Diyala Journal of Engineering Sciences

ISSN 1999-8716
Printed in Iraq

Vol. 10, No. 02, pp. 94-106, June 2017

PERFORMANCE EVALUATION OF HIGH DATA RATE OPTICAL COMMUNICATION SYSTEM UTILIZING FBG COMPENSATED DISPERSION SCHEMES UNDER DIFFERENT MODULATION TECHNIQUES

Riyadh Khlf Ahmed [1], Hussein Ahmed Mahmood [2]
[1] Lecturer, [2] Assistant Lecturer,
Department of Communications Engineering, College of Engineering, University of Diyala,
Email: riyadhkhlf@gmail.com
(Received: 6/3/2017; Accepted: 30/4/2017)

ABSTRACT: - In this paper, comparative study of three dispersion compensation fiber models, namely, pre, post and symmetrical involving ideal dispersion compensation fiber Bragg grating for three different modulation schemes in 40 Gb/s single channel optical fiber transmission system are performance evaluated. Three modulation schemes, different namely, duo-binary coding, modified duo-binary and carrier suppressed return to zero are simulated and analyzed in terms of Q-factor and bit error rate for each set up by range of CW laser power. The simulation of optical system based on optisystem-10.The result report that the symmetrical with ideal FBG at duo-binary coding depicts good performance for increasing the input power from-5 dBm to 10 dBm. It is clear that best Q value obtained is 28.24 dB for BER of 5.9 $\times 10^{-176}$ at input power of 5 dBm using symmetrical compensation cascaded with ideal FBG for duo-binary modulation scheme.
***Key words**: Dispersion compensation, fiber Bragg grating, duo-binary modulation.*

INTRODUCTION

In the last twenty years, the field of optical communication witnessed dramatic developments as result to the large efforts which have been made to improve the characteristics of optical communication channel [1]. The main advantages of the optical transmission media such as wide bandwidth, high bit rate with large channel capacity made it most favorable delivering transmission media [2, 3]. The light signal is transmitted from the source to the destination over optical fiber communication channel. Through the transmission of light signal from the transmitter to the receiver, various frequencies or modes are transmitted at Different Group Velocity Dispersion (GVD). The reason behind the GVD is that the refractive index of the class will be changed slightly with respect to the change of frequency of the light. At the receiving side, the receiver will receive these modes at different times. Group Velocity Dispersion can be specified from the pulse width measurements through the propagation of signal inside the material of the optical fiber. Dispersion and losses are restricting factors for modern optical communication technology. Losses of fiber can be solved using optical amplifier such as erbium doped fiber amplifier. The second problem still accumulates over multiple stages of amplifiers as a consequence of electronic regenerators could not recover the original state.

Different delay times between different spectral components of the optical signals as a consequence of dispersion will generate. For single mode fiber of a certain length (L), the specified wavelength components at the angular frequency (ω) would receive at the fiber terminal at time delay (τ):

$$\tau = L/v_g \qquad (1)$$

Where υ_g is the group velocity is given by:

$v_g = dw/d\beta$ (2)

Where β is the propagation constant.

To solve the dispersion or sometimes named as inter symbol interference of pulses, many methods with different techniques were implemented or simulated with support of professional simulation software. Some of techniques are used to manage the problem of fiber dispersion based on Chirped Fiber Bragg Grating (FBG), Dispersion Compensating Fiber (DCF) [4,5] and High Order Mode (HOM) [6]. Format .The using of efficient modulation scheme leads to reduce the value of the dispersion is closed to zero at 1550 nm [4].

In our work, comparative study of three dispersion compensation fiber models pre, post and symmetrical involving ideal dispersion compensation Fiber Bragg Grating for three different modulation schemes duo binary, modified duo binary and suppressed carrier return to zero operating in high bit rate 40 (Gb/s) single channel optical fiber transmission system are performance evaluated in term of Q factor and BER.

DISPERSION PROBLEM

Dispersion can be observed in the linear range when the intensity of the optical signal is low but it may be has the properties of the nonlinearity if the incident light intensity is high sufficient. The performance of optical fiber is restricted by chromatic dispersion which is usually called Group Velocity Dispersion. For long haul optical communication link, a specific type of fiber named as Compensated Dispersion Fiber which is used to solve the problem. The average optical power must be low enough so that the non-linearity in side optical fiber is negligible. Several nonlinear effects such as self-focusing, Kerr effect-induced briefings, solitons and self-phase conjugate can increase the pulse distortion by spreading the duration time and that increase the error because of dispersion [7, 8]. In addition, different wavelength modes of a signal acquire various states of optical polarization, resulting in pulse increasing. This phenomenon is usually named polarization-mode dispersion (PMD).

For optical link description, the frequency broadening Δω can be determined by the term of the wavelength Δλ emitted by the optical source [9].

$$\Delta\tau = \frac{d}{d\lambda}\left(\frac{L}{\upsilon g}\right)\Delta\lambda = \mathrm{D L}\Delta\lambda \qquad (3)$$

$$D = \frac{d}{d\lambda}\left(\frac{1}{\upsilon g}\right) \qquad (4)$$

D is called the dispersion parameter and is measured in units of ps/(km-nm).The equation (4) determines how much an optical pulse would spread on propagation over the fiber.

In fibers with constant birefringence (polarization-maintaining fibers), pulse broadening can be determined directly from the time delay $\Delta\tau$ between the two polarization components through propagation of the pulse

$$\Delta\tau = \frac{L}{\upsilon gx} - \frac{L}{\upsilon gy} = L\,(\beta_{1x} - \beta 1y) = L\,(\Delta\,\beta_1) \qquad (5)$$

Where the subscripts x and y identify the two orthogonally polarized modes and $\Delta\beta_1$is related to the difference in group velocities along the two principal states of polarization [10].

DISPERSION COMPENSATION

Dispersion plays the major impact to limit the band width of the light inside the fiber. Dispersion compensation is may be done by combing suitable classes with different refractive. Communication applications require large band width, so the single mode fibers are the suitable selection because modal dispersion. The reason behind this is zero dispersion of pure silica is near the window of a real minimum of attenuation at 1550 nm wavelength. Transmission links based on this wavelength have the advantage of low attenuation and low dispersion; therefore these are the best choice for long-haul optical communication.

The choice of suitable optical modulation setup has a great influence on the performance evaluation in optical transmission. Most of the conventional optical transmission system based on return to zero or non-return to zero and it was reported that return to zero scheme is superior as compared with return to zero scheme [11].Other schemes of modulation format were suggested such as carrier suppressed return to zero [12-14], optical duo-binary [15-17], modified duo-binary, duo-binary format and Fiber Bragg Grating [18]. The criteria for selecting the suitable modulation scheme are spectral efficiency, power margin, group velocity dispersion and the behavior of the system at high intensity.

The property of duo-binary format that has high a tolerance to group velocity dispersion facilities to implement long haul transmission link and spectral efficiency make it has superiority in optical transmission design. Indeed the demodulation at receiver side can easily detect the binary signal from the original duo-binary.

SIMULATION SETUP

In our work high data rate at 40 Gb/s optical transmission link for different transmitter data source duo-binary, modified and carrier suppressed carrier return to zero under different compensated dispersion schemes pre, post and symmetrical with ideal dispersion compensation FBG is designed and simulated using optisystem- 10. Optical signal to electrical signal conversion is done by electrical driver to generate the desired data transmission format. The simulation setups of the proposed optical system are shown in figures from Fig.1 to Fig.9.

For simulation each of the pre, post and symmetrical of DCF schemes are cascaded to ideal FBG. At the transmitting side, each transmitter consists of input data signal source operates at high bit rate within different formats, namely, duo-binary, modified duo-binary and carrier suppressed carrier return to zero, electrical driver to generate the desired data transmission format by converting the logical input signal into an electrical signal, the laser source line width is 100MHz amplitude modulator. Locations replacements of DCF and single mode fiber by changing the virtual position to propose post, pre and symmetrical compensation. To investigate DCF-Pre compensation setup, DCF is placed first then it connected to SMF. DCF- Post compensation is attained by place DCF next to SMF. The last setup is combination of Pre and Post compensation.

The laser source is CW type at frequency 193.1 THz and output power is varied from -5 dBm to 10 dBm. The modulator is of Mach-Zehnder modulators have the Excitation ratio 30dB.The loop control system has two loops in post and pre setup. Each span consists of 100 km of transmission fiber (SMF) and 20 km DCF in order to fully compensate for the dispersion slope and accumulated dispersion in the transmission fiber but in symmetrical setup has only one loop, so the total length of fiber channel remains 240 km. it is segmented in the ratio of 1:5 i.e. 20 km DCF and 100 km of SMF.

EDFAs are positioned according to setup type with 12dB, 20 dB gains and noise figure of 6dB.In receiver side the signal is converted from optical to signal using PIN photo diode then the electrical signal is filtered using low pass Bessel filter. Ideal FBG operate at 193.1 THz and 125GHz bandwidth is used to enhance the dispersion compensation in the system. Tables 1 and 2 show the simulation parameters and fiber parameters respectively.

RESULTS AND ANALYSIS

The results are simulated using optisystem-10 simulator. The optical performance evaluation especially (BER) can be described by measuring the relationship between the Q-factor and (BER). Many various parameters which include optical output power (dBm), attenuation coefficient (dB/km) at cable section and Signal power (dBm) at receiver will be evaluated to investigate the higher performance communication link configuration setup for a high performance optical transmitter. Figures 11, 13 and 15 show Q-factor for the three dispersion configurations pre, post and symmetrical cascaded with FBG for the three types of modulation format. Figures 12, 14 and 16 show Bit Error Rate for the three dispersion configurations pre, post and symmetrical cascaded with FBG for the three types of modulation format. From the figures above we can conclude that the symmetrical with ideal FBG at duo-binary coding depicts good performance for increasing the input power from -5dBm to 10dBm.It is clear that best Q value obtained is 28.24 dB for BER of $5.9 * 10^{-176}$ at input power of 5 dBm using symmetrical compensation for duo-binary modulation . The benefit of using FBG in the optical transmission system so that FBG acts as dispersion compensator, optical amplifier which can be used to reduce the fiber loss and amplify the signal before being received by photo detector PIN at the receiver side. Dispersion parameters can be varied as a consequence of refractive index changing of the fiber that can be caused by the variation of temperature.

CONCLUSION

We can realize high speed optical communication system using three modulation techniques duo binary, modified duo binary and carrier suppressed return to zero with three different types of dispersion compensation fiber pre, post and symmetrical. All setups were proposes and demonstrated using optisystem-10. The performance of each set up was reported in term of Q- factor and BER. The evaluations of the systems depend on the best value of Q which is corresponding to BER. The result reported that the duo binary modulation scheme with the cascading of symmetrical and FBG is the higher performance.

Our analysis about that is the receiver unable to make the correct decision about the received signal when the physical transmission impairments such as the induced chromatic dispersion, noise, optical polarization and non- linear effects lead to degrade the signal with closing eye in horizontal and vertical coordinates at receiving side which that means the BER will be increased as consequence of the increasing error decisions of bits detection.

REFERENCES

1) Mochida Y, Yamaguchi N, Ishikawa G, "Technology-oriented review and vision of 40Gb/s-based optical transport Networks", Journal of light-wave technology. PP. 2272-228, 2012.
2) Zhang Hong bin, Q iu Kun, "Emulation of characteristics of optical fiber transmission for a 10Gb/s single channel situation," acta photonica sinica, vol.30 No.6,pp. 715-720, 2001.
3) Omae T, "Universal conditions for estimating the nonlinear refractive index n2 of dispersion compensating fibers by the CW- SPM method", IEEE Photon. Technol. Lett., Vol 13. No.6, pp. 571-573, Nov, 2001.
4) Zhao huai gang, "study on dispersion compensation in optical transmission system", study pn optical communications, Vol. 3 , No.141, 2007.
5) Wang chen, Rao min, "the performance of the DCF Transmission system", Journal of applied sciences, Vol. 21, No.2,pp.177-181,June, 2003.
6) Jianjun Yu, Bojun Yang,"Dispersion-allacated soliton technology with long amplifier spacing and long distance," IEEE photon technol. Let., vol 9, pp. 952-954,No.7, 1997.

7) Killy R I, Thiele H J, Mikhailov v, "Reduction of inter channel nonlinear distortion in 40-Gb/s based WDM transmission over standard fiber" [J]. IEEE Photonics Technology Letters, 12(12): 1642-1626. 2000.
8) Eggleton B. "Dynamic dispersion compensation devices for high speed transmission systems". Optical Fiber communication conference and exhibit, (3), 2001.
9) M. Born and E. Wolf, "of Optics", 7th ed., Cambridge University Press, NewYork, 1999.
10) C. D. Poole and J. Nagel, "in Optical Fiber Telecommunications III", Vol. A, I. P. Kaminow and T. L. Koch, Eds., Academic Press, San Diego, CA, Chap 6, 1997.
11) M.I. Hayee and A.E. Willner, "NRZ Versus RZ in 10–40-Gb/s dispersion managed WDM transmission systems", IEEE Photonics Technology Letters, 11,pp. 991–93, 1999.
12) A. Hodzik, B. Konrad, K. Petemann, "Alternative modulation formats in N X 40 Gb/s WDM standard fiber RZ-transmission systems", IEEE Journal of Light wave Technology, 20,No.4 ,April ,2002.
13) T. Hoshida, O. Vassilieva, K. Yamada, S. Choudhary, R.Pecqueur, .Kuwahara, "Optimal 40 Gb/s modulation. formats for spectrally efficient long-haul DWDM systems", IEEE Journal of Light wave Technology, Vol. 20,No.12, 2002.
14) L. Sharan, V K Chaubey , "Design and Simulation of CSRZ Modulated 40 Gbps DWDM System in Presence of Kerr Non Linearity", IEEE Xplore, "in press"
15) P.J. Winzer, R.J. Essiambre, " Optical Modulation Formats", proceedings of the IEEE, Vol. 94,No.5, pp. 952–985, May 2006.
16) K. Yonenaga and S. Kuwano, "tolerant optical transmission system using duobinary transmitter and binary receiver", Journal Of Light wave Technology, Vol. 15, No. 8, pp. 1530–1537, Aug. 1997.
17) Yue Zhou, Yufengshao, Zhifengwang, "Research on dispersion compensation of 40 Gb/s optical duobinary coded transmission system" optics and photonics journal, vol 6, pp 190-195, 2016.
18) Mehtab Sing, Rajveer 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.

Table.1: Simulation Parameters

Parameters	**Value**
Bit rate	40 Gbps
Sequence length	64
Samples / bit	256
Central frequency (THz)	193.1 THz

Table .2: Fiber Parameters

Parameters	Single Mode Fiber (SMF)	Dispersion Compensation Fiber (DCF)
Length (km)	100	20
Dispersion (ps/nm/km)	17	-85
Dispersion slope (ps/nm^2/km)	0.075	-0.3
Attenuation	0.2	0.6
First order dispersion coefficient (ps^2/km)	-20	-20
Differential group delay (ps/nm)	0.5	0.5
Nonlinear refractive index (m^2/w)	2.6e^{-20}	2.6e^{-20}

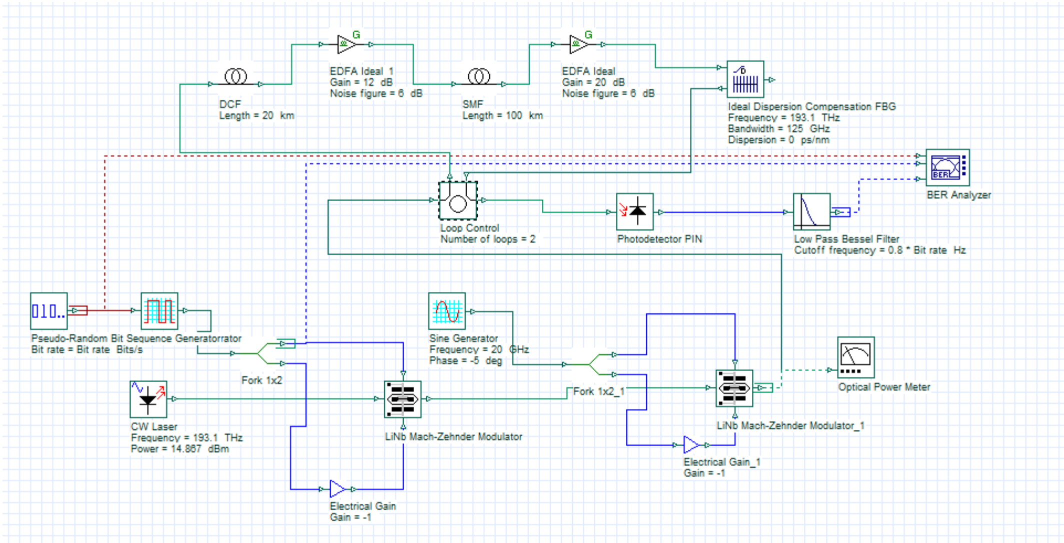

Figure .1: Simulation setup for pre compensation carrier-suppressed return-to-zero modulation format

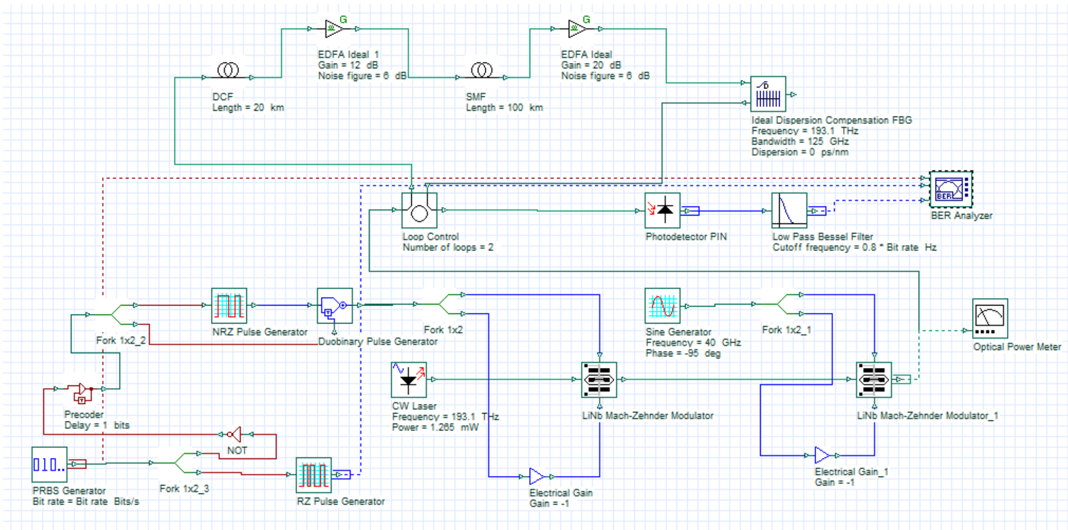

Figure .2: Simulation setup for pre compensation duo-binary modulation format

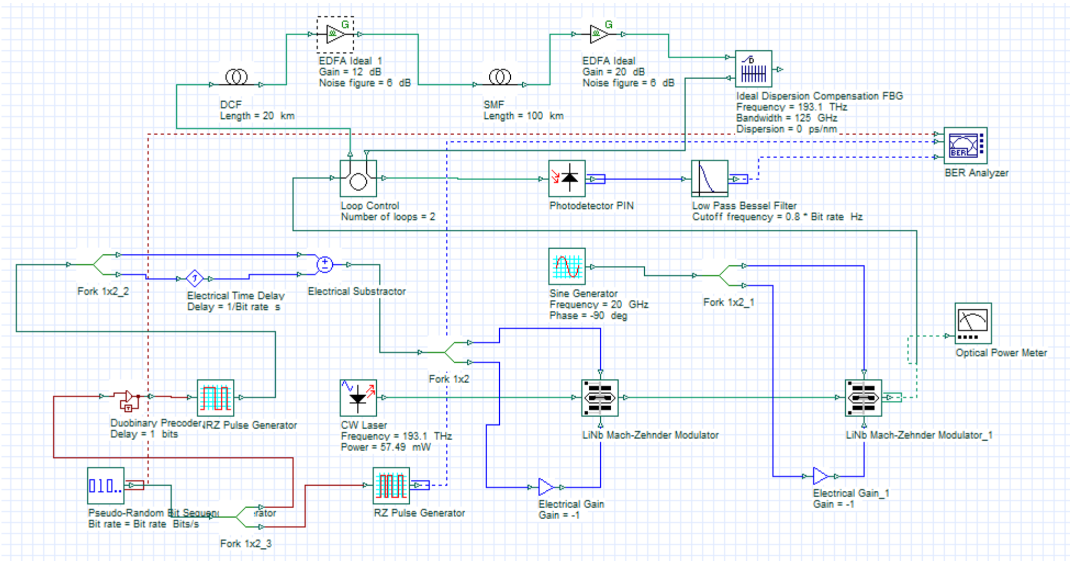

Figure .3: Simulation setup for pre compensation modified duo-binary modulation format

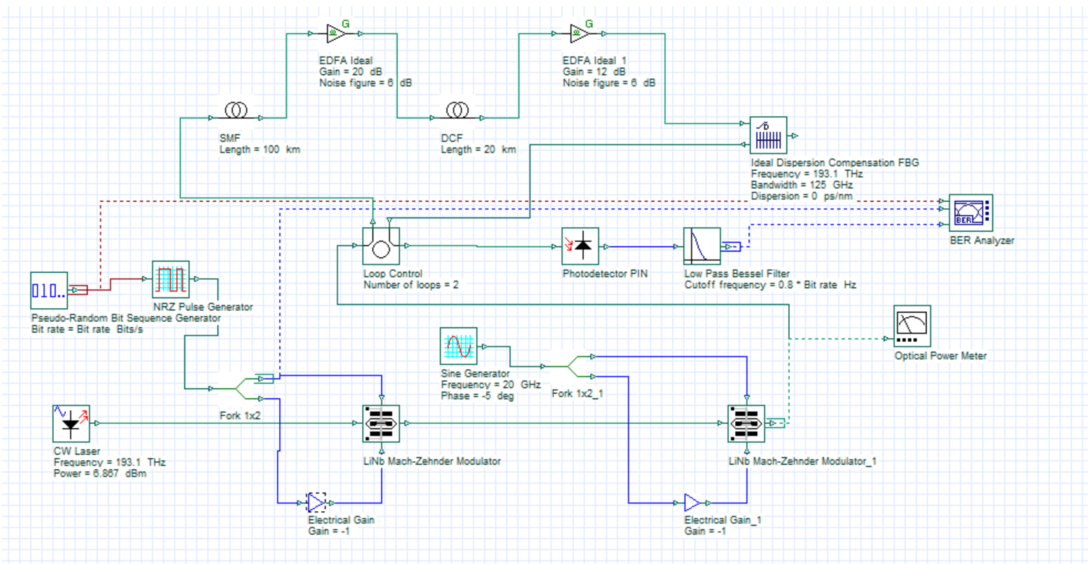

Figure .4: Simulation setup for post compensation carrier-suppressed return-to-zero modulation format

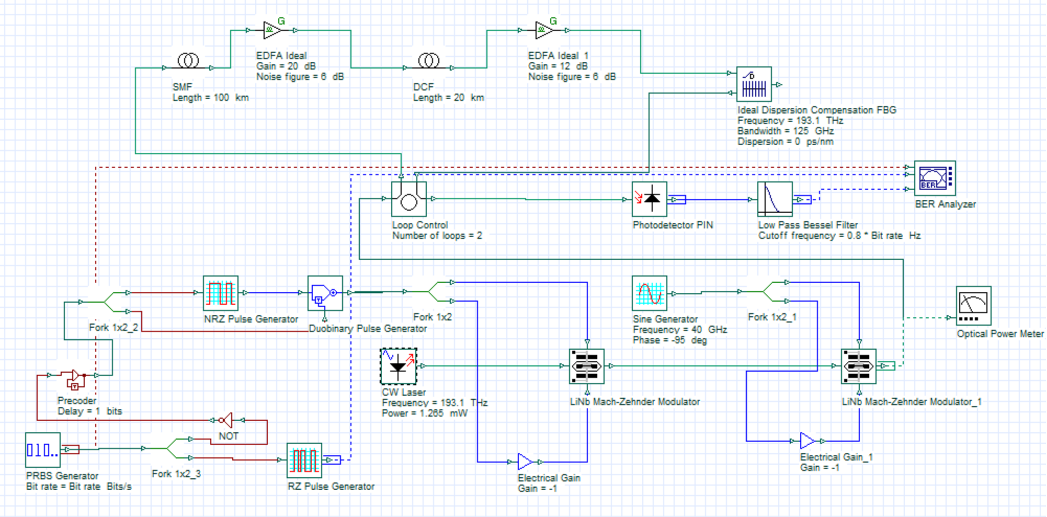

Figure .5: Simulation setup for post compensation duo-binary modulation format

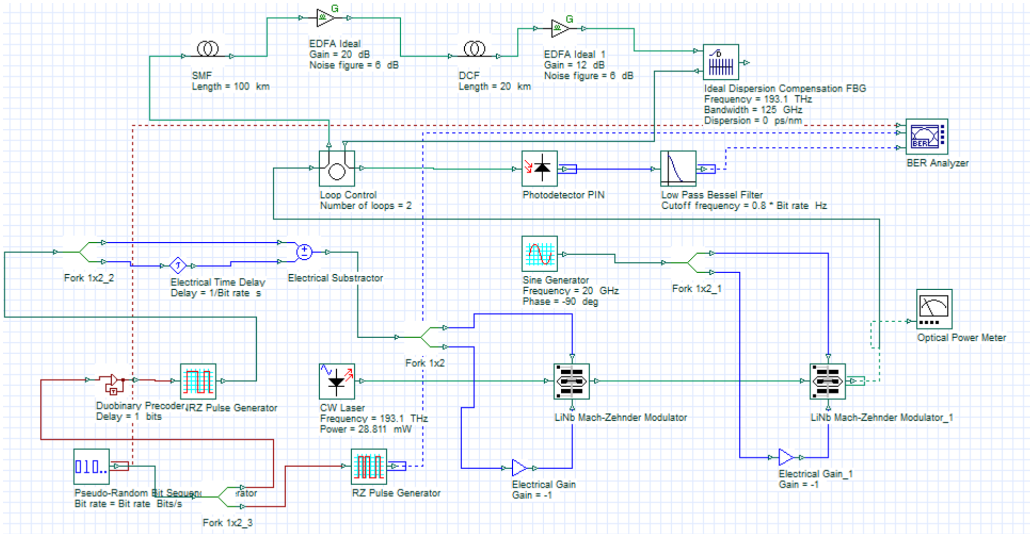

Figure .6: Simulation setup for post compensation modified duo-binary modulation format

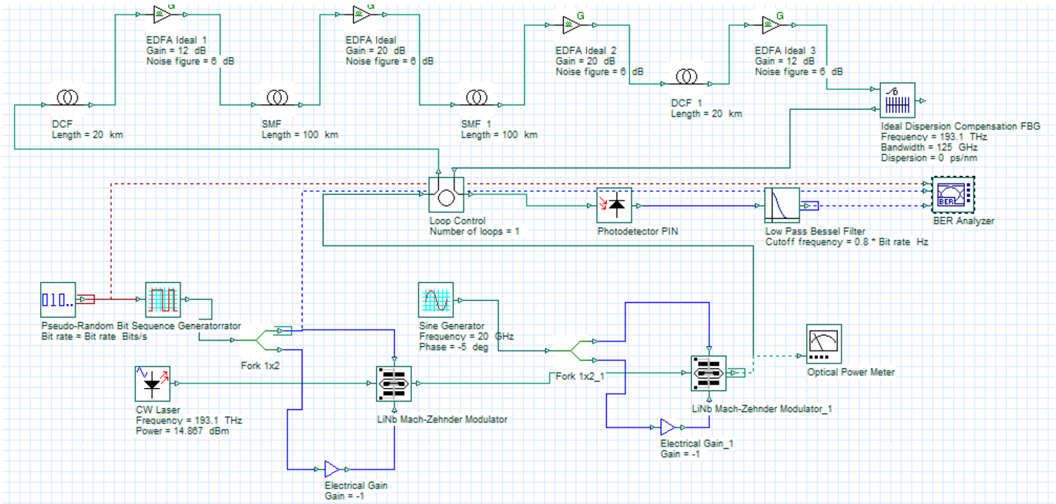

Figure .7: Simulation setup for symmetrical compensation carrier-suppressed return-to-zero modulation format

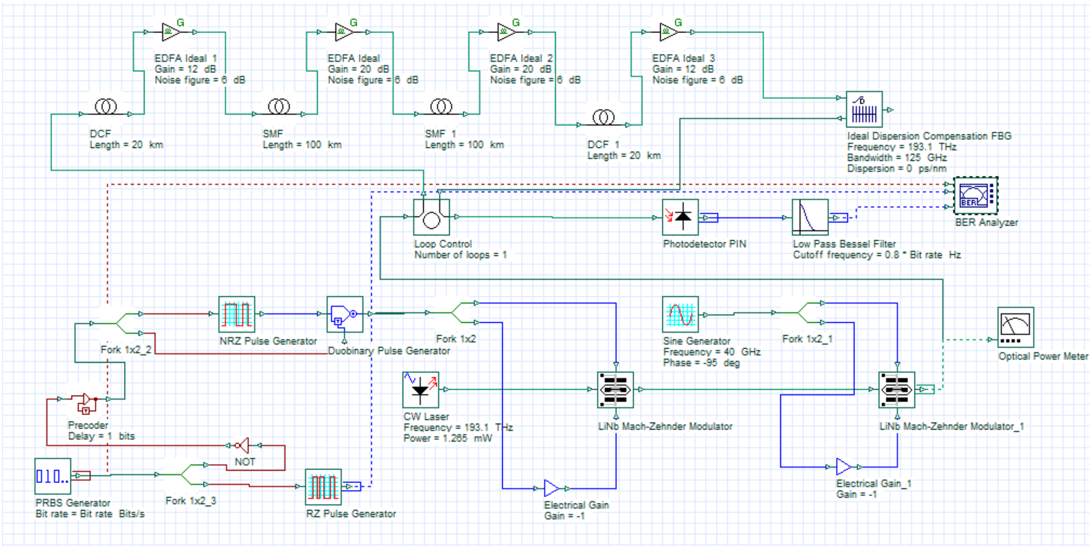

Figure .8: Simulation setup for symmetrical compensation duo-binary modulation format

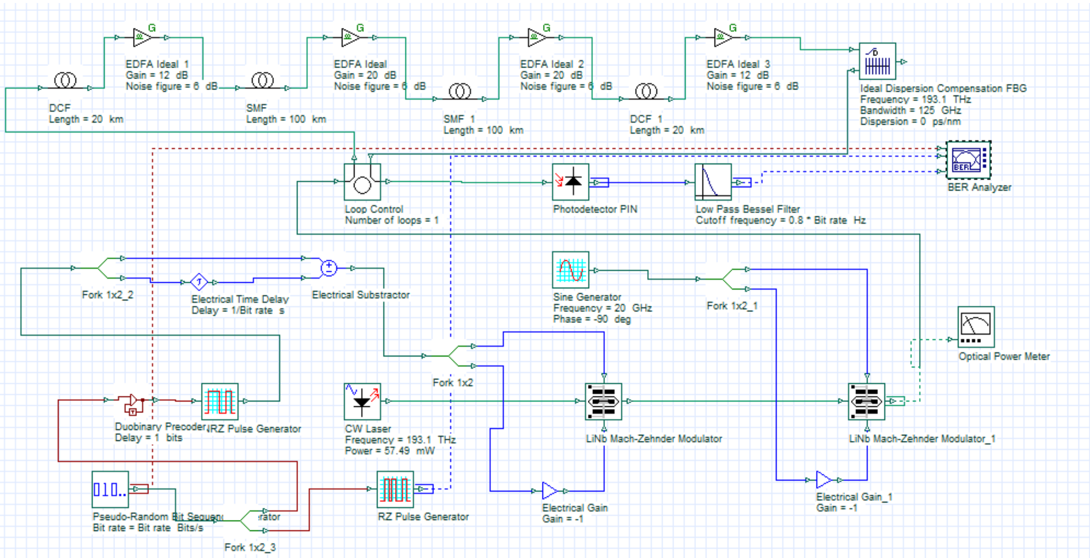

Figure .9: Simulation setup for symmetrical compensation modified duo-binary modulation format

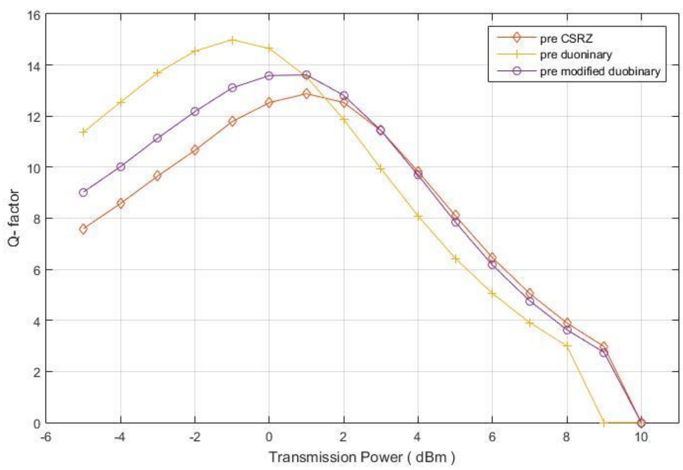

Figure .10: Comparison of transmission power vs Q factor influence of pre scheme for three modulation system

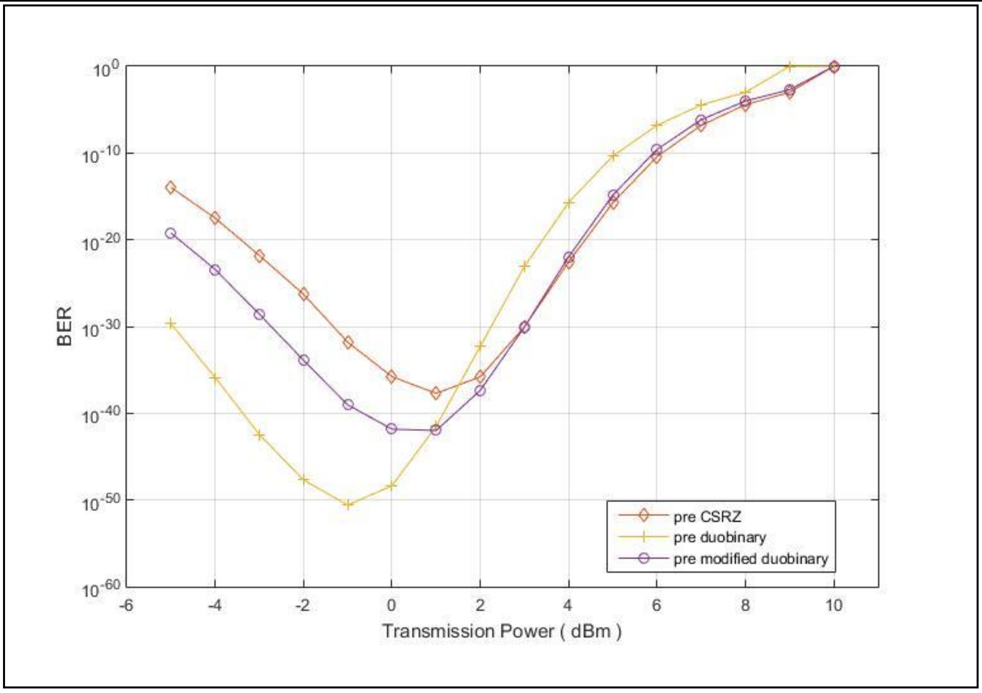

Figure .11: Comparison of transmission power vs BER influence of pre scheme for three modulation system

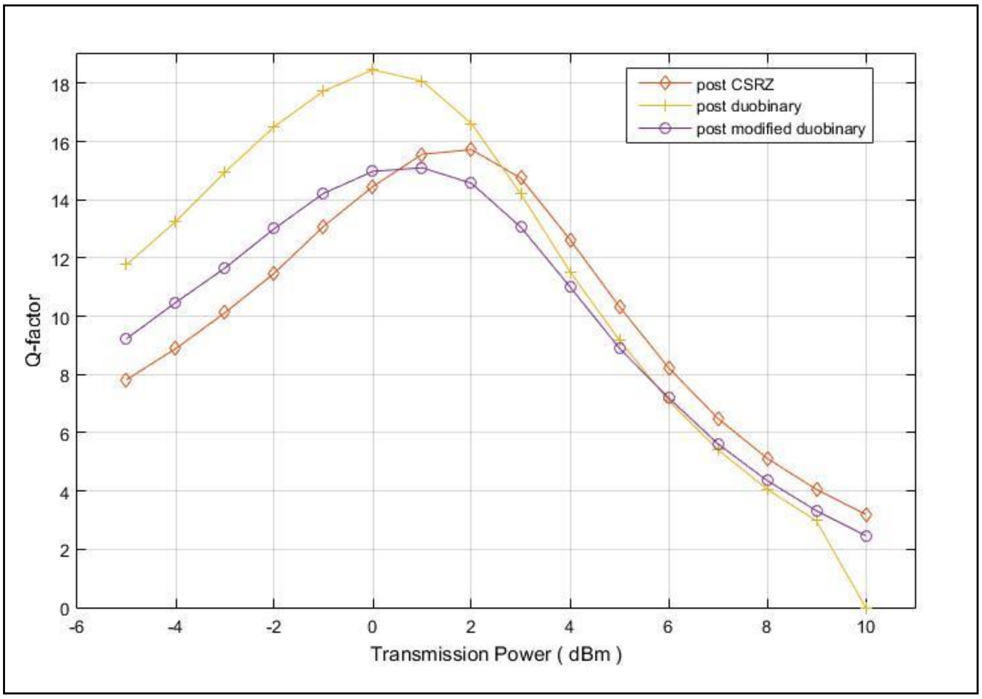

Figure .12: Comparison of transmission power vs Q factor influence of post scheme for three modulation system

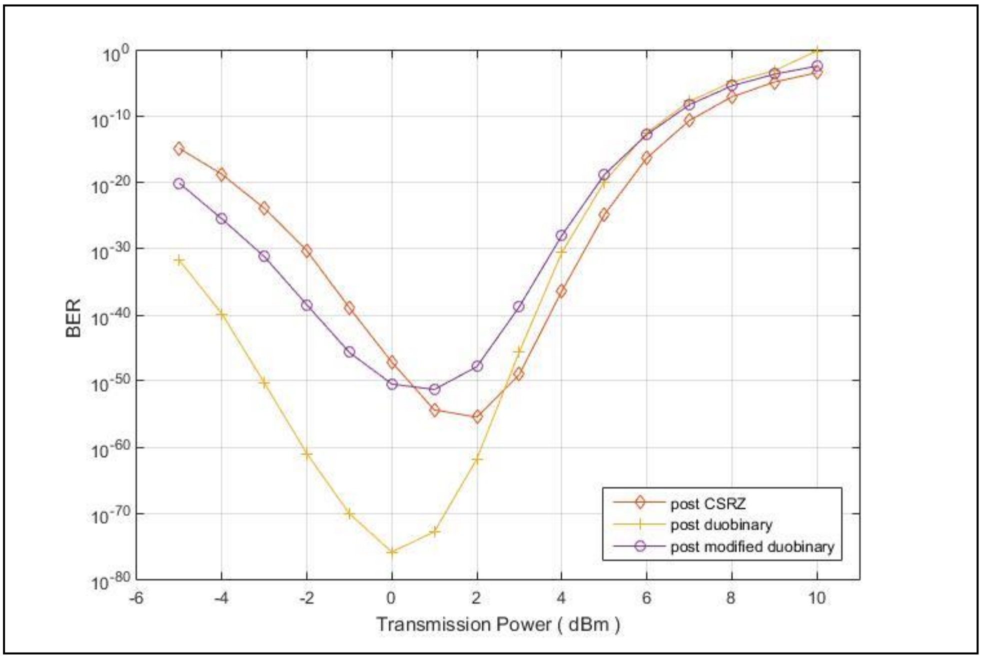

Figure .13: Comparison of transmission power vs BER influence of post scheme for three modulation system

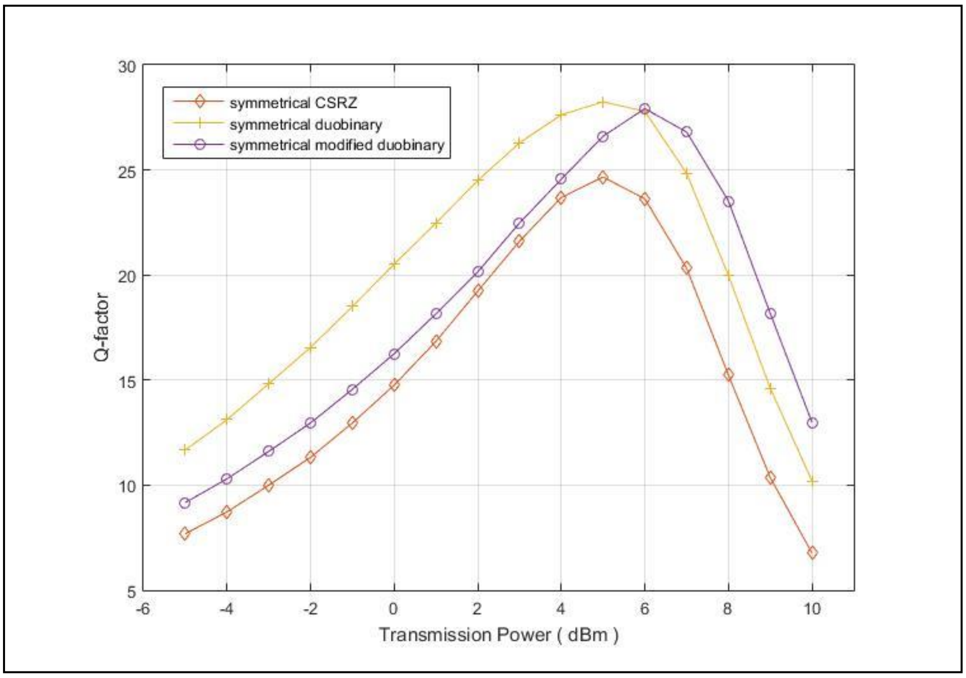

Figure .14: Comparison of transmission power vs Q factor influence of symmetrical scheme for three modulation system

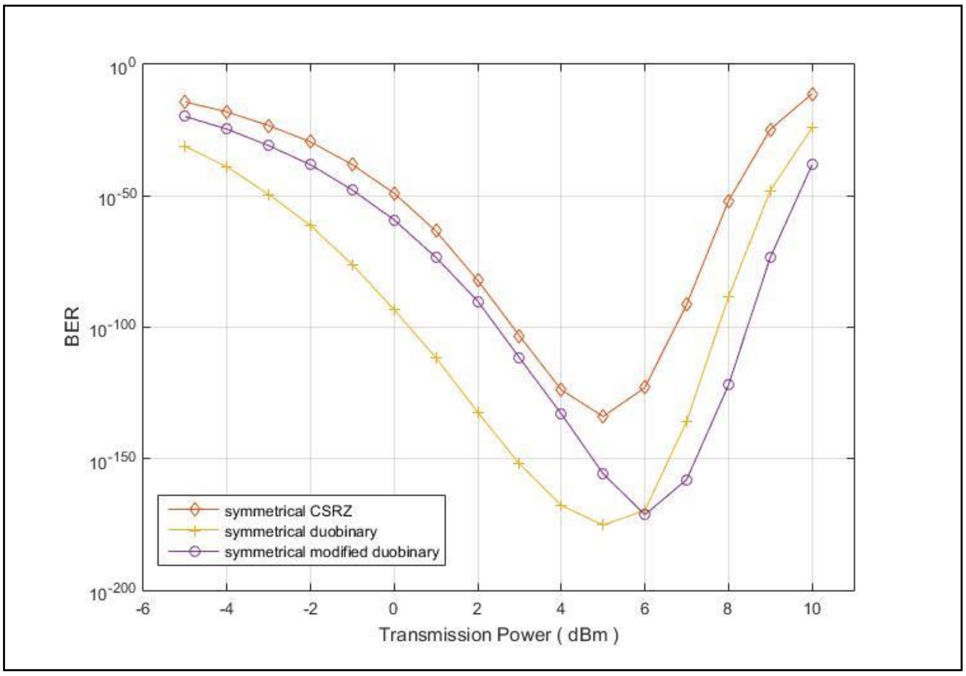

Figure .15: Comparison of transmission power vs BER influence of symmetrical scheme for three modulation system

تقييم اداء نضام اتصالات بصري عالي سرعة البيانات متضمنا محزز براغ الليفي محسن التشتت وبتقنيات تضمين مختلفة

م.د رياض خلف أحمد ، م.م حسين أحمد محمود

قسم هندسة الاتصالات، كلية الهندسة،جامعة ديالى

الخلاصة:

في هذا البحث تم تقييم اداء ومقارنة ثلاث نماذج لتحسين التشتت الليفي قبل ومشاركة متماثلة متضمنة المحزز مثالي نوع براغ ولثلاث انواع مختلفة من نماذج التضمين وبمعدل ترميز مقداره 40 گيكا بت/ ثانية في قناة احادية الليف الضوئي. ان نماذج التضمين ثنائي- الثنائي و ثنائي- الثنائي المحور والرجوع للصفر خامد الموجة الحاملة قد قيمت وحللت لمعيار عامل الجودة ونسبة الخطا في معدل نقل البيانات ولكل نموذج وذلك بتغيير قدرة الليزر المستمرالمدى. ان المحاكاة للرابط الضوئي قد تمت باستخدام البرنامج (optisystem 10). ان تقارير النتائج تثبت ان تحسين المشتت اللفي نوع المتماثل في التضمين ثنائي- الثنائي هو الافضل عند زيادة القدرة من -5 ملي ديسبل الى 10 ملي ديسبل. من الواضح ان افضل قيمة للعامل Q كانت 28.24 لقيم نسبة خطئ مقدارها 5.9×10^{-176} ولقدرة ادخال 5 ملي ديسبل وللتضمين نوع ثنائي- الثنائي.