Simulation based Performance Analysis of Fiber Bragg Grating as Dispersion Compensator in Optical Transmission System

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Abstract - *This article conversed on a 10 Gbps - single mode optical fiber communication link. In order to achieve a compelling performance of the system, existing fiber dispersion which abates the fiber performance must be compensated. Fiber Bragg Grating (FBG) was chosen as an important element to compensate the chromatic dispersion in a single mode fiber system. This analysis was entirely based on the simulation of transmission system hinged on various parameters by using Opti-system simulation software produced by the 'Optiwave' enterprise. An information signal travels through 50 km single mode optical fiber with the operable speed of 10 Gbps. Performance of the designed system was measured and analyzed through the simulation using practical value of optical parameters. Our comparison hingedon parameters like eye diagrams, BER, Q-factor showed a significant boosting in the link performance.*

Key Words: **BER, Bragg Grating, Compensation, Dispersion, Opti-system, Opti-wave**

1. INTRODUCTION

Fiber-optic communication refers to the transmission of an information signal through the light as a carrier in a fiber link medium [1]. In this era of modernization and technology, fiber communications are widely used and has proven to be reliable form of data transmission. The implementation of optical fibers throughout the globe is sky-rocketing due to its higher bandwidth, higher information security, and other numerous advantages. The design and analysis of the optical communication system can be done using Optiwave. Optisystem is an optical simulation software application that simulates optical circuits and systems[3]. Dispersion alludes to the spreading of signal as it travels through the fiber channel. A longer optical link is accompanied by single mode fiber which is mainly prone to chromatic dispersion [2]. This destructive effect of dispersion should be compensated in order to enhance the fiber performance. Fiber Bragg grating (FBG) is chosen against the Dispersion Compensated Fiber(DCF) technology as an essential component in this optical system for avoiding dispersion - a wavelength filter. Our simulations and analysis were visualized through practical approach so that it could contribute to realize a real scenario in the area of optical data communication.

1.1 Fiber Bragg Grating

A fiber Bragg grating (FBG) delineates an inline optical filter/sensor constructed in a short lump of optical fiber filtering specific wavelengths. A Bragg Grating technology is implemented to minimize the effect of dispersion.[2] Refractive index of the core is alternated by creating periodic variations.[7]FBG enables the grating which are placed along with the fiber in order to reflect the incoming pulses having different wavelengths at different areas across its grating length. Therefore, it imparts series of delays for every different frequencies or wavelengths. Shorter travelling pulses will be accompanied by longer delays and vice-versa denominated as the Bragg's condition.

1.2 MZ Modulator

Mach-Zahnder(MZ) modulator is suitable for the highspeed optical channel. They are made of Lithium Niobate(LiNO3) material. M-Z modulator is used for higher fiber communication lengths.

2. Related Work

Different simulation based research are conducted in the field of Fiber Bragg Grating because of its impact and importance in long distance transmission. As mentioned above it is small in the range of millimeter. Because of small size and low cost it can be easily be implemented in fibers. [1] FBG is used to compensate chromatic dispersion. This paper deals with the improvement of long transmission channels by comparing the system executing FBG and system without FBG executed. And from the simulation we can clearly see that system using FBG perform better. Whereas, in [2] it deals with the bit error rate. From these paper we were motivated to work on this topic and after clear study on this topic we found that by changing some design consideration we can further increase the performance of optical fiber transmission.

3. Design considerations

Prime elements of an optical transmission system can be divided into mainly three parts, optical transmitter, modulator and the optical receiver. The following parametric considerations were made for modeling the optical system .

- Light Source - CW Laser (193.1 THz)

- Non- Return To Zero (NRZ) Pseudo Random Bit Generator (101010101..)
- 10Gbps Practical Bit-Rate
- sequence length is 8-bit.
- Operating wavelength is 1550 nm
- Typical value of attenuation is 0.20 dB/km.

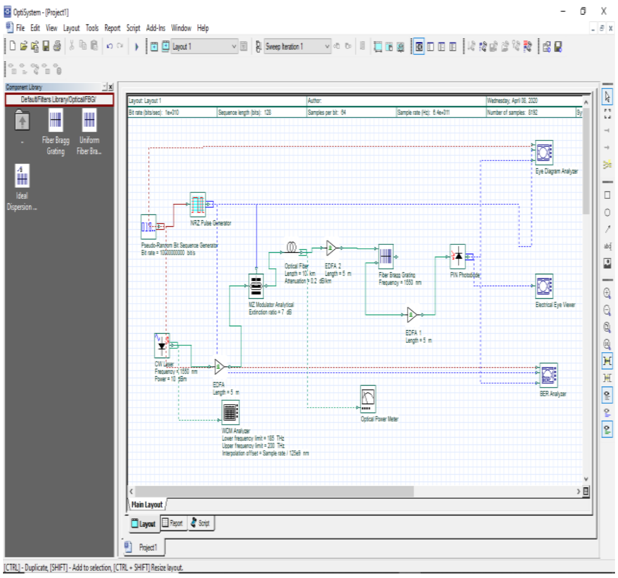


Figure 1 Optiwave Simulation Model for Dispersion Compensation Optical Transmission System

4. Simulations and Results

Our designed optical communication system is modeled and simulated.

- *STEP (1)*: The uncompensated model is simulated. Waveforms and Eye diagram are observed.
- *STEP (2)*: After that, FBG is implemented along with the fiber amplifier Erbium-doped Fiber Amplifier (EDFA) and various parameters like link lengths, sample bits were changed and the results were analyzed. Q- factor, eye diagrams were continuously visualized.
- STEP (3): Performance comparsion between these two were done.

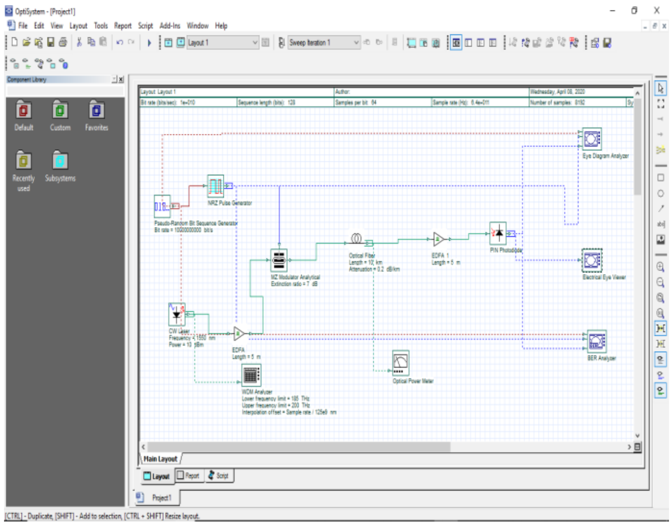


Figure 2 No compensation Model

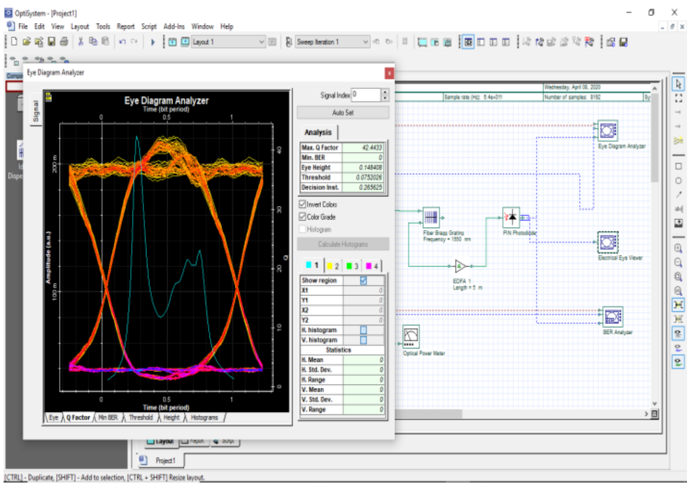


Figure 3 Clearer Eye Diagram with Higher Q-factor after compensation Applied

4.1. 1310 nm VS 1550 nm

The choice of wavelengths to be implemented subjects on various factors mainly loss and dispersion which must be minimized in order to achieve an elegant transmission performance. 1550 nm is operated in a single mode fiber while 1310 nm is implemented in both single mode and multimode optics. The attenuation used in our simulation model is for an average fiber type condition i.e. 0.2 dB/km for 1550 nm fiber whereas 0.4 dB/km for 1310 nm fiber although maximum attenuation can range upto 1 dB/km.

5. Tabulations and Analysis

We ran our simulation for different operating wavelengths. The output values of the parameters representing the optical performance of our model is based on the Eye Diagram Analyzer component subject to the: Optisystem application. The readings are tabulated by varying the fiber link length (Km).

TABLE I
OPTICALLINK LENGTH VARIATION TABLE

S.N	1550 nm		
	Fiber Link Length	*without FBG*	*With FBG*
1	10	14.21	42.44
2	20	10.29	21.64
3	30	5.84	15.41
4	40	5.67	11.88
5	50	5.57	7.64

[a] Link length in Km

- **1310 nm fiber link was implemented on the same simulation model and following results were tabulated :**

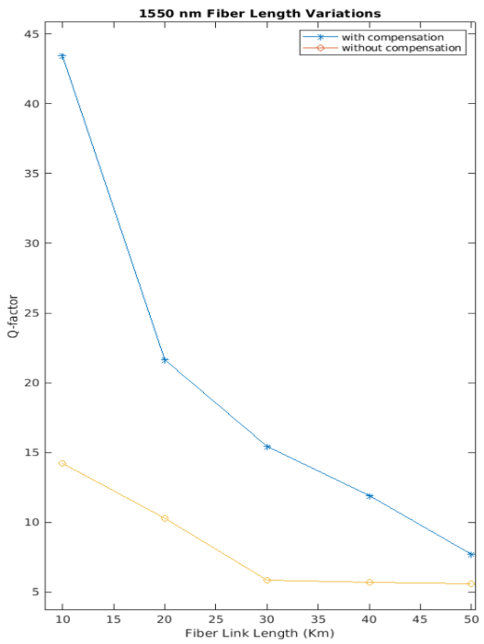
TABLE II
OPTICAL LINK LENGTH VARIATION TABLE

S.N	1310 nm		
	Fiber Link Length	*without FBG*	*With FBG*
1	10	12.47	27.08
2	20	8.75	20.29
3	30	5.93	9.23
4	40	5.92	6.70
5	50	5.44	6.67

[a] Link length in Km

6. Eye Diagram Analysis

Eye Diagrams are used to visualize a data signal and its inter-symbol interference(ISI) during the data transmission. Various parameters were visualized like wider eye opening, eye height (represents SNR noise level), jitter, bit period, decision instant , etc.



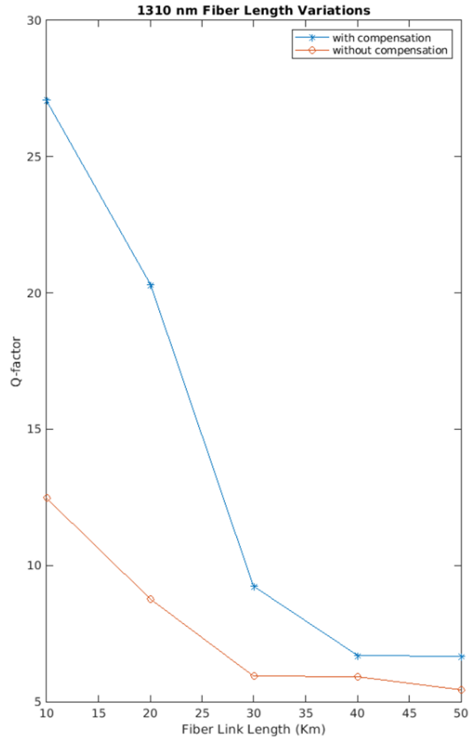


Figure 4 compersion of Q-factor for different fiber length

7. RESULTS

We ran our comparative analysis on the fiber communication system with dispersion compensation systems (i.e EDFA's + FBG) and without it. Eye diagrams and BER were contiously analyzed for a 50 km, 1550nm optical fiber. The eye height increased to certain extent when the FBG was implemented. The signal to noise ratio (SNR) of information signal is directly represented by the eye closure. [10] From our analysis, it can be surmised that compensated system resulted in less distortion consequence by clearer wider. Eye diagram with the significant improvement in the Quality factor(Q-factor).

Q-factor represents the minimal signal-to-noise ratio(SNR) required to achieve desired bit-error rate(BER) for the acceptable receipt of the optical signal. So, for better BER, the value of Q-factor should be higher. The decision instant decreases significantly from 0.843 to 0.265 for a 1550 nm fiber after using FBG compensation. The eye diagram becomes less susceptible to distortion and wider eye opening. Similarly, the Q-factor also increased significantly when the dispersion compensation components were applied to the same simulation model.

8. CONCLUSION

Performing this optical simulation has significantly helped in gaining apprehension to a lot of extent in the world of fiber optics communication. Related articles have been uncovered and thorough idea around the subject has been achieved. Based on the research, the transmission system design elements like light source, modulator were separately studied and chosen to fit for the best practical optical transmission scenario. From our above analysis, it can be culminated that the optic fiber channel length is inversely proportional to the Q-Factor. Hence, it is concluded that the application of fiber dispersion compensator FBG will be the best for a 1550 nm single mode fiber than to the 1310 nm SMF for a long distance transmission(50 km). The best use of the fiber compensation techniques can be implemented for 10 Km fiber.60 km would not be feasible for a 10 Gbps system since it doesn't satisfy the tolerable Q-factor as simulated. In order to improve the transmission performance, the simulation implemented the Bragg Grating mechanism and the results were rigorously monitored and visualized.

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