Simulation and Performance Analysis of a Fiber Communication System based on FBG as Dispersion Compensator

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***Abstract*— A high data rate and large number of transmission channels which lead to broadband based fiber communication systems can provide the technological advancement in telecommunication system. The dispersion mechanism within the optical fiber cause broadening of the transmitted light pulses as they travel along the optical fiber channel. In this paper an Optical Fiber Bragg Gratings (FBG) used to compensate the element inter symbol interference of transmitted data due to dispersion effect, which reduces the bit error rate and enhances the quality factor of the received optical signal in a fiber optics based on wavelength division multiplexer (WDM) communication systems. Optisystem 7.0 software used to simulate and performance analysis study for long haul optical fiber communication system.**

***Index Terms*— Dispersion Compensator, FBG, BER, Q-Factor, Optisystem 7.0 software .**

I. INTRODUCTION

The advance communication systems require a large bandwidth, high data and high speed to some other destination. Fiber optics communication system as shown in Figure (1) is one of the most important link which use the optical fiber media in communications system.

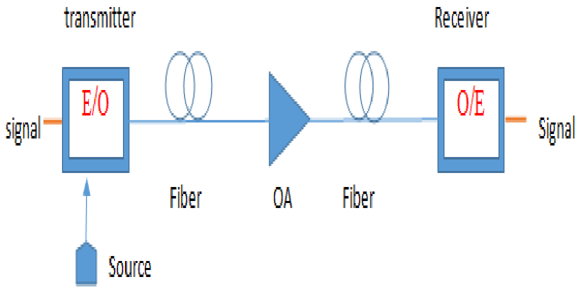

Figure (1): Basic fiber optic communication system [1].

Although of a lot of above advantages of optical fiber communication, but the dispersion is the main performance limiting factor. Fiber Bragg Grating with amplifiers is equipped with the long haul optical communication systems designs, because the low cost of filter for wavelength selection and low insertion loss, in addition to customized reflection spectrum and wide bandwidth [2]. Dispersion Compensated Fiber (DCF) is an effective method to upgrade the single mode fiber links . However the limitation in using transmission of light over (DCF) component is due to the optical input power ,where nonlinear impairments will create a high insertion loss over the link [3]. Fiber Bragg Grating provides the fiber dispersion for long distance transmission with obtained gain factor. An important characteristics of (FBG) as a dispersion compensator such like, negligible nonlinearity, small size and low insertion loss can possibly impact the system performance through increasing the long distance fiber network capacity. Using a chirped (FBG) can easily impact the system performance [4]. The designed system performance is analyzed in this study by using (FBG) over (10-50) Km fiber link leading to error free transmission of 10 G/bit NRZ signal. The simulation of the optical fiber system has been discussed by analyzing the values an evaluation of quality through the BER (Bit Error Rate). This parameter is the ratio between the number of bits with errors and the number of the total bits transmitted during a space of time studied, which has been investigated using different parameters setting [5].

II. (FBG) DISPERSION COMPENSATION MODEL

The model illustrates how to compensate fiber dispersion using the realistic fiber grating component. Here the compensating fiber component has some grating with different refractive indices, which give different velocities for different modes of light signals so compensated the delay between two different modes [2]. The Bragg wavelength variations along the grating length so different frequency components of the incident beam are reflected back [6].

$$\lambda_B = 2\, n\, \Lambda \qquad (1)$$

The grating dispersion, D_g, is expressed as

$$D_g = 2\, n / c\, (\Delta\lambda) \qquad (2)$$

Where n is the average mode index, $\Delta\lambda$ is the grating bandwidth, and c is the velocity of light.

The compensation fiber has a high negative dispersion compared with the DCF. In the first assumption we took a fixed effective refractive index but the bandwidth is optimized to get the best results.

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III. SIMULATION OF (FBG) DISPERSION COMPENSATION

The design model explores dispersion compensating module (DCM) discussing the Fiber Bragg Gratings (FBGs) for the dispersion compensation. The system is operated with the basic optical communication which consists of a transmitter, transmission link and a receiver. The system transmits information using optical carrier wave from transmitter to receiver via optical fiber. Figure (2) shows the initial settings for the design that show the layout parameters from Optisystem 7.0.

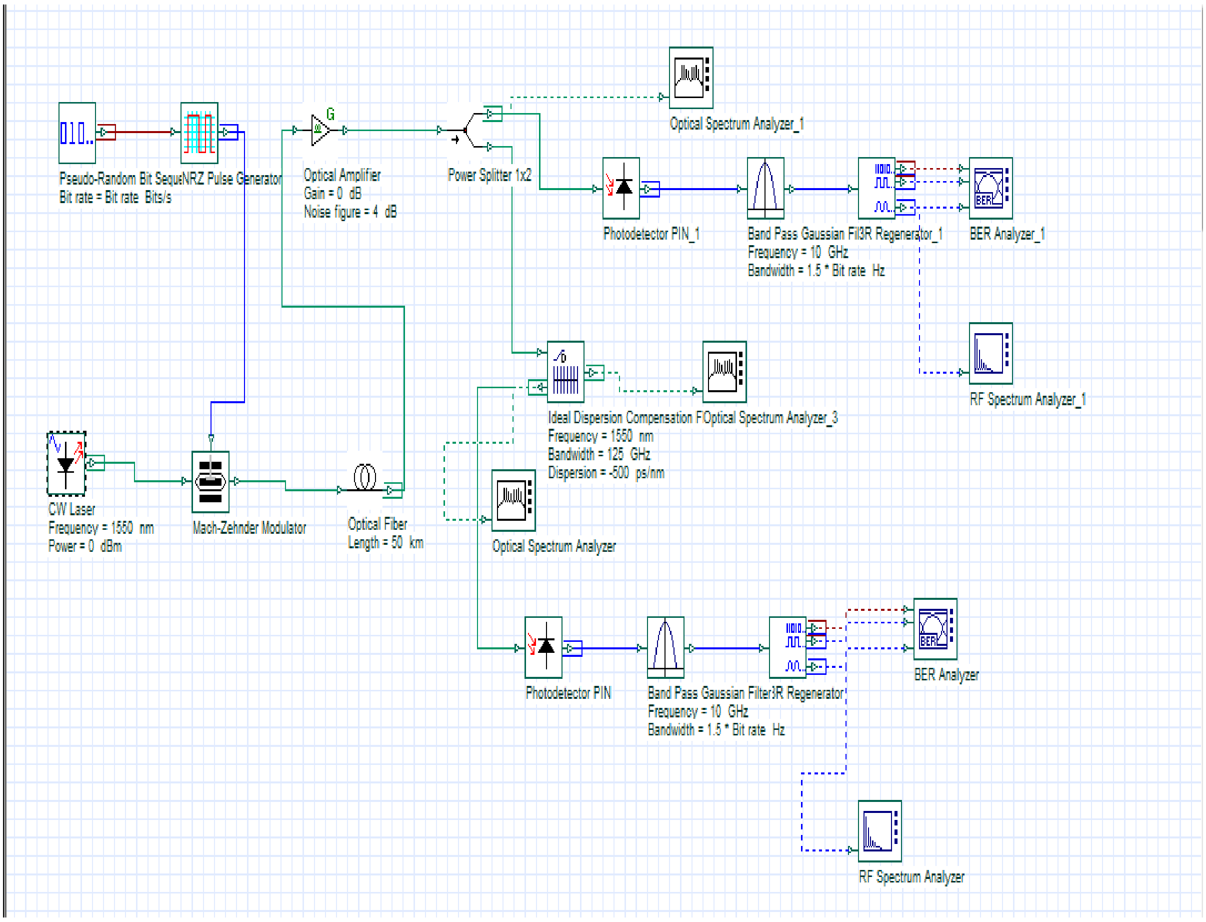


Figure (2): The Simulation of designed model with Optisystem7.0 software.

The components used are: Pseudo - Random Bit to scramble data signal in terms of sequence random bits (0 or 1), NRZ pulse generator to controlling bandwidth, (MZ) Mach Zender- Modulator which has two inputs (optical and electrical) signal and one optical output, used to modulate the input (CW) laser signal. A (CW) laser diode used to generate 1550 nm wavelength optical signals with 5dBm input power, which is externally modulated at 10 Gbits/s with 30 dB of extinction ratio. A single mode optical fiber used as transmission link for it higher data rate and less dispersion for long haul distance with attenuation coefficient at cable section 0.2dB/km. The (FBG) within (1- 6 mm) length used as a dispersion compensator. (EDFA) fiber amplifier used to amplify the optical signal and overcome the fiber loss before receive by the receiver part, which include (PIN) photodetector to convert the optical signal into an electrical signal. Finally an Optical Spectrum Analyzer (OSA) used for output signals monitoring after each component. In addition different measuring instrument used such as, power meter, RF spectrum analyzer and (BER) tester.

IV. SIMULATION RESULTS

The optimized simulation of the fiber optics communication link design is done using Optisystem 7.0 simulation software. The performance improvement of (FBG) when dispersion was compensated at the Optical receivers illustrated from the eye diagram analyzer of electrical output signal results based on before FBG and after using FBG as dispersion compensator, as shown in Figure(3) . Also, at the receivers the results output was analyzed the Q-factor and Bit Error Rate of photo detector with and without using (FBG) device.

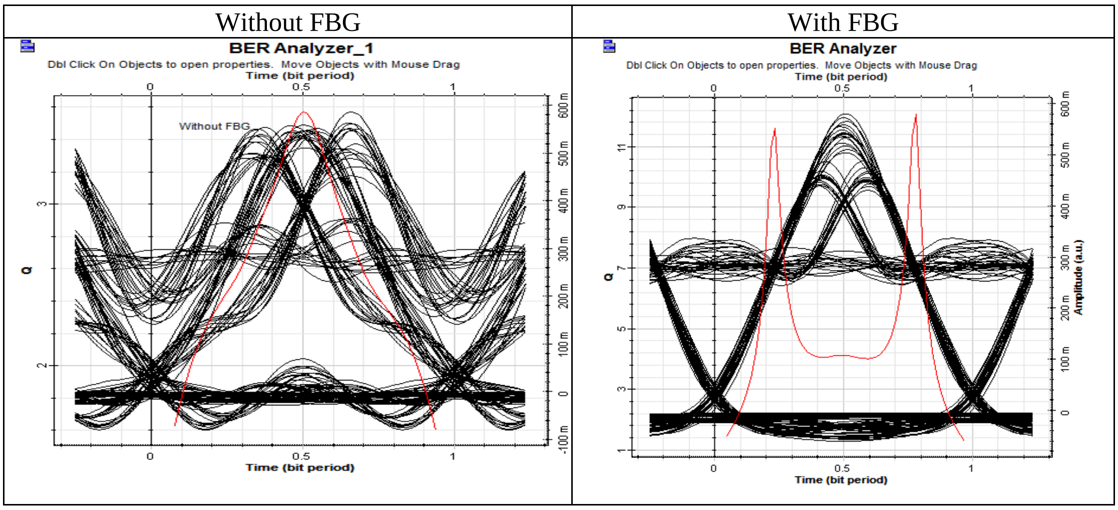


Figure (3): The eye diagram differences for the designed link over 50 km NRZ at amplifier gain=40dB, with and without using (FBG).

The results of using (PIN) photodetector as the receivers are shown in Table (1) at different amplifier gain, the eye diagram has improves many times as shown in Figure (4) (a) and (b), in case of the results comparison with and without FBG. Results show that when amplifier gain increases, min BER value decreases.

Table (1): PIN Photodiode output readings are tabulated by varying amplifier gain (dB)
Dispersion= -300 ps/nm

Gain dB		Without FBG	With FBG
1	Q-FACTOR	3.36936	6.08206
	BER	0.000308212	5.73268e-10
10	Q-FACTOR	3.57191	8.24447
	BER	0.000138696	7.57992e-17
20	Q-FACTOR	3.57114	8.31587
	BER	0.000139233	4.14719e-17
30	Q-FACTOR	3.57048	8.31727
	BER	0.000139615	4.07783e-17
40	Q-FACTOR	3.5703	8.31784
	BER	0.000139717	4.09739e-17

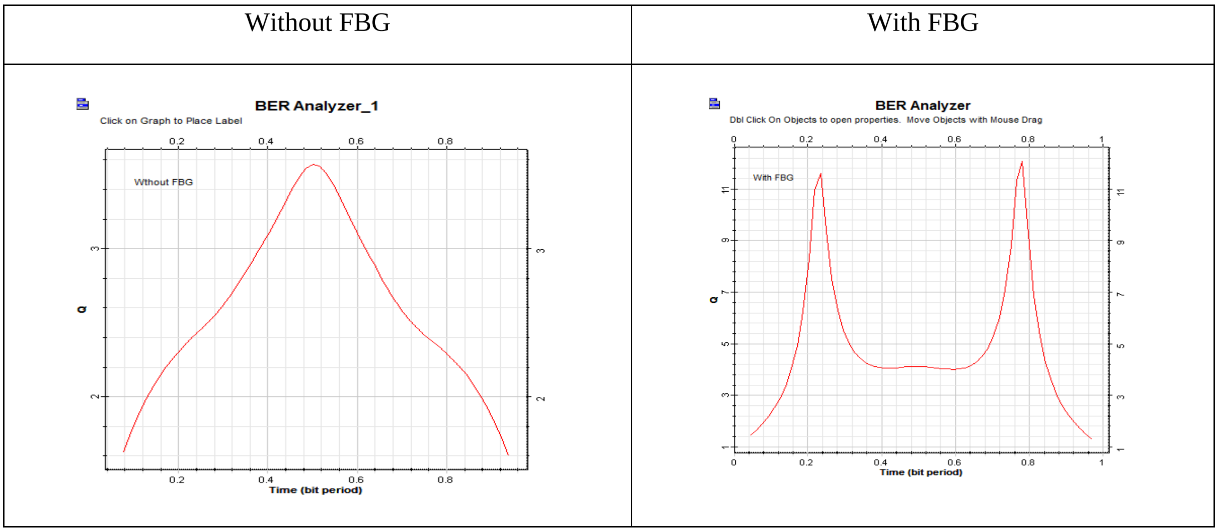


Figure (4): MIN BER output (a): without FBG, (b): with FBG at Amplifier gain=40dB

The eye diagrams and results of output power, Signal power (dBm) at receiver, noise power for variable length of FBG (1- 6 mm) as shown in Table (2).

Table (2): PIN Photodiode output readings measured for different (FBG) lengths.

Length (mm)	Signal Power (dBm)	Noise Power (dBm)	Output power (mw)
1	13.236	-20.395	-3.560
2	15.746	-23.916	1.358
3	16.455	-26.330	2.672
4	16.746	-27.909	3.160
5	16.895	-28.951	3.376
6	16.980	-29.642	3.481

The related graphs are also plotted as shown by using different values of input power (dBm), attenuation coefficient (dB/km) in Figures (5), (6) and (7) respectively.

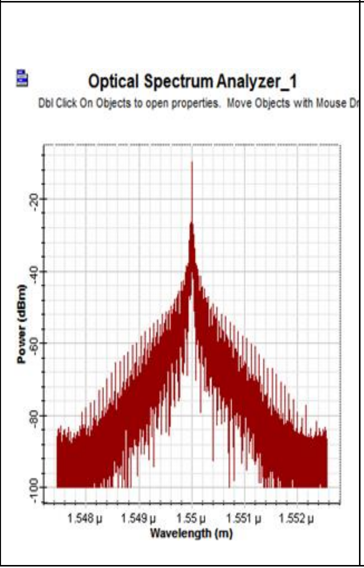
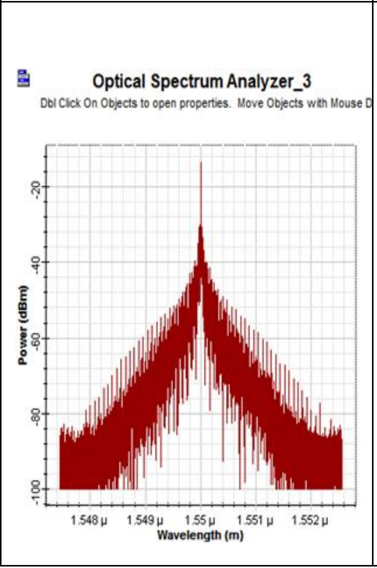
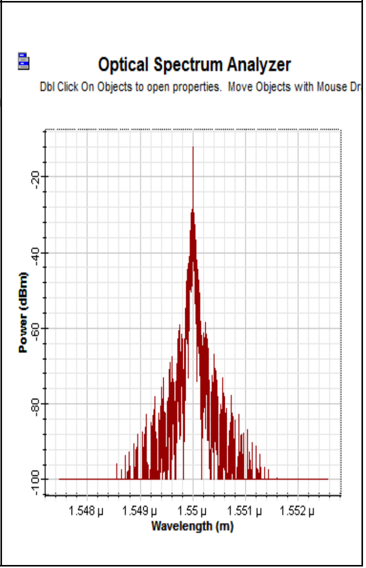
Without FBG	With FBG	Reflected from FBG
		

Figure (5): The output Optical (Transmitted and Reflected) power for the designed link with and without using (FBG).

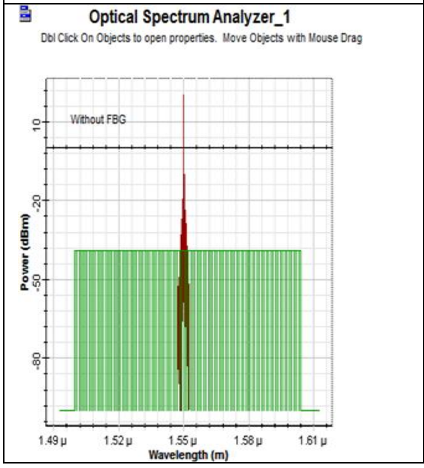
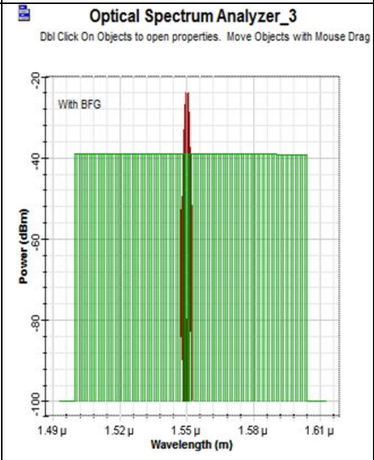
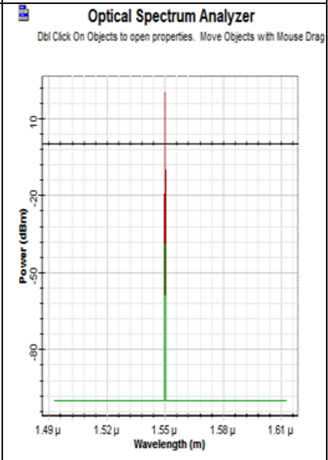
Without FBG	With FBG	Reflected from FBG
		

Figure (6): Optical spectrum analyzer output for transmitted & reflected power, without and with FBG at amplifier gain=40dB.

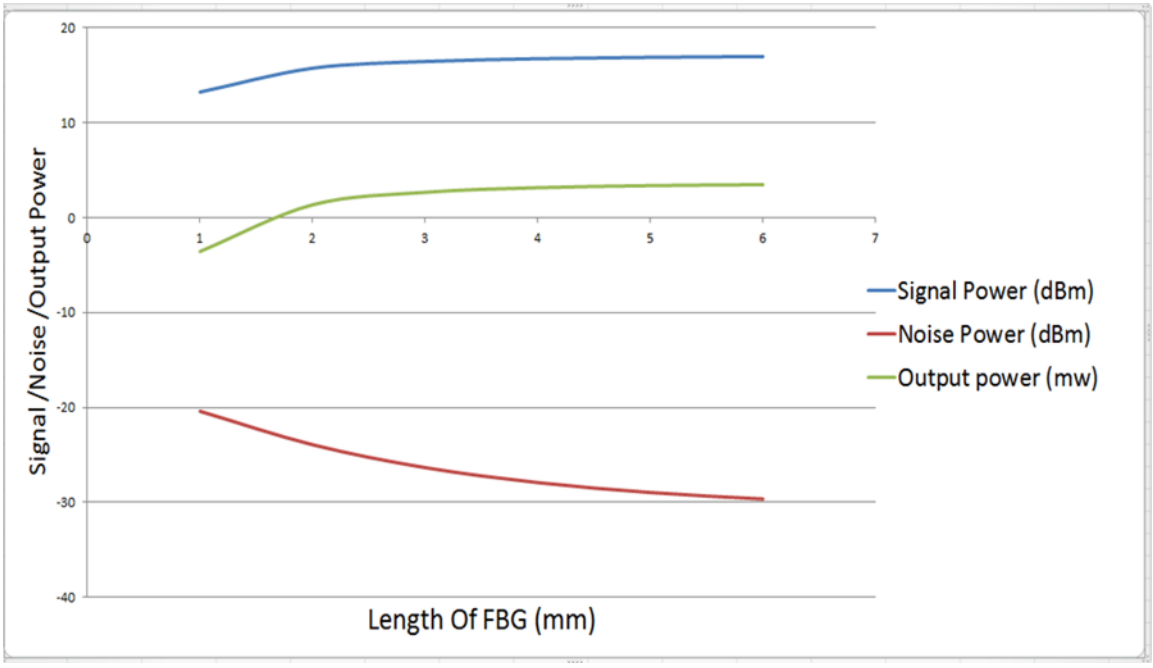


Figure (7): Signal/noise/output power figure versus (FBG) length.

From analyzing data listed on Table (2), it shows that the length of (FBG) is directly proportional to the value of noise signal, while the length of (FBG) is inversely proportional to the Noise power .Also, both the signal power and output power reading by electrical power meter is increase linearly with increasing (FBG)length as shown in Figure(7).

V. CONCLUSIONS

Design and simulation of optical fiber communication system based (FBG) as a dispersion compensator using Optisystem 7.0 software, shows the effect through the enhancement of (BER) performance in optical fiber link. The Q-factor of the system has been clearly increased before and after using (FBG) at the receiver, while minimum (BER) OF the system is evaluated at BER of 10 -9 was reduced significantly by using (FBG) at different gain. The numerical results indicate that the BER performance can be improved significantly and dispersion can be compensated using FBG-based compensator.

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