Dispersion Compensation Analysis of Optical Communication Link using FBG

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***Abstract*-This paper is discussed on an elimination of dispersion using Fiber Bragg Grating (FBG). FBG is termed as a Bragg reflector constructed in a short segment of optical fiber that reflects particular wavelengths of light and transmits all others. The modulation format used is Return to Zero. In this paper initially we analyze the fiber optical transmission using Return to Zero formats for increasing lengths and then comparing those results with the optical transmission integrated with dispersion compensation technique. FBG is used as the key element for optical communication as dispersion compensators. The performance analysis is based on the occurrence of dispersion for varying lengths.**

Index Terms- Single mode fiber, Fiber Bragg Grating and Return to Zero.

I. INTRODUCTION

Fiber Optic Communication is a method of transmitting information from one place to another place by sending pulses of light waves through fiber. The light wave forms an electromagnetic carrier wave that is modulated to carry information through fiber [1].The optical fiber used here is single mode optical fiber which gives the minimum pulse broadening and greatest bandwidths in gigahertz range [2]. Optical fiber is used for long haul communication and for high demand applications.

The transmission characteristics of the optical fibers are attenuation (or loss) and bandwidth. The material used for the fiber is glass which can be used to carry wideband telecommunications signals. The attenuation is due to the absorption of the glass material and is caused by some impurities such as iron, manganese, copper etc [3]. The second important characteristic is bandwidth, which is limited by the dispersion of the signal within the fiber and is defined as the number of bits transmitted in the given time period. The dispersion in optical fibers causes distortion for both analog and digital transmission. In 1970, fiber optics was successfully developed with low attenuation and 0.8um wavelength. Hence it replaces the copper wire in the core network. As the fiber optic systems were complex and costly, they are demanded for long distance applications and they can be used to their full transmission capacity. Since 2000, cost of fiber optic system dropped to considerable value.

A block schematic of a general communication system is shown in the given figure1. It is used to convert the signal from the source over transmission medium to the destination. The optical source consists of semiconductor laser and LED. Here, Continuous wave laser acts as the optical source input to modulator. Then the signal is modulated using Mach Zehnder modulator and transmitted through the fiber. This modulator increase the achievable distance over transmission by eliminating laser chirp. At the receiver, Photo detector is used to convert optical signal into electrical signal. Then the output is displayed using spectrum analyzers.

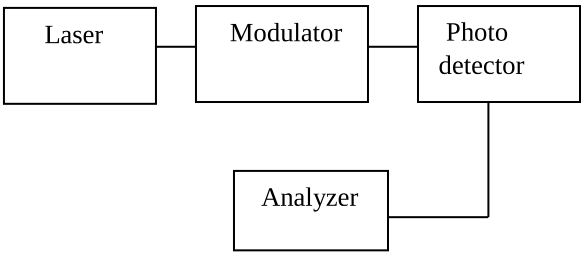


Fig. 1.Basic block diagram of optical communication link

In mach zehnder modulator signal is converted into optical signal which is transmitted through the optical fiber. When we increase the length of the fiber, losses will occur in the form of attenuation and dispersion where attenuation creates less loss in fiber when compared to dispersion. Attenuation can be reduced by using amplifier such as EDFA. Dispersion in the fiber, when consider with the digital modulation is defined as the broadening of the signal pulse width with the dependence of refractive index of the fiber material. When each pulse broadens it overlaps with the neighbor pulse and becomes indistinguishable at receiver output. This effect is known as inter symbol interference (ISI). The dispersion degrades the quality of received signal output [4]. Hence, one of the dispersion compensation techniques Fiber Bragg Grating is used. The fundamental principle of FBG is Fresnel Reflection. It states that when a light travels between media of different refractive indices for e.g. Air and glass, they tend to reflect and refract at the interface [5],[6].

The optical carrier frequency is about 10^{13} to 10^{16} Hz. It yields a far greater potential transmission bandwidth. Optical fibers have very small size, diameter and light weight. It has immunity to interference and cross talk.

II. RZ MODULATOR

The Return-to-zero modulation format is used for digital transmission of data in the transmitter section. The RZ line code acts according to the fact that, if the bit one is transmitted, the pulse amplitude returns to zero before the bit duration is completed [7]. Hence, this format has same pulse width throughout the bit transmission.

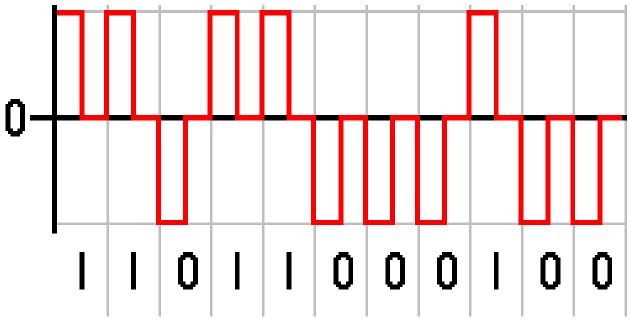


Fig. 2.graph of RZ format

Figure2 represents an example for the binary signal encoded with RZ format,in which the amplitude drops to zero with short duration of pulses.

The RZ format is used for telecomunication signals and the zero between each state is called neutral or rest condition and is considered as the halfway between significant condition of bits one and zero[8]. The RZ format is considered as that when bit 1 is transmitted it travels in half of the bit period. The data rate is equal to the bandwith in Hertz. Thus, B_T=B. Where B_T is the digital bit rate and B is the bandwidth for metallic conductors.The RZ format is used for high capacity communication systems [8]. It is used for producing the electrical input signal which is obtained by using the pseudo random bit sequence generator as the input source.

The RZ sequence generator consists of two states of bit transmission (i.e.) lower and higher binary states. The lower state denotes zero bits and higher state denotes one bit [9]. The changes between the states are represented by the voltage pulses. There are two logics for RZ format, one is positive logic which has more negative voltage in lower state and less negative voltage in the higher state and another one is the negative logic which has less negative voltage in the lower state and more negative voltage in the higher state. The RZ format uses twice the bandwidth as it reduces to Zero even for consecutive ones [10]. They have a self-clocking behavior which does not require a separate clocking signal to be sent alongside with the light waves.

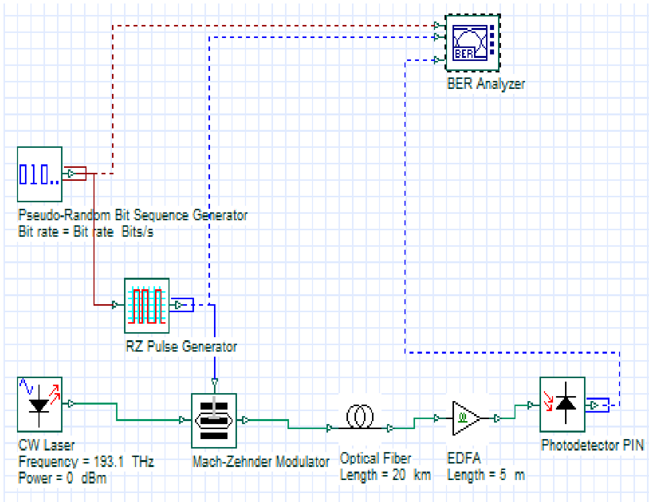


Fig. 3.The model of simulated software using RZ

In Figure3 the optical transmitter consists of electrical and optical sources, where the RZ modulation format is given as electrical input to the Mach-Zehnder Modulator and the optical input to it is Continuous Wave laser. The frequency of CW laser is 193.1THZ. The Mach-Zehnder Modulator output is given as input to the optical fiber link. The fiber link used here is the single mode fiber. SMF can be used for long haul communication and provides less dispersion as they transmit signals with one fundamental mode. The output of the fiber is given into the EDFA.

EDFA is erbium doped fiber optic amplifier which is used as a optical repeater. It splits the input signal into two arms. When the voltage is applied through one arm, phase is induced through that arm and it is cancelled with another arm. The advantage of using EDFA is the amplification of optical signal directly [11]. The electrical output is given into the receiver side where photo detector (i.e.) PIN diode is used and the result is viewed from Bit Error Rate (BER) analyzer.

III. RZ MODULATOR WITH FBG

The FBG plays a challenging role in obtaining dispersion free communication through optical systems. It has a vital phenomenon in the growth of optical components and it acts as the enabling technologies for communication [12]. When the broad spectrum of the light is send through the Fiber Bragg Grating, the reflection from each segment alter the refractive index of the particular wavelengths which is knows as Bragg wavelengths incident on grating and passes all other wavelengths [13]. The figure4 represents the block diagram model of RZ format which has the same blocks as that of RZ simulation except that FBG component is connected as post compensator for dispersion that produced due to increase in transceiver distance [14]. Then the simulation results are analyzed for increasing lengths say 10Km,20Km,40Km,60Km,80Km,100Km and their corresponding Q factor and BER are determined.

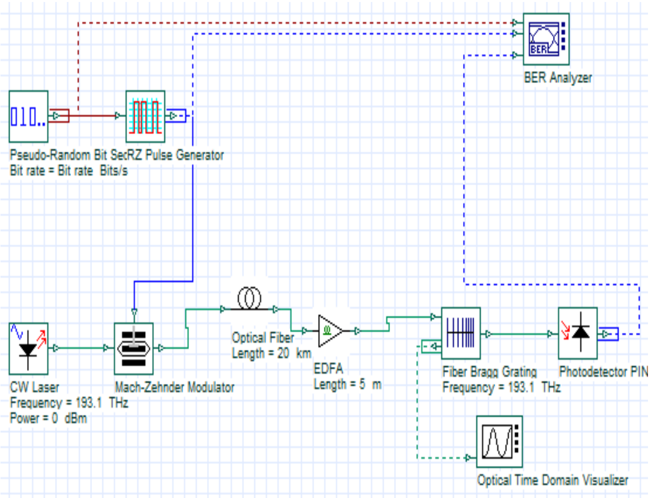
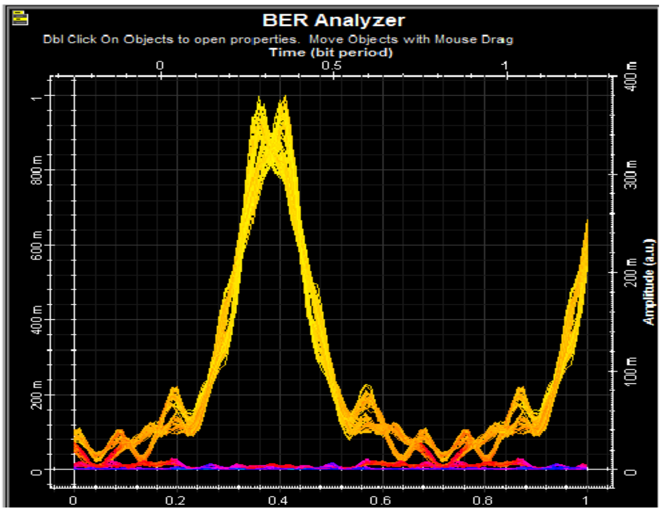


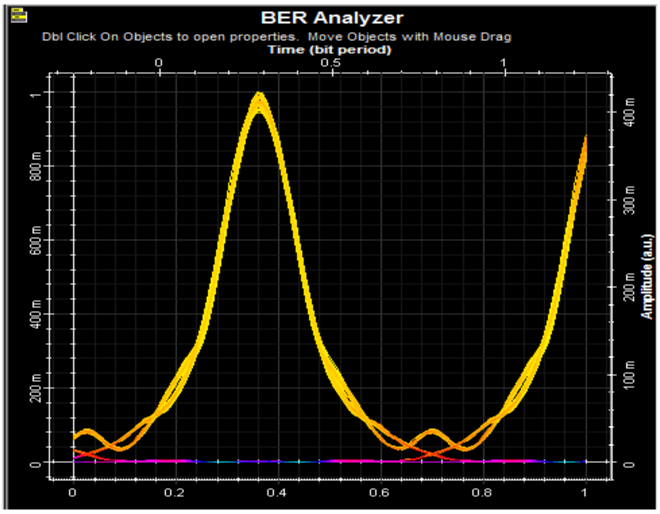
Fig. 4.The RZ simulation with FBG

IV. SIMULATION RESULTS

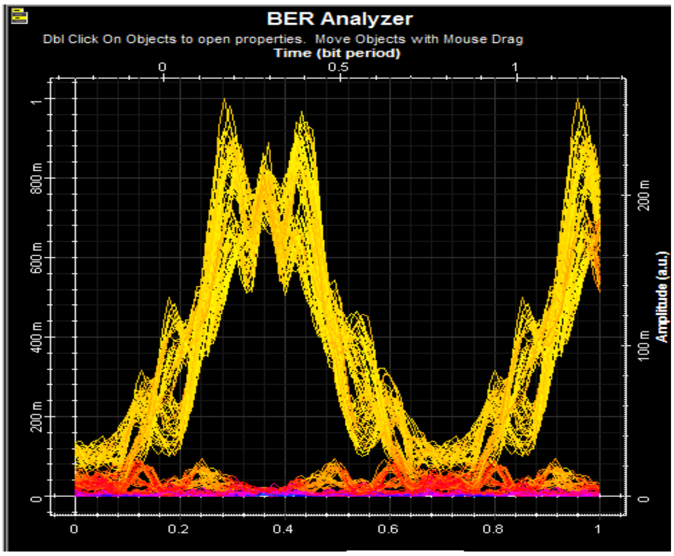
By simulating the above block diagram for RZ modulator without FBG and RZ modulator with FBG, the analysis can be done by varying the lengths of the optical fiber and obtaining the result for parameters BER,Q factor, EYE height opening. The length is varied by certain kilometers as 10, 20, 40, 80, and 100.



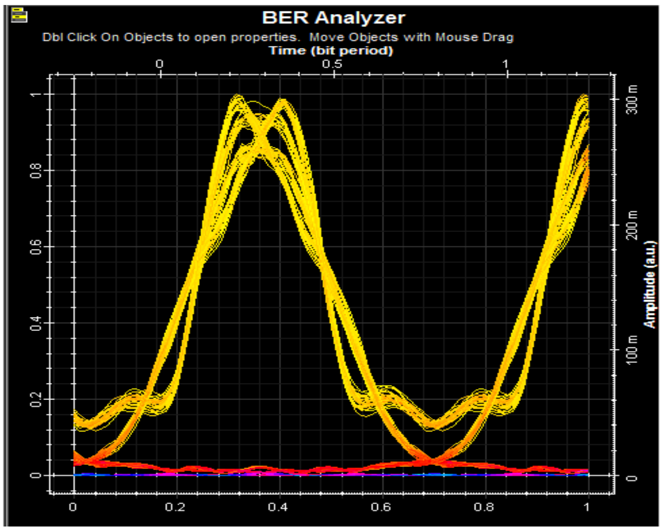
(i) 10KM



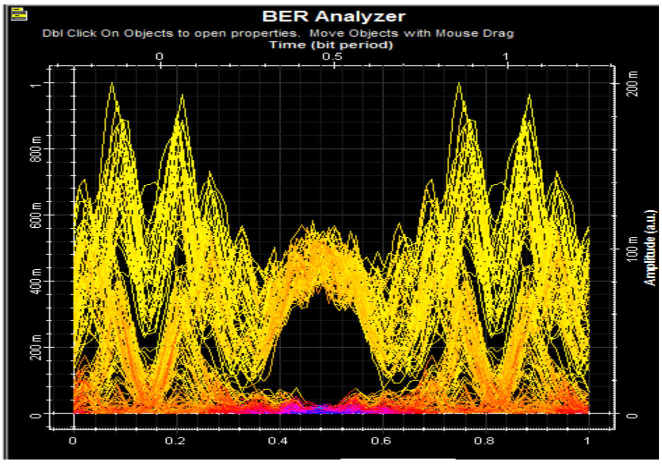
(ii) 10KM



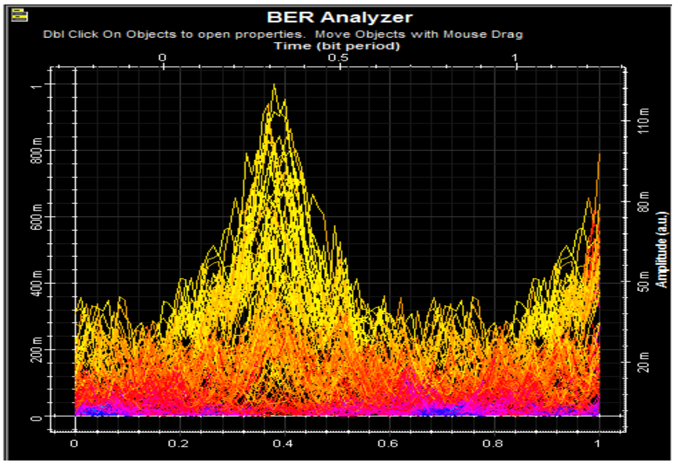
(i) 20KM



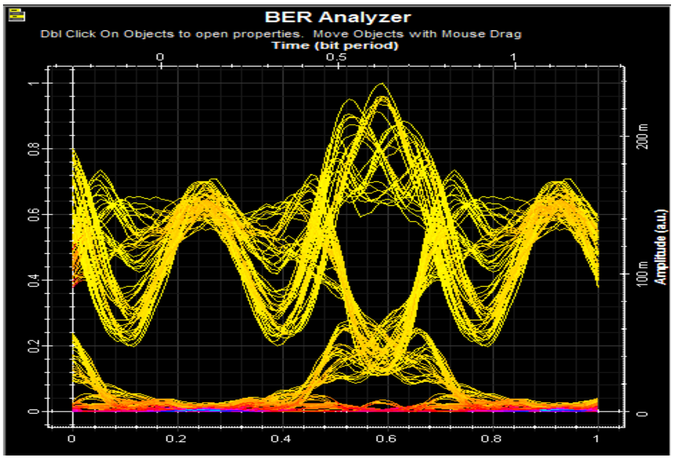
(ii) 20KM



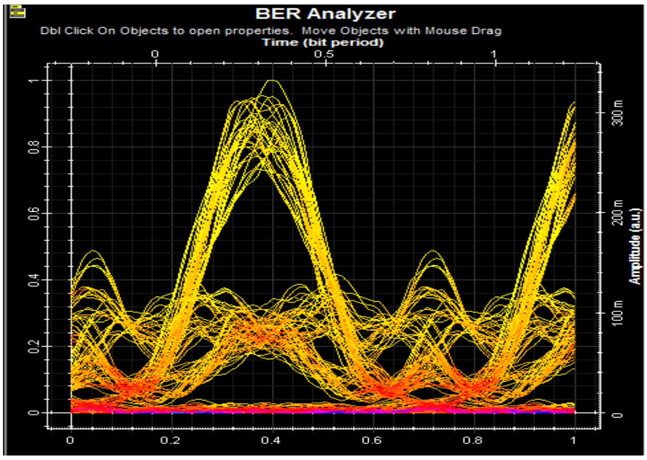
(i) 40KM



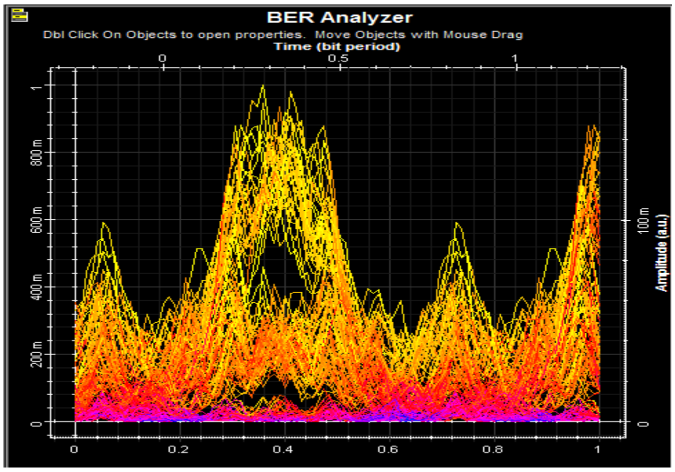
(ii) 60KM



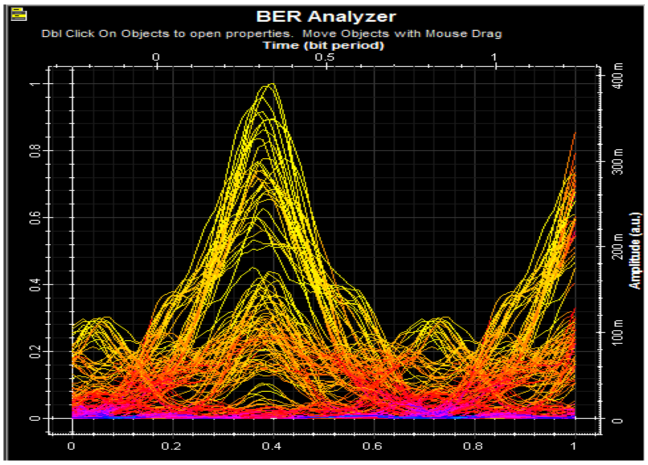
(ii) 40KM



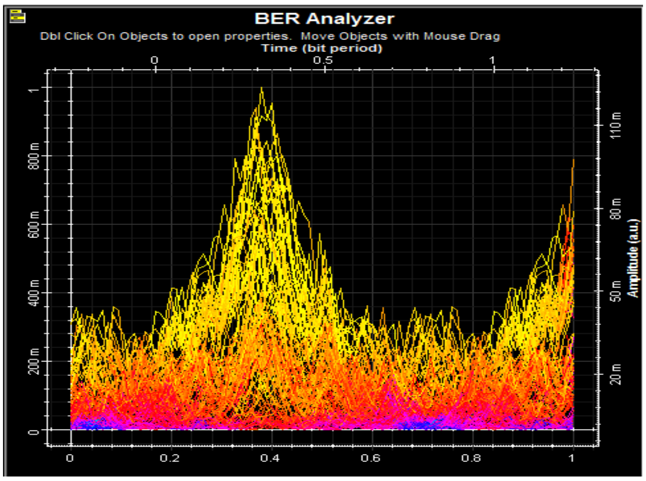
(i) 80KM



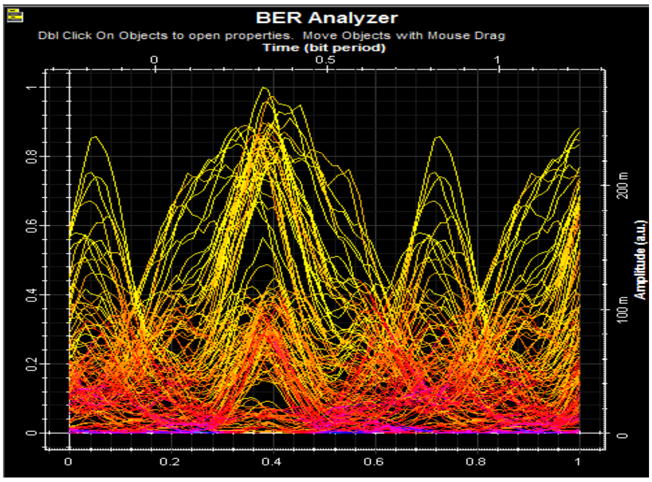
(i) 60 KM



(ii) 80KM



(i) 100KM



(ii) 100KM

Fig. 5.The EYE diagram analysis for RZ with FBG and with FBG

The figure5 (i) shows the results analysis of EYE opening for the RZ modulator without FBG and figure5 (ii) represents RZ modulator with FBG. It is observed that the eye opening is wide for the simulation result obtained with FBG used as dispersion compensator for various lengths

V. TABULATION

The tabulation is obtained by using various analyzers like BER, Q factor and EYE height opening. The BER is defined as that the number of bits that has been error during transmission for the given unit of time. The RF Spectrum Analyzer is also used to view the simulated output, which is used to measure the power of the known and unknown signals and noise values for particular values. The Q factor is used as one of the important parameter to determine the results for various lengths. The Q factor or quality factor is a dimensionless parameter which describe the under damped value of an oscillator. Higher the Q value lesser the rate of energy loss. In this simulation, the output is obtained with less distortion and higher Q value for shorter distance of optical transmission

TABLE1. Simulated results of RZ modulator

Length (km)	Q-Factor	BER	Eye Opening Width
10	31.3078	$1.40e^{-215}$	0.2119
20	16.1791	$2.44\ e^{-059}$	0.1634
40	9.2413	$8.61e^{-021}$	0.0612
60	4.1285	$10.84e^{-010}$	0.0254
80	1.2763	$12.06e^{-002}$	0.0127
100	0.1926	1	0.0089

TABLE2. Simulated results of RZ modulator with FBG

Length (km)	Q-Factor	BER	Eye Opening Width
10	80.3999	0	0.5922
20	21.3959	$5.754e^{-102}$	0.4309
40	15.3424	$1.512e^{-053}$	0.1188
60	12.3374	0.0094	0.1033
80	8.0413	0.0063	0.0829
100	5.0071	0.00025	0.0165

VI. RESULTS AND CONCLUSION

The optical transmission system is designed with the single mode fiber, RZ as the modulation format and FBG as the dispersion compensator. Hence, from the above analysis, we can conclude that, during long haul communication the RZ pulses subject to some losses due to dispersion and when analyzed with FBG, the performance increases by compensating dispersion along the fiber for increasing lengths.

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