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PERFORMANCE ANALYSIS OF OPTICAL TRANSMISSION SYSTEM USING FBG AND BESSEL FILTERS

Antony J. S., Jacob Stephen and Aarthi G.
ECE Department, School of Electronics Engineering, VIT University, Vellore, Tamil Nadu, India
E-Mail: antonprotonspare@gmail.com

ABSTRACT

The optical fiber has found great application in long distance communications, as light the medium of information transfer attenuates very less compared to electric pulses in cables. However the major issues that limit efficiency are chromatic dispersion and non-linear effects. Fiber Bragg Grating (FBG) is widely used as a component to compensate dispersion on account of its low insertion loss. This paper provides a method of using a combination of FBG as a dispersion compensator and Bessel filter to improve the Q factor of the system and also reduce the noise figure. A 10 Gb/s NRZ pulse is launched into the fiber and the performance of the system is evaluated using Optisystem simulator. The Q factor of the system is then investigated with and without use of Bessel filter. The simulation is analysed with respect to input power, fiber length, and attenuation coefficient.

Keywords: fiber bragg grating (FBG), erbium doped fiber amplifier (EDFA), bessel filter.

1. INTRODUCTION

Fiber optic communication is the process of representing the digital ones and zeroes as pulses of light. The message is transmitted from transmitter to receiver connected by an optical fiber, which acts as a channel. Fiber optics offer exceptionally low loss, longer distance between repeaters, high data carrying capacity and less cross talk. However one of the major problems it faces during its propagation is dispersion which causes overlapping of pulses leading to inter Symbol interference (ISI). This paper investigates a method of using FBG to reduce dispersion [1] and also discusses further improvement in the quality factor and performance of the system. FBG is the key component in optical communication system as, dispersion compensators, filters and flatteners gain. In the transmission section, the gratings are placed in the line with the fiber. It helps to achieve the maximum compression ratio [2]. Another key component is EDFA .These provide high bit rate data transmission over long distance with appropriate optical amplification. [3] Bessel filters is used to remove the noise in both the optical and electrical part of the system. Opti-System is a comprehensive software design suite that enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks [4].

In this paper, the simulation of the optical transmission system in optical fiber has been discussed by analyzing the effect of the attenuation coefficient (dB/km) at cable section, input power (dBm) of the laser and length of the fiber cable (km). Parameters such as output power (dBm), noise figure (dB), and gain (dB) at receiver have their values improved [1] using cubic root chirped FBG and Bessel filters.

2. BACKGROUND THEORY

A. Fiber Bragg Grating

Fiber Bragg Grating (FBG) is very simple and low cost filter for wavelength selection which has various applications to improve the quality and diminish the costs in optical networks [3]. FBG executes some operations like reflection and filtering with high efficiency and low loses [3]. In this paper a chirped FBG is used as a Dispersion compensator. Due to dispersion there is a phenomenon of broadening of light pulse. This pulse broadening can be re-compressed by using FBG. FBG introduces wavelength specific time delays. The faster wavelengths of the pulse are reflected farther away than the slower wavelengths. This means that they are reflected after longer propagation than the shorter wavelengths. Thus there is a delay created in the faster wavelength. This delay in the faster wavelength is exactly opposite to that created due to dispersion and is enough to compensate for the pulse broadening.

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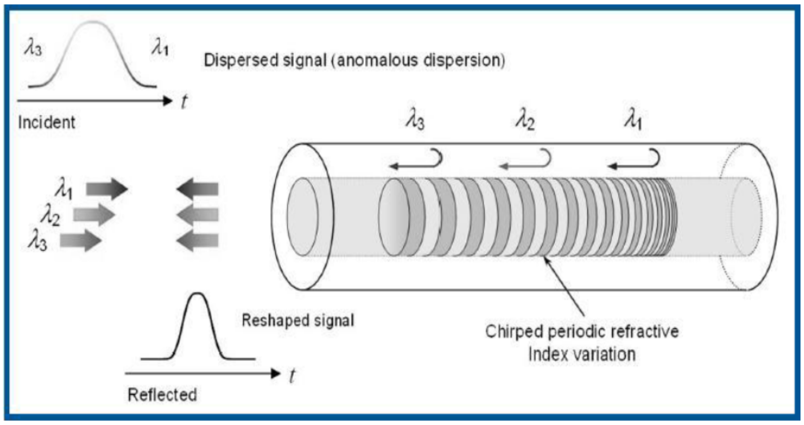

Figure-1. A chirped FBG compensate for dispersion by reflecting different wavelengths at different locations along the grating lengths [3].

3. SIMULATION

A. Components

Non Return to Zero (NRZ) pulse generator is used since the NRZ format has the characteristic of conservation of bandwidth. Pseudo-random bit sequence generator is used to scramble data signal in terms of bit rates [5]. The input signal is modulated on a laser source represented by a CW laser at a wavelength of 1550nm and power of 5 dBm. Modulation is done using a Mach-Zehnder modulator which has two inputs (optical signal and electrical signal) and one output (optical). The system is analysed with variation to the input power of the laser source and also the length and attenuation factor of the optical fiber. The FBG is used as a dispersion compensator. Erbium Doped Fiber Amplifier (EDFA) is used to amplify the signal. PIN photo detector is used in the receiver to convert the optical signal to electrical signal. The Bessel filters are used both in the optical part and the electrical part (i.e. after conversion by photo detector) of the receiver. It has maximally flat group delay which means that its phase response is the most linear when compared to other filters. It does not produce any ringing in its response in the pass band, thus being an ideal analog filter to be used in this design. The Bessel optical filter is used in the optical part of the receiver to reduce the noise. The noise after conversion from optical to electrical is reduced by low pass Bessel filter.

B. Design consideration

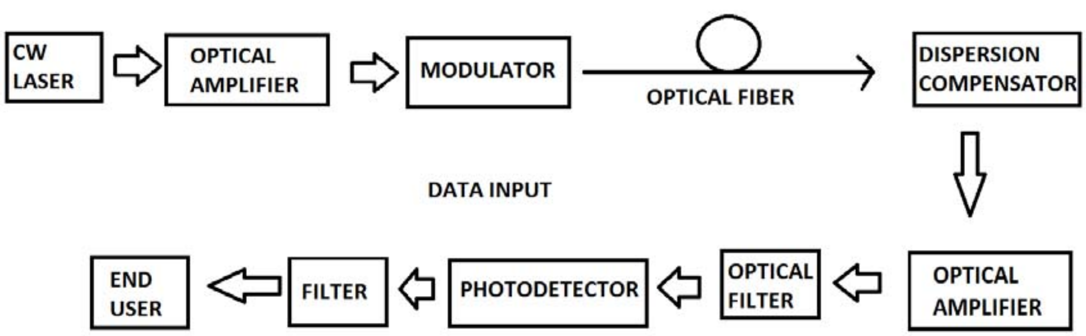

Figure-2. Functional block diagram of the system.

The functional block diagram of our system can be fundamentally reduced to a transmitter section, a fiber media section (channel) and a receiver section. The transmitter section consists of the pseudo random bit sequence generator, the Mach Zehnder modulator, NRZ pulse generator and a CW laser. The input signal is modulated on a laser source represented by a CW laser at a wavelength of 1550nm and power of 5 dBm. Modulation is done using a Mach-Zehnder modulator with an extinction ratio of 30 dB. The pseudo random generator is set to a bit rate of 10 GHz and the line width of the CW laser is defined as 5 MHz. The system is analysed with

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variation to the input power of the laser source and also the length and attenuation factor of the optical fiber. The FBG used is designed for the wavelength of 1550nm and a length of 6mm. The chirp function of the FBG is set to cubic root. Erbium Doped Fiber Amplifier (EDFA) is used to amplify the signal. PIN photo detector is used in the receiver to convert the optical signal to electrical signal.

The Bessel filters are used both in the optical part and the electrical part (i.e. after conversion by photo detector) of the receiver. It is set to have a frequency equal to that used in transmitter (i.e. wavelength of 1550nm) and bandwidth four times that of the bit rate of the system. The cut-off frequency of the low pass Bessel filter is set to be 0.75 times that of the bit rate.

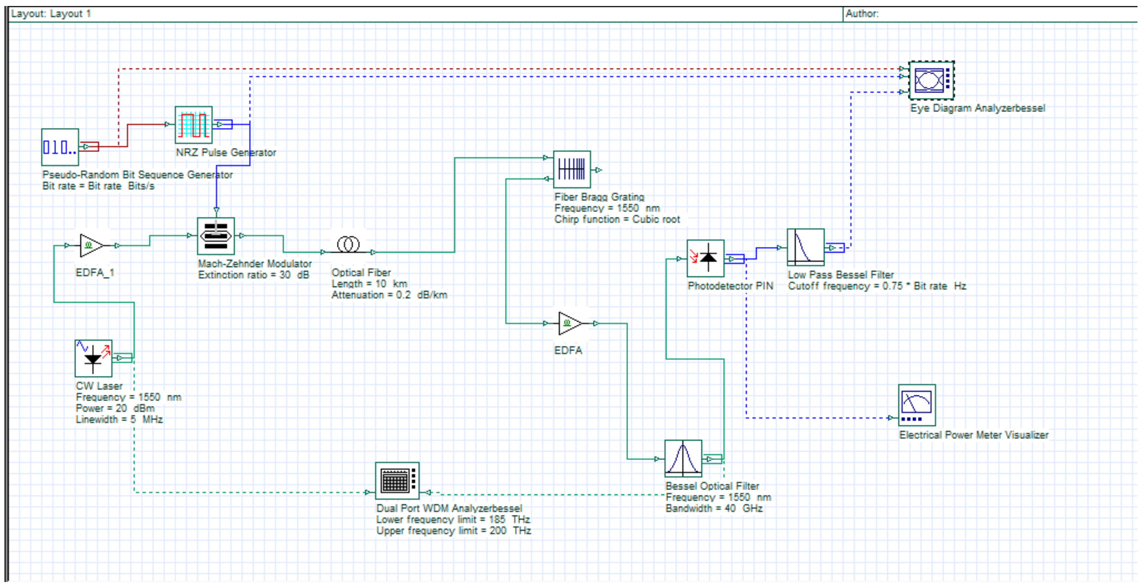

Figure-3. Model design in Opti system software.

4. RESULT AND DISCUSSIONS

The simulation and optimization of the design is done by OptiSystem simulation software. The eye diagrams and results of output power, gain (dB) at receiver, noise figure are tabulated into the following tables by using different values of input power (dBm), attenuation coefficient (dB/km) at cable section, and fiber cable length (km). The related graphs are also plotted as shown in Figure 5, 6, and 7.

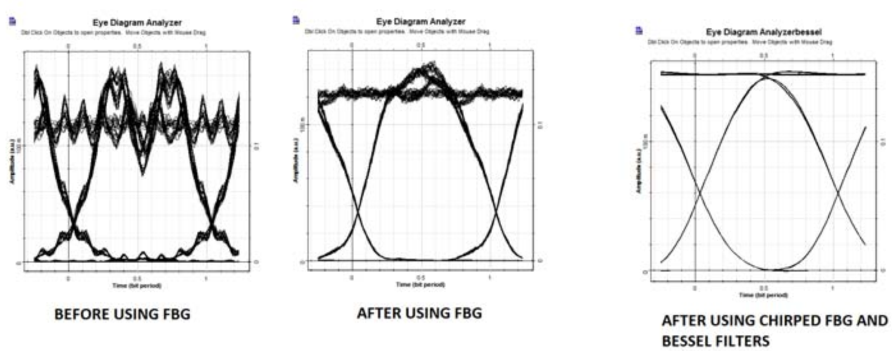

Figure-4. The differences of the eye diagram for the various designs.

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Table-1. The output readings by varying the fiber lengths.

Length (km)	**Gain** (dB)	**Noise figure** (dB)	**Output power** (mW)
5	13.464391	-0.841248	10.675
10	13.272746	-0.217414	9.747
15	13.104021	0.44038	9.060
20	12.956952	1.12484	8.570
25	12.824551	1.85122	8.213
30	12.70577	2.61864	7.953

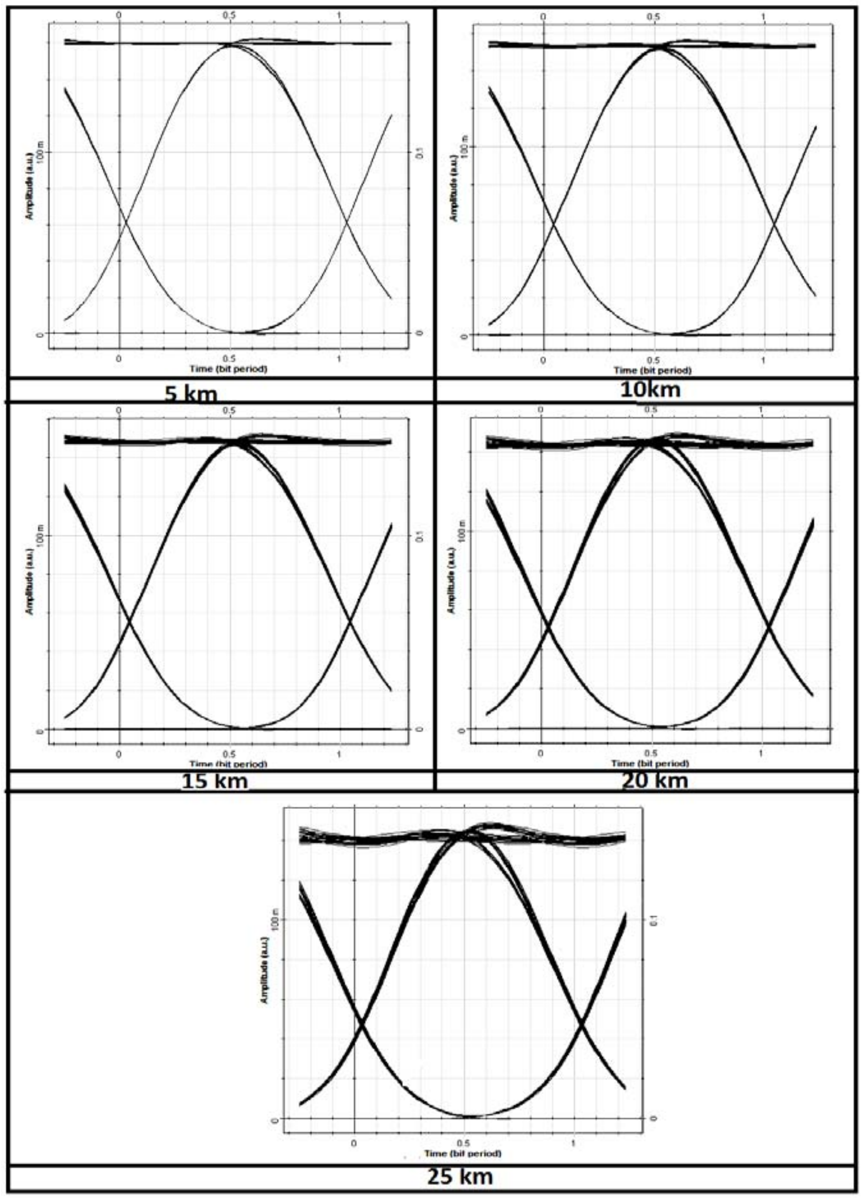

Figure-5. Eye diagrams for different values of fiber length.

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Table-2. The output readings by varying the input power.

Input power (dBm)	**Gain** (dB)	**Noise figure** (dB)	**Output power** (mW)
1	17.236009	-4.06752	9.583
5	13.272746	-0.217414	9.747
10	8.367746	4.45018	10.185
15	3.623914	8.70523	11.490
20	-0.73461185	12.3188	15.919

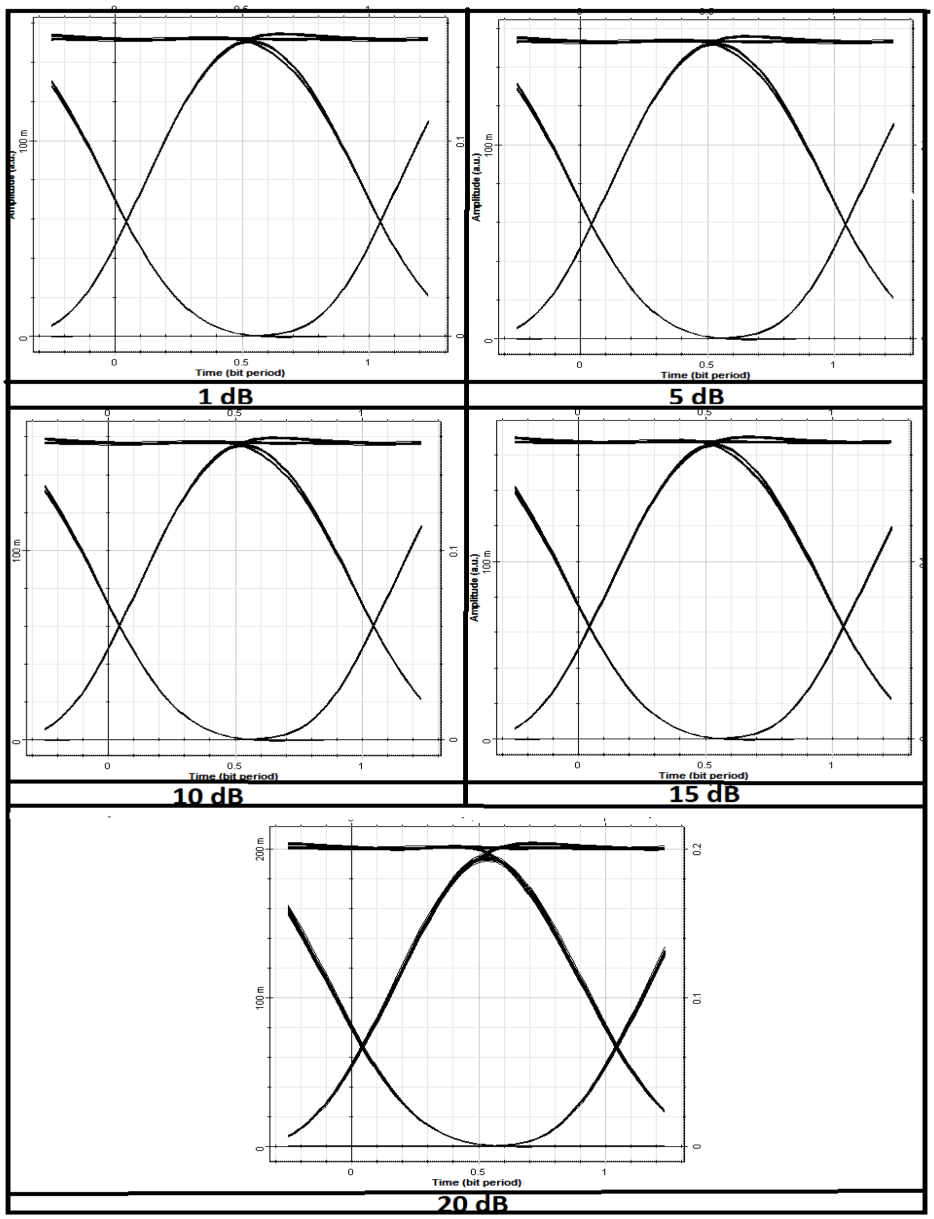

Figure-6. Eye diagrams for different values of input power.

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Table-3. The output readings by varying the attenuation coefficient at cable section.

Attuenation coefficient (dB/km)	**Gain** (dB)	**Noise figure** (dB)	**Output power** (mW)
0.2	13.272746	-0.217414	9.747
1	12.502719	5.69918	6.862
3	9.8232566	25.5088	2.004
5	-6.6110594	46.0584	0.0001098

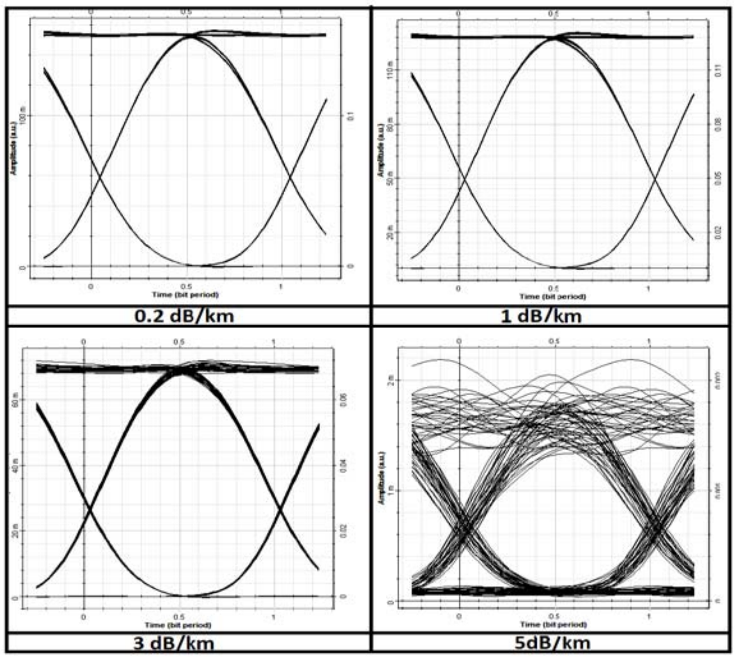

Figure-7. Eye diagrams for different values of attenuation coefficient at cable section.

In this paper an efficient implementation of the optical system using FBG has been designed. This improvement can be seen from Figure-4 as seen in the comparison of the eye diagram. The system before using FBG has a Q factor of 13.389. Normal implementation of FBG improves the eye diagram and also the Q factor to 60.145. Finally the implementation of the system used in the paper shows further improvement in the eye diagram and also increase in Q factor to 103.6. The tables show the variation of noise Figure, gain and output power with length and attenuation factor of the fiber cable, and input power fed. From Table 1 it can be seen that as fibre length increases the gain and output power decreases while the noise figure increases. Increase in input power fed increases both noise and output power and this can be inferred from Table-2. Table-3 shows that increase in attenuation coefficient increases noise while decreasing the output power.

6. CONCLUSIONS

Usage of FBG as a dispersion compensator is prevalent and this paper discusses a method to further improve its performance by using Bessel filter and implementation of cubic root chirp function in the FBG. The system block diagram focuses on improvement on Q factor and decrease of noise figure through usage of Bessel filters. The optical carrier wave is modulated by the Mach Zehnder modulator and launched to the fiber. The loss of power is compensated by sufficient amplification introduced by the Erbium Doped Fiber Amplifier. Through in-depth research the most appropriate length of the grating element was found to be 6mm. From the analysis of the eye diagram in the Figures 5, 6, 7 we can see that the attenuation coefficient of the fiber introduce the greatest change in the output.

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