup: (a) pre compensation scheme, (b) post compensation scheme, (c) symmetrical compensation scheme

3. Results

The design simulation is analyzed by operated three different dispersion compensation techniques (pre, post and symmetrical). The schemes have been duo-binary modulation analyzed at various Bit rates (10 Gbit/s, 20Gbit/s, 30Gbit/s and 40Gbit/s) with different laser input power from (1 dBm to 10 dBm). The results are analyzed and compared in relations of Q factor and BER. Figure 3 shown the effect of transmission power with respect to Q factor for pre-compensation scheme at various Bit rate, the maximum value of Q factor is 18.7203 at 10 dBm transmission power and 10 Gbit/s Bit rate. Figure 4 is shown the effect of transmission power with respect to BER factor. Pre-compensation scheme at various bit rates. The BER factor is 1.0809e^{-078} at 10 dBm transmission power and 10 Gbit/s Bit rate. Figure 5 is shown the effect of transmission power with respect to Q factor for post-compensation scheme at various bit rates, the maximum value of Q factor is 17.4177 at 10 dBm transmission power and 10 Gbit/s bit rate. Figure 6 is shown the effect of transmission power with respect to BER factor for post-compensation scheme at various bit rates, the BER factor is 1.08002e^{-068} at 10 dBm transmission power and 10 Gbit/s bit rate. Figure 7 is shown the effect of transmission power with respect to Q factor for symmetrical-compensation scheme at various bit rates. The maximum value of Q factor is 52.977 at 10 dBm transmission power and 10 Gbit/s Bit rate. Figure 8 is shown the effect of transmission power with respect to BER factor for symmetrical-compensation scheme at various bit rates, the BER factor is 0 at 10 dBm transmission power and 10 Gbit/s bit rate.

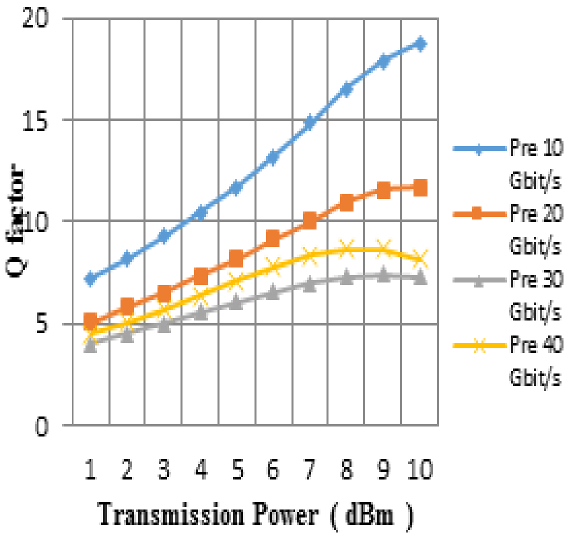


Figure 3: Comparison of transmission power vs Q-factor influence of various Bit rates for pre- scheme

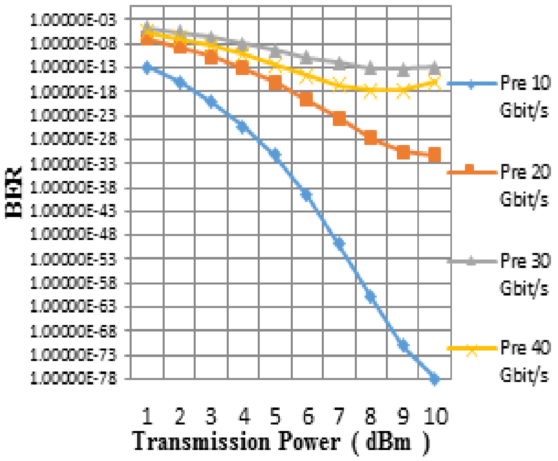


Figure 4: Comparison of transmission power vs BER influence of various Bit rates for pre- scheme

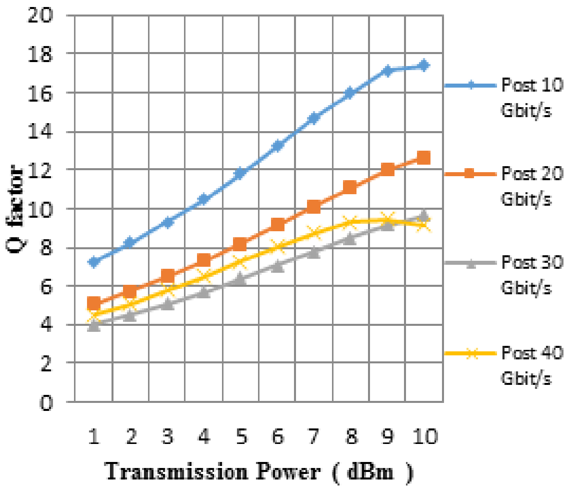


Figure 5: Comparison of transmission power vs Q-factor influence of various Bit rates for post- scheme

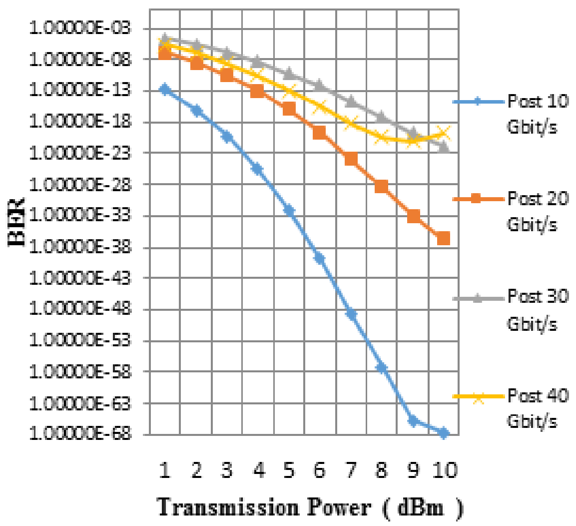


Figure 6: Comparison of transmission power vs BER influence of various Bit rates for post- scheme

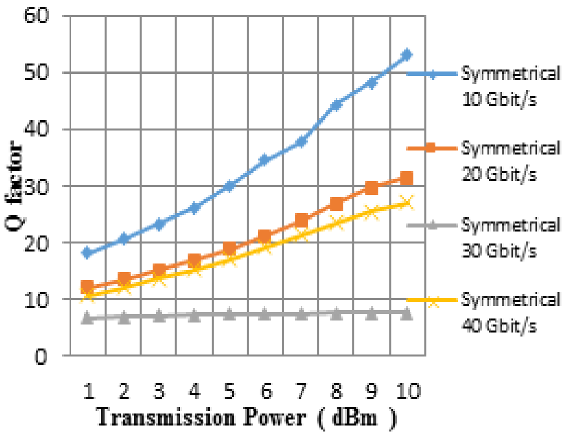


Figure 7: Comparison of transmission power vs Q-factor influence of various Bit rates for symmetrical- scheme

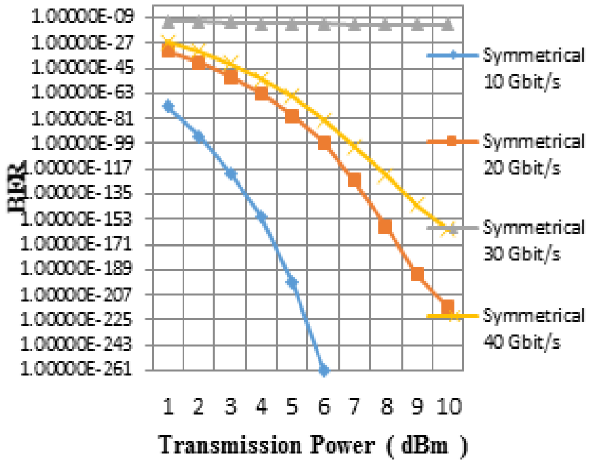


Figure 8: Comparison of transmission power vs BER influence of various Bit rates for symmetrical- scheme

4. Conclusion

In this work, performance is analyzed at three dispersion compensation schemes (pre-, post-and symmetrical) by using dispersion compensation fiber (DCF) with fiber Bragg grating (FBG) are elaborated. The results are analyzed and compared used the Q factor and BER parameters. We concluded that the Q factor is decreased with increase the bit rate and then is increased with the increasing of transmission power. Moreover, the symmetrical compensation technique is shown a better performance in compare to others schemes at high transmission power and low Bit rate.

References

[1] D. Dey, and Neha, “Compensation in Optical Fiber WDM System Using Different Compensation Techniques,” International Journal of Advanced Research in Computer Science and Software Engineering, Vol. 4, no5, May 2014.

[2] R. Mishra, N.K. Shukla, and C.K. Dwivedi, “A Comparative Performance Analysis of Optical Fiber System with FBG Compensated SMF for High Data Rate,” Imperial Journal of Interdisciplinary Research, Vol.2, no7, 2016.

[3] M. Kaur, and H. Sarangal, “Simulation of Optical Transmission System to Compensate Dispersion Using Chirped Fiber Bragg Grating (FBG),” International Journal of Advanced Research in Computer and Communication Engineering, Vol. 4, no2, February 2015.

[4] S.O. Mohammadi, S. Mozaffari, and M.M. Shahidi, “Simulation of a transmission system to compensate dispersion in an optical fiber by chirp gratings,” International Journal of the Physical Sciences, Vol. 6(32), pp. 7354 - 7360, 2 December 2011.

[5] Neha, and R.L. Sharma, “Performance Analysis of 8-Channel WDM System using Symmetrical DCF and Optigrating,” International Journal of New Trends in Electronics and Communication, Vol. 2, no4, June 2014.

[6] G.P. Agrawal, “Fiber Optics Communication Systems,” 3rd Ed. Wiley & Sons, Inc. 2002

[7] G. Gnanagurunathan, and F.A. Rahman, “Comparing FBG and DCF as dispersion compensators in the long haul narrowband WDM systems,” IEEE, 2006.

[8] Y. Zhou, Y. Shao, Z. Wang, C. Li, J. Zhou, and W. Ma, “Research on Dispersion Compensation of 40 GB/s Optical Duo-Binary Coded Transmission System,” Optics and Photonics Journal, Vol. 6, pp. 190 - 195, August 2016.

[9] G. Singh, J. Saxena, and G. Kaur, “Dispersion Compensation Using FBG and DCF in 120 Gbps WDM System,” International Journal of Engineering Science and Innovative Technology (IJESIT), Vol.3, no 6, November 2014.

[10] G.P. Agrawal. “Nonlinear Fiber Optics,” 4th Ed. Elsevier, Inc. 2007.

[11] B. Prasad, B. Mallick, and A.K. Parida, “Fiber Bragg Grating as a Dispersion Compensator in an Optical Transmission System Using Optisystem Software,” International Research Journal of Engineering and Technology, Vol.2, no 6, September 2014.

[12] A. Bhardwaj, and G. Soni, “Performance Analysis of 20 Gbps Optical Transmission System Using Fiber Bragg Grating,” International Journal of Scientific and Research Publications, Vol. 5, no 1, January 2015.

[13] P. Singh, “DISPERSION COMPENSATION IN AN OPTICAL FIBER BY USING CHIRP GRATINGS,” International Journal of Research in Engineering and Technology, Vol.3, no 7, July 2014.

[14] M. Singh, and R.B., “Analysis of Dispersion Compensation using Fiber Bragg Grating in Optical Fiber Communication System,” International Journal of Computer Applications, Vol. 126, no.5, September 2015.

[15] Sarita, S. Vishwakarma, and M. Dutta, “Different Type Modulation Technique for Fiber Transmission,” International Journal of Engineering Science and Computing, Vol. 6, no 8, August 2016.

[16] N. Pandey, A. Lavingia, and K. Lavingia, “ANALYZING THE PERFORMANCE OF OPTICAL SYSTEM USING DIFFERENT MODULATION TECHNIQUES,” International Journal of Advance Engineering and Research Development, Vol. 2, no 12, December 2015.

[17] L. Sharan, and V.K. Chaubey, “Design and Simulation of Long-Haul 32 x 40 Gb/s Duobinary DWDM Link in the Presence of Non-Linearity with Under-compensated Dispersion,” 3rd International Conference on Photonics 2012, Penang, 1-3 October 2012.

[18] W. Kaiser, T. Wuth, M. Wichers, and W. Rosenkranz, “Reduced Complexity Optical Duobinary 10Gb/s Transmitter Setup Resulting in an Increased Transmission Distance,” IEEE Photonics Technology Letters, August 2001.

Author biography

Hussein Ahmed Mahmood. M.Sc. in Communication Engineering, Kazan National Research Technical University, Kazan, Russia. B.Sc. in Laser Engineering, Al- Rasheed College of Engineering and Science, University of Technology, Baghdad, Iraq.