Simulation and Analysis of Dispersion Compensation using Proposed Hybrid model at 100Gbps over 120Km using SMF

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Abstract*—In this paper, a high capacity model having the transmission rate of 100Gbps using Hybrid dispersion compensation technique is proposed over a distance of 120Km.But due to longer transmission distances, fiber linearties occurs. EDFA can mitigate the effects of these fiber linearties over repeated long distance transmissions but there are still some factors like dispersion, which restricts the transmission distance. In this paper, the complete focus is given in the reduction of chromatic dispersion. In previous papers DCF, IDCFBG and uniform FBG has been used separately for dispersion compensation and it has been found that uniform FBG has greatest Q-Factor and least BER among them. The technique proposed in this paper for dispersion compensation consists of a hybrid model of uniform FBG with EDC (Electronic dispersion compensation). Eventually results are analyzed for the proposed system at distinct input powers ranging from 1-10dBm and it is found that maximum value of Q-Factor and minimum value of BER have been achieved. For transmission of high bit rate over longer distance in the existing communication system, this model can provide a significant change.

Keywords- Dispersion; Single mode fiber (SMF) Q-factor; BER (Bit error rate); CD (Chromatic Dispersion); Uniform Fiber Bragg Grating; Dispersing Compensating Fibers (DCF); Optisystem 7.0

I. INTRODUCTION

Every year, the rate of data transfer goes on increasing due to the more and distinct technologies. The usage of new system advancements and increase in the transmission speed of the data has given a chance to make new and better services for the users like video calling, cloud computing etc. [1]. In the infrared region and the visible region of the electromagnetic spectrum high carrier frequencies are used by the optical fiber communication system. In optical fiber communication system the information is transmitted from one location to another location in the form of optical pulses using optical fiber as a channel. The information to be transmitted is first modulated and then send over the optical fiber. The reason behind the development and utilization of the optical communication system all over the world is its bandwidth and high capacity. Optical Fiber system also suffers from various distinctive losses, non-linear effects and dispersion which degrades the signal quality. Among them, dispersion is the most significant signal deteriorating factor. So, work should be done to avoid the degradation of the system and to improve the quality of signal transmission with little dispersion or no dispersion. Hence, dispersion compensation techniques are used [2].

a. Dispersion:- The phenomenon in optical fiber communication system in which wave velocity is the function of frequency i.e. with the change in the frequency the propagation velocities of the waves changes. This causes the different waves to reach at the receiver at different time intervals. These further causes the pulse to be spread and phenomenon is called chromatic dispersion. The effect of spreading of pulses can be reduced upto some extent by using dispersion compensation techniques like DCF, FBG and EDC etc.

The basic principle behind the pulse spreading is defined in equation(1) given below:-

$$\Delta\tau = D_s l_s + D_c l_c + D'_s l_s (\lambda - \lambda_1) + D'_c l_c (\lambda - \lambda_1) \quad (1)$$

Where, τ = total pulse widening per unit source bandwidth due to the transmission over SMF

l_s = length of single mode fiber(SMF)

l_c = length of dispersion compensating fiber

D_s and D_c = First order dispersion coefficients at wavelength = λ_1 for SMF and dispersion compensating fibers, respectively.

D'_s and D'_c = Second order dispersion coefficients [3].

b. Techniques for dispersion compensation: -Chromatic dispersion is a fundamental characteristics for optical communication systems as well as for other systems. Dispersion compensators should be tunable in the optical fiber communication systems, mainly for systems having rate equal or greater than 40Gbps [4].There are some most commonly techniques to mitigate the effects of the chromatic dispersion up to some extent which are DCF(Dispersion compensating fibers), FBG(Ideal dispersion compensation FBG, Uniform FBG and Chirped FBG), EDC(Electronic dispersion compensation).

DCF (Dispersing Compensating Fibers):- DCF is the most extensively used dispersion compensating technique for the chromatic dispersion. The spans of DCF and SMF are great competitors because their large dispersion is famous for decreasing the phase matching, the factor responsible for four wave mixing. Deterioration of signal in these type of systems is because of the consolidated impact of GVD (Group velocity dispersion). In this technique, along with the main fiber, a negative dispersion fiber known as Reverse dispersion fibers is used to invalidate the whole dispersion.[5].

FBG (Fiber Bragg Grating):-In this a particular wavelength is reflected by the grating whereas all other wavelengths are passed by the grating. A term Bragg's wavelength is used to define the particular wavelength reflected by the gratings [6].
Bragg's wavelength can be defined as given below in equation (2):-

$$\lambda_B = 2n_{eff}\Lambda \quad (2)$$

Where, Λ = Grating Period
λ_B = Bragg's Wavelength
Dispersion compensating modules based on FBG have diverse fascinating features such as minimum insertion loss, non-existence of non-linearity etc.But the imperfections occurs during fabrication causes FBG modules to give rise to the group delay ripple (GDR) which further results in degradation of the signal [7].

EDC (Electronic Dispersion Compensation):-To tackle the dispersion in optical fiber transmission channel, an extensive range of schemes have been suggested for example nonlinear electrical equalization, DFEs (Decision feedback equalizers), EFEs (Electrical feedback equalizers), and advanced electrical equalization for random dispersion [8].
EDC are widely used for dispersion compensation in mobiles and modems. The basic principle is that in EDC, immediate recognition is done at receiver due to which the distortions having linear properties like chromatic dispersion are converted into non-linear after the conversion of optical pulses back into electrical form. It is due to this reason the idea of nonlinear cancellation pulled in the attention towards EDC. The performance of the system can be increased huge times by using EDC only at small expense. The advantages of EDC includes upgraded margins and low cost components. Optical fiber communication systems decline from various factors mainly when large bit rates are considered [9].
Penalty in dB is explained in equation (3) as given below:-

$$\text{Penalty (dB)} = A.\left(\frac{\Delta\tau}{T}\right)^2 \gamma(1-\gamma) \quad (3)$$

Where, $\Delta\tau$ = Differential delay in relationship with bit duration T
A = Factor showing interface performance
γ = Relative power

. The formatter will need to create these components, incorporating the applicable criteria that follow.

II. SYSTEM CONFIGURATION

The system is designed by using software Optisystem 7.0 and it is a platform for designing and simulation of various optical fiber systems. The transmitter side comprises of a source of light, a modulator and a bit sequence generator. Continuous wave laser as source of light, NRZ modulation format and Mach-Zehnder as a modulator is used in the proposed system. On the transmitter side, the electrical signal is converted into the optical signal and then transmitted over the optical fiber channel at 100Gbps.

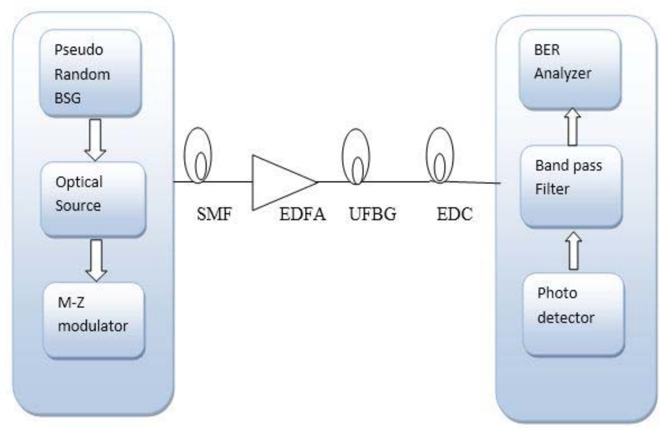

Figure 1. Block diagram of Hybrid Model

Figure 1 is showing the basic block diagram of Hybrid Model both at transmitter and receiver whereas Figure 2 is showing the basic components of EDC in the form of block diagram.

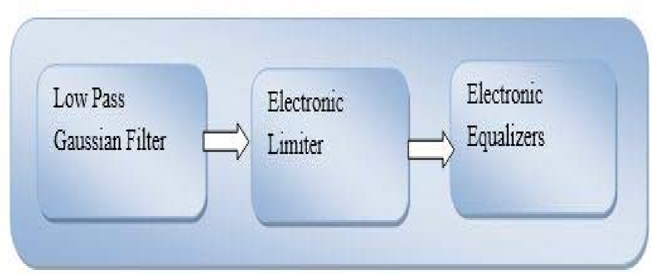

Figure 2. Block Diagram of EDC

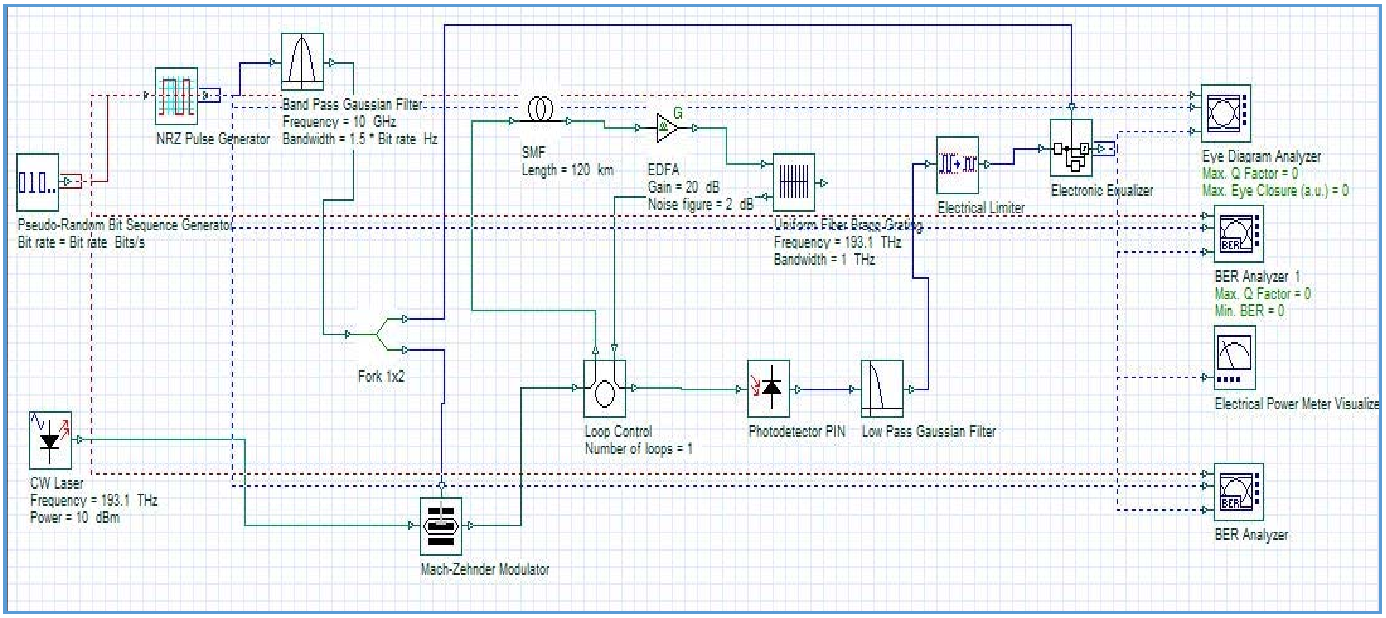

Figure 3. Hybrid model simulation setup

The input power is varied from 1dBm to 10dBm and corresponding to that Q-Factor and BER at the receiver is analyzed. For analyzing the results, proper arrangement at the receiver is done. Initially at the receiver, optical pulses are detected by pin detector photodiode and then translated into electrical pulses. The combination of UFBG and EDC has been proposed as dispersion compensators after SMF and EDFA for the transmission of signal through optical fiber. EDC comprises of three main blocks- Low pass Gaussian filter, Electronic Limiter and Electronic Equalizer.Fig. 3 is showing the simulation setup for the Hybrid model at both the transmitter and the receiver.

Table-1 is showing the various simulations parameters used in the computational model.

TABLE-1:- SIMULATION PARAMETERS

Components	***Parameters***	***Value/Units***
Uniform FBG	Frequency	193.1 THz
	Bandwidth	1 THz
	Noise Threshold	-100dB
EDC	Bit Rate	100Gbps
	Step Size	0.3
	Minimum Amplitude	0
	Maximum Amplitude	1
SMF	Length	120 Km
	Attenuation	0.2dB/Km
	Dispersion	0.01ps/nm/km

III. RESULTS AND DISCUSSION

Fig. 4 shows the eye diagram for maximum input power = 10dBm, which includes the typical value for Q-factor, BER and so on. The eye diagram should be as clean as possible and eye height should be as much as possible.

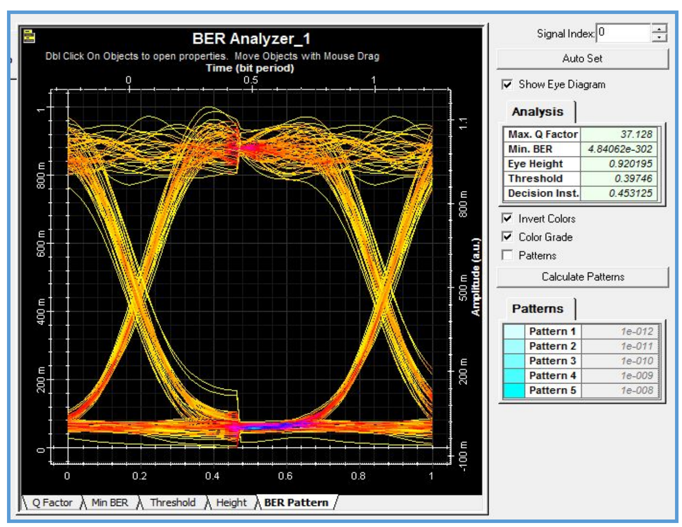

Figure 4. Eye diagram for input power = 10dBm

Fig. 5 shows the graph between Q-Factor and input power at different iterations showing change of Q-Factor with respect to change in the input power. It is clear from the graph that as the input power vary from 1 to 10 dB, corresponding Q-factor will

Identify applicable sponsor/s here. *(sponsors)* also increase, which is the required condition. The value of Q-factor must as high as possible.

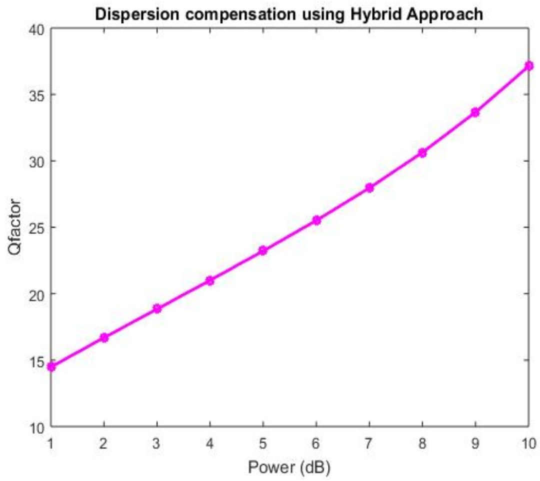

Figure 5. Q-Factor Vs Input power plot

Fig. 6 shows the graph between BER and input power showing the change in Bit Error Rate with respect to change in input power. It is clear from the graph that as the input power vary from 1 to 10 dB, corresponding Bit Error Rate will decreases, which is the required condition. The value of Bit Error Rate (BER) must as low as possible. This will shows that the output is free of error.

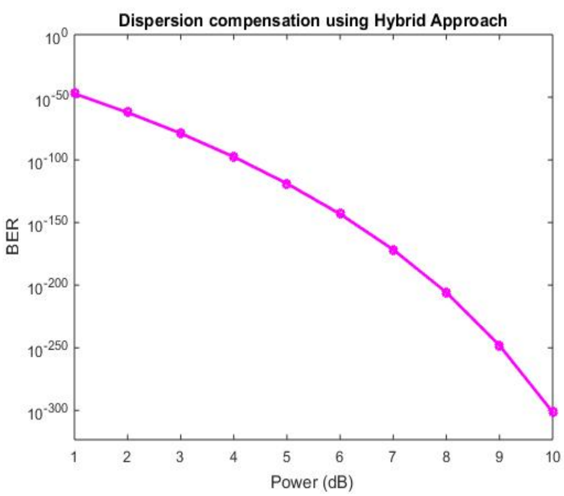

Figure 6. Bit Error Rate Vs Input power plot

Fig. 7 shows the graph between received power and transmitted power showing the change of the received power due to the variation in the input power.It is clear from the graph that as the input power vary from 1 to 10 dB, corresponding received power will decrease. But it is clear from the graph that the received power is more as compared to the transmitted power, and it is the required condition.

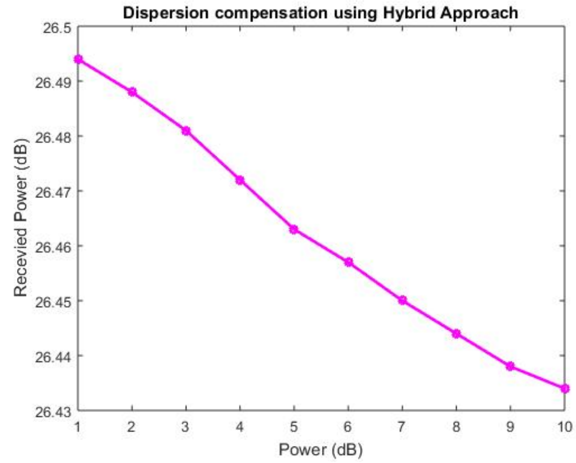

Figure 7. Received power Vs Input power plot

Fig. 8 shows a graph between Eye height and input power showing the extent of eye opening with respect to the input power. It is clear from the graph that as the input power vary from 1 to 10 dB, corresponding Eye Height will also increase, which is the required condition. The value of Eye Height must as much as possible

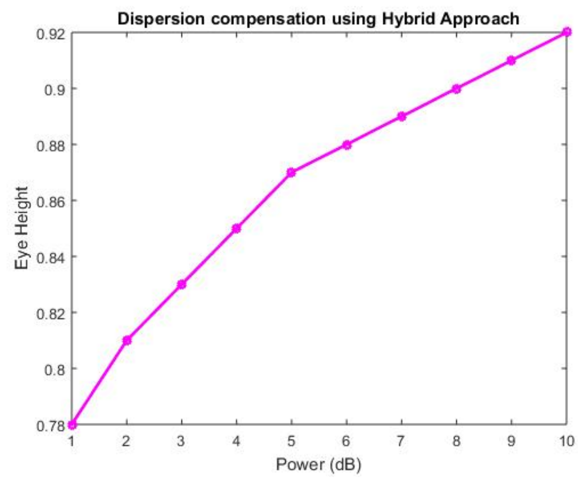

Figure 8. Eye Height Vs Input power plot

So by considering all these factors,It is cleared that Q-Factor is continuously increasing as the input power is increased and hence become maximum at the highest input power (here 10dBm). BER experiences a significant decrease with the increase in the input power and thus making this hybrid model more reliable at higher input power.

The comparative results achieved in simulation of proposed Hybrid model by using Optisystem 7.0 (software) are compiled in tabular form shown inTable-2, in which input power ranging from 1dBm to 10dBm.

TABLE-2:- PERFORMANCE OF HYBRID MODEL AT DIFFERENT INPUT POWER (1-10dBm)

Input Power (dBm)	Max Q factor	Min BER	Eye Height	Received Power (dBm)
1	14.48	7.75E-48	0.78	26.494
2	16.69	7.40E-63	0.81	26.488
3	18.84	1.56E-79	0.83	26.481
4	21.01	2.58E-98	0.85	26.472
5	23.22	1.33E-119	0.87	26.463
6	25.51	6.30E-144	0.88	26.457
7	27.96	2.40E-172	0.89	26.45
8	30.64	1.52E-206	0.9	26.444
9	33.66	8.45E-249	0.91	26.438
10	37.12	4.84E-302	0.92	26.434

IV. CONCLUSION

The work in this paper outlines the simulation and then analysis of the optical fiber communication system at 100Gbps over 120Km transmission distance using Hybrid model of Uniform FBG and EDC. At the input power of 1dBm, Q-factor observed is equal to 14.48 with BER of 7.75 e-48.As the input power reaches 10dBm, Q-Factor sharply increased to 37.12 with BER of 4.84 e-302.Hence, the simulation outcomes portrays that Hybrid model is prevalent at input power = 10dBm. This system can further be compared with other dispersion compensation techniques like DCF, IDCFBG and Uniform FBG.

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