Dispersion Compensation in Optical Fiber Communication using Fiber Bragg Gratings

Ankit Tyagi[1] Aditya Prakash Kulshrestha[2] Dr. Amit Kumar Garg[3]
[1,2]M.Tech Student [3]Chairman
[1,2,3]Department of Electronics and Communication Engineering
[1,2,3]DCRUST, Murthal, Sonipat, Haryana

Abstract— Chromatic dispersion is a critical factor that limits the quality of transmitted optical signal in high speed fiber optic communication systems. Chromatic dispersion occurs due to the propagation delay spread of different spectral components of the transmitted signal. This leads to the pulse broadening of transmitted signal. In order to operate the fiber optic communication system with a sufficiently low bit error rate and to minimize the performance degradation caused by pulse distortion and broadening, dispersion compensation is needed. The purpose of this article is to compensate the chromatic dispersion using Fiber Bragg grating. Simulation results will be obtained using OPTSIM software version 5.4. Effect of chromatic dispersion in an optical fiber link was analyzed. Simulation using Fiber Bragg grating by varying its grating period and linear chirp coefficient was obtained.

Key words: Chromatic dispersion, OptSim, Fiber Bragg grating (FBR), Eye diagram.

I. INTRODUCTION

Optical transmission systems have been managed to our demands to be able to transfer the required data volumes. Unfortunately, these requirements are increasing, forcing us to deal with problems, which we saw only in theory so far. Specifically, one of these is the chromatic dispersion influence. Optical transmission system transmits information encoded in optical signal over long distances. The electrical signal in the transmitter at the fibre input is converted into light impulses that are transferred through the fibre to the receiver at the end of the fibre. In the receiver the light impulses are converted back to the original electrical signal (1).

The use of erbium doped fiber amplifiers (EDFA) in optical communication systems has made chromatic dispersion the most significant limitation for the transmission performance since EDFAs compensate for the transmission losses. The chromatic dispersion in optical fiber is a phenomenon caused by the wavelength dependence of its group refractive index (2). In optical fiber, the wavelength dependence of the fiber group refractive index causes a temporal broadening of the pulses as they are propagating. Fiber Bragg Grating (FBG) is commonly chosen as important components to compensate the dispersion in optical communication system. Because the low cost of filter for wavelength selection and low insertion loss, it has also customized reflection spectrum and wide bandwidth. The simulation of transmission system will be analyzed based on different parameters by using OptSim simulator .By simulating a model of optical communication system (3).

In this study, the simulation of the optical transmission system in input power (dBm), fiber cable length (km) and attenuation coefficient (dB/km) at cable section has been discussed by analyzed the effect of the components in data receiver by using different parameters setting. The value of parameters has been investigated such as output power (dbm), noise figure (dB), and gain (dB) Q-Factor (db) at receiver. All the results are analyzed using OptSim simulation at 10 Giga bits per second (Gb/s) transmission systems (4).

II. FIBER BRAGG GRATING

A fiber Bragg grating is a piece of optical fiber with periodic variation of the index of refraction along the fiber axis. Such a phase grating acts as a band rejection filter reflecting wavelengths that satisfy the ragg condition and transmitting the others [5]. Fiber Bragg gratings act like tiny mirrors in a fiber that reflect specific wavelengths due to periodic changes in the index of the fiber core. Fiber Bragg gratings couple light from a forward propagating guided mode into a backward or counter propagating guided mode at the Bragg wavelength (λB) (6, 12). This is the wavelength for the Bragg reflection, which is the phenomenon by which a single large reflection can result from coherent addition of many small reflections from weakly reflecting mirrors spaced a multiple of half of the wavelength apart. The equation relating the grating periodicity and the Bragg wavelength depends on the effective refractive index of the transmitting medium, n_{eff}, and is given by equation 1 (7);

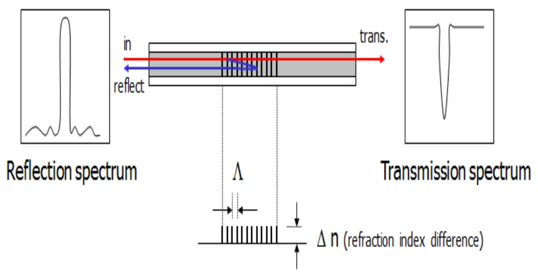

Fig. 1: Fiber Bragg Gratings (8).

$$\lambda_B = 2n\Lambda \quad (1)$$

In the equation (1), n and Λ are refractive index of core and grating period in fiber, respectively (9).

Figure1.also shows the application of a FBG as a filter. Light waves at several different wavelengths are traveling through the optical fiber and entering into the FBG. One of the wavelengths (λB) is reflected back by the FBG which comes back to the coupler. The coupler separates the Bragg wavelength from the incoming wavelengths and the reflection spectra of this reflected wavelength can be seen on an optical spectrum analyser (10, 11).

III. OPTSIM SIMULATOR

OPTSIM is a modelling tool and simulation environment supporting the design and the performance evaluation of the transmission level of optical communication systems. The OptSim is a suitable platform in designing of all optical networks. In this paper, OptSim will be evaluating the performance analysis such as Q value, BER, Power, and eye diagram. Eye diagram is often used to display the transmitted or received signal quality. The eye opening is a useful parameter in determining the degradations of an optical link. An open eye with large, wide and sharp lines means good performance, while noise and inter symbol interference appears as spreading of the rails. Figure 3.1 shows the layout of OPTSIM used to create the optical link design.

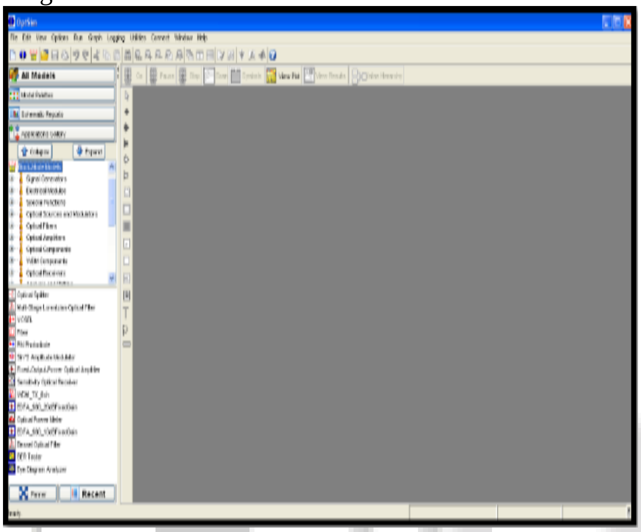

Fig. 2: OptSim Simulator.

IV. DESCRIPTION OF COMPONENTS AND CONSIDERATION

NRZ pulse generator has an advantage on controlling bandwidth. This is due to the characteristic of the generator that the returning signals to zero between bits. Pseudo-random bit sequence generator is used to scramble data signal in terms of bit rates. Mach Zehnder Modulator (MZ) has two inputs (optical signal and electrical signal) and one output (optical). Then the input signal is modulated with semiconductor laser that is represented by Continuous Wave (CW) laser Frequency 193.1 THz through Mach- Zehnder modulator. Continues laser diode (CW) to generate optical signals supplies input signal with 1550 nm wavelength and input power of 5dBm which is externally modulated at 10 Gbits/s. with a non-return-zero (NRZ) pseudo random binary sequence in a Mach-Zehnder modulator with 30 dB of extinction ratio. The optical fiber used is single mode fiber because has higher data rate and long distance transmission. The fiber Bragg grating is used as the dispersion compensator.The FBG length 5 mm Photodetector (PIN) Diode Positive Intrinsic Negative to translate the optical signal into an electrical signal. The initial settings for the design are shown in Figure2. Order to operate as the optical transmission system: Input power 5Db, Reference wavelength 1550nm, fiber length 15km, and Attenuation coefficient of cable 0.2dB/km.

V. SIMULATION OF A TRANSMISSION SYSTEM

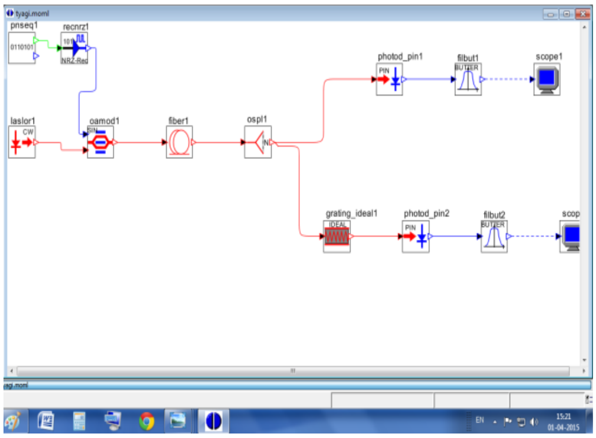

Fig. 3.The Designed Model of Simulated System With Optsim Software.

The dispersion compensation is simulated by comparing the eye diagrams of before compensation amd after compensation.

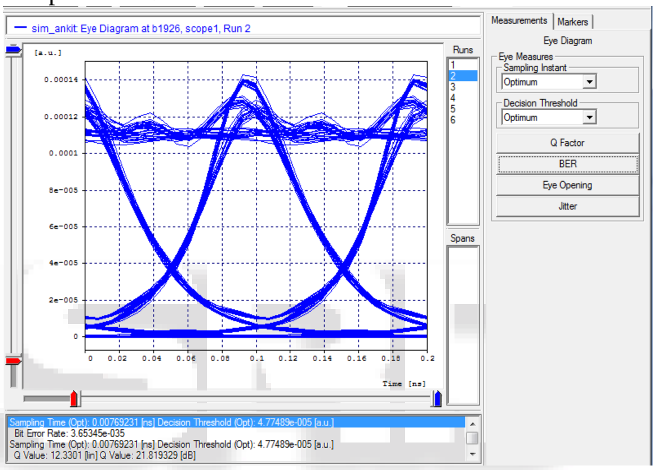

Fig. 4: Before Compensation

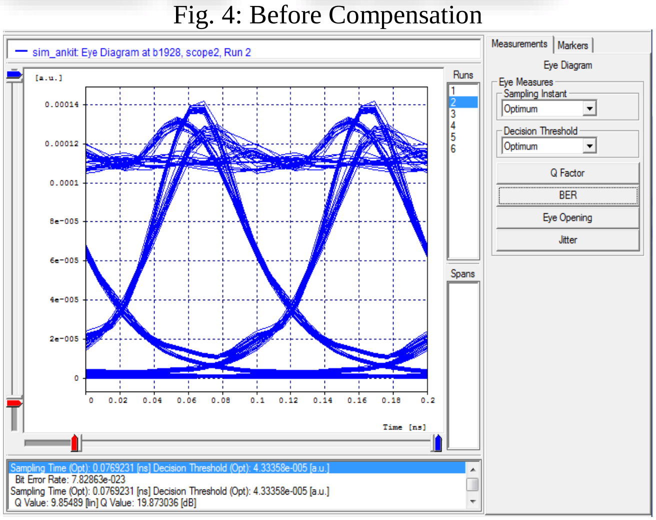

Fig. 5: After Compensation

VI. RESULTS

The Figure 4 shows signal of transmitting waves after through the fiber. This shows the error signal is more compare to before transmitting through the fiber. The Figure 5 shows Eye diagram obtained after transmitting through FBG. From the Table 1, it is concluded that as the bit error rate decreases the dispersion also decreases. It is concludes that as grating period decreases the dispersion decreases.

Fiber Length	Eye Height	Q Factor	BER Rate
10	2.66*10-4	23.0001	$4.24*10^{-18}$
30	1.07*10-4	12.3301	$2.303*10^{-15}$
50	4.03*10-5	8.868873	$3.2*10^{-8}$
70	1.43*10-5	6.97178	$3.66*10^{-5}$
90	4.14*10-6	5.08341	$2.865*10^{-3}$
120	1.31*10-6	2.66065	$0.7*10^{-2}$

Table 1: Before Compensation

Fiber Length	Eye Height	Q Factor	BER Rate
10	2.66*10-4	21.897	$4.24*10^{-18}$
30	1.04*10-4	9.85489	$8.032*10^{-10}$
50	3.84*10-5	8.86873	$2.57*10^{-7}$
70	1.37*10-5	6.97178	$2.08*10^{-5}$
90	3.31*10-6	5.08341	$1.08*10^{-2}$
120	1.04*10-6	2.66065	$0.3*10^{-2}$

Table 2: After Compensation

VII. CONCLUSION

Different dispersion techniques in optical fiber communication system are studied. Effect of dispersion in fiber optic link was analyzed using eye diagrams. Fiber Bragg Gratings techniques used to compensate the chromatic dispersion. Simulation model for dispersion compensation using fiber Bragg grating is developed. Bit error rate of signal before and after transmitting through the fiber Bragg grating was compared by varying its grating period and linear chirp coefficient

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