

Investigation of the Different Compensation Methods for Single Optical Channel

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Abstract: In the optical channel each of pulse broadening and distortion produced by dispersion, lead to degrading the fiber performance. To deal with the dispersion, several techniques have developed and improved. To mitigate the pulse broadening in the optical channel, Fiber Bragg Gratings (FBGs) and Dispersion Compensation Fiber (DCF) have utilized separately. Single channel transmission system with 10 Gbits/sec data rate optical system is designed and simulated by using optisystem software package. All the designs are compared in forms of Quality factor (Q-factor). The optimum parameters setting of FBG are achieved by varying the chirp function and apodization function of the FBGs. Among the methods presented in this research, the q-factor of DCF is better than using FBGs for 100 km length. The Q-factor by using DCF is 10.08 and by using FBG is 4.83 but DCF needs huge negative dispersion coefficient and it has high insertion loss with increasing the nonlinear effects and costly, so that, FBG is a promising approach in compensating the dispersion.

Key words: Fiber Bragg Gratings (FBGs), Dispersion Compensation Fiber (DCF), nonlinearity effects, optisystem apodization function, quality factor, dispersion, coefficient

INTRODUCTION

In recent decades, fiber optics becomes a powerful system in field of large transmission band width and lower attenuation (Fazlina *et al.*, 2017; Mahdi *et al.*, 2018) but confronts issues such as losses, attenuation, dispersion and non-linear effects which corrupt its performance. Among them the dispersion influences of the system behavior and it's hard to eliminate. Hence, it is essential to incorporate a useful dispersion compensation technique in optical systems that lead to upgrade the behavior of the transmission system (Kaur and Sarangal, 2015). In this study, 2 forms of dispersion compensation technique, DCFs and FBGs have been applied and computed their performance. Many researchers have proposed and discussed this subject. A brief review of the preceding researchers is given such as used spectral inversion though optical phase conjugation to reduce the non-linear and linear optical impairments (except for polarization mode dispersion) (Tariq and Al-Jumaily, 2011). Teja *et al.* (2012) conclude smaller core diameter has made a reduction in dispersion which allows fewer modes. Therefore, the (SMF) was used to decrease the modal dispersion (Teja *et al.*, 2012). Udayakumar *et al.* (2013) they used FBG and optical phase conjugation techniques to compensate the chromatic dispersion, the simulation of using FBG by varying its grating period and linear chirp coefficient was obtained. Kumar *et al.* (2014) they have analyzed the dispersion treatment using FBG at different fiber lengths. Bhardwaj and Soni

(2015) the researchers simulated FBG by using a 50 km length standard (SMF) with 20 GB/sec Non-Return to Zero (NRZ) signal. Singh *et al.* (2015) they used DCF to compensate the dispersion of the signal. Three different compensation schemes were used pre-post and symmetric compensation were simulated (Singh *et al.*, 2015). Kaur *et al.* (2015) the positive dispersion accumulated over the length of 250 km at 10 Gbits/sec with 50 km (DCF) has been compensated. Aladadi *et al.* (2016) the behavior of Chromatic Dispersion Compensator (CDC) based on optimized CFBG apodization profile is presented.

MATERIALS AND METHODS

Optical fiber compensation techniques: In this study, several techniques that used to treat the optical dispersion are (DCF) and (FBG).

Dispersion compensation fiber: DCF is used to equalize the positive dispersion that produced from the optical link by adding a negative dispersion. The use of (DCF) is a significant potential method to enhance the behavior of the standard (SMF). Conventional (DCF) has a significant negative dispersion -70 to -90 ps/nm.km. The relative positions of DCF and SMF are sorted as post compensation, pre-compensation and symmetrical/mix compensation. If the DCF is inserted before the single mode fiber this type called a pre-compensation else if it

inserted after the SMF then called a post-compensation else the 2 types are used both then in this case called a symmetrical compensation. There is a relationship between the negative dispersion of the DCF and the positive dispersion of the SMF the net dispersion will be zero:

$$D_{SMF} \times L_{SMF} = -D_{DCF} \times L_{DCF} \quad (1)$$

where, D is the dispersion and L is length of each fiber segment (Kaur *et al.*, 2014).

Fiber bragg gratings: FBG is one of the imperative techniques that applied for limiting the dispersion. FBG is a portion of fiber with the occasional variety of refractive index along the fiber. The idea behind FBG is reflecting wave lengths that satisfy the bragg condition and transmitting the desired wave lengths. The unwanted wave length selected by changing the grating period. Therefore, FBG is a low-cost filter for wave length selection (Chaba and Kaler, 2010). The equation relating the grating periodicity, bragg wave length and effective refractive index of the transmission medium is given by (Kaur and Kaur, 2014):

$$\lambda_B = 2n\Delta \quad (2)$$

In this equation, λ_B , n and Δ are the bragg wave length refractive index of core and grating period, respectively. FBG is the inclusion of alternative modulation of refractive index which acts as a wave length selective mirror. A chirp is where variations in grating period (and as a result changes in reaction to different wave lengths) are created along the grating. Figure 1 different wave lengths are reflected from several parts of a grating when a signal gets into chirp. Thus, a delay related to wave length of signal is produced by grating. Some wave lengths have more dilation than others. This feature is used for dispersion treatment in communication links (Tariq and Al-Jumaily, 2011).

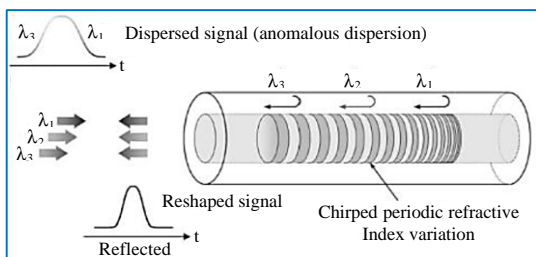


Fig. 1: A chirped FBG treat for dispersion by reflecting different wave lengths at different locations along the grating lengths

RESULTS AND DISCUSSION

The specifications of the simulated system of single channel optical system without any compensation device are deprecated in Table 1. The next step a comparative study is done between the 2 methods, the Q-factor of the signal is taken as a constraint to obtain the efficient research of the FBGs and DCF. To examine the Q-factor of the receiving signal, different lengths of fiber in km is used as in Fig. 2 that it shows the relationship between the lengths of the optical fiber with the Q-factor.

It's obvious from the curve that when the length of optical fiber increased the Q-factor decreased which is not acceptable in the practical life. However, these results show the need to compensate the dispersion in the optical fiber. To solve this problem, FBGs and DCF are used as a compensation device. The model of the simulated system of single-channel optical system with the compensation device FBGs is illustrated in Fig. 3. The same previous parameters of (Single channel optical fiber system without dispersion compensation) are used here to simulate the transmitter and receiver study but the FBGs are applied in the optical channel as a dispersion compensator. There are two factors inside FBG that give the optimum performance of FBG in the optical system which are chirp function and apodization function. The types of chirp

Table 1: Simulation parameters of single channel optical system without dispersion compensation

Parameters	Values
Dispersion	17 (ps/nm/km)
Dispersion slope	0.05 (ps/nm ² /km)
Attenuation index	0.2 (dB/km)
Length	Variable (km)
C/W input power	15 dBm
C/W laser frequency	193.1 (THz)
Reference wave length	1550 (nm)
Mach-zender modulator with of extinction ratio	30 (dB)
EDFA gain	10 (dB)
EDFA noise figure	4 (dB)
PIN responsivity	1 (A/W)
PIN dark current	10 (nA)

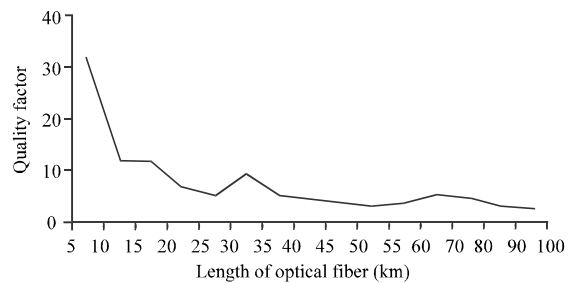


Fig. 2: Optical fiber length versus Q-factor for single channel optical system without dispersion compensation

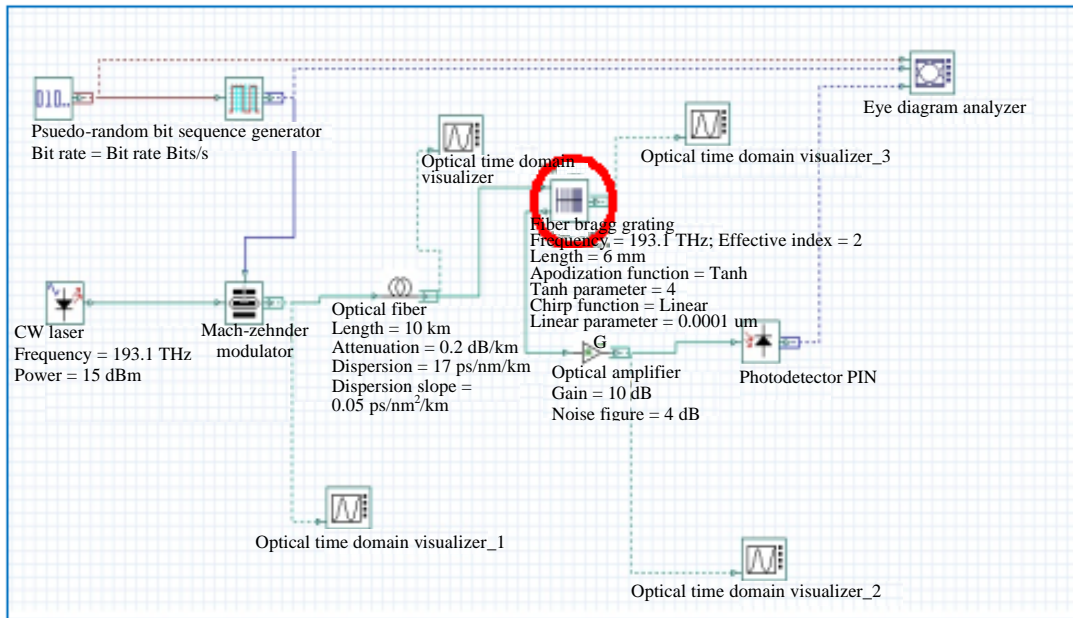


Fig. 3: Single channel optical system with FBGs

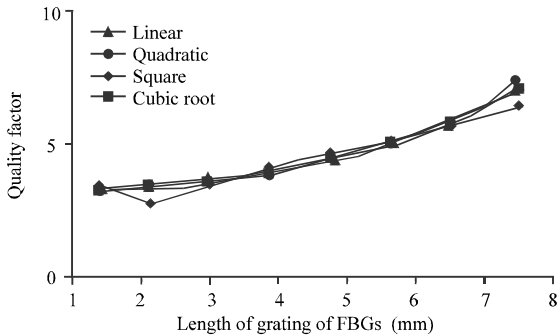


Fig. 4: Length of grating versus Q-factor for different chirp functions for optical system with (FBGs)

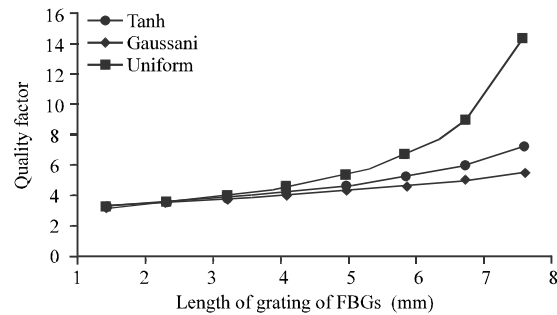


Fig. 5: Length of grating versus Q-factor with different apodization functions for optical fiber system with FBGs

function have been changed until getting high Q-factor of the receiving signal that pass throughout the optical fiber as shown in Fig. 4.

It's apparently clear that the linear chirp function represents the best behavior and leads to efficient research of FBGs and the quadratic function is less efficient. Also, the types of apodization function has been changed until getting high Q-factor of the receiving signal that passes throughout the optical fiber as mentioned in Fig. 5. From the curve in Fig. 5 it's evident that the length of the grating is directly proportional to the Q-factor and inversely proportional to the dispersion of the signal no matter what is the type of the apodization function. From the obtained results, we can say that the uniform a podization function represents the best performance and

the gaussian apodization function is less efficient. Table 2 summarized the optimum parameters setting of FBGs based on the results obtained from previous Fig. 4 and 5 of the optical system with FBGs.

DCF with different lengths of Table 3 summarized the Q-factor of the receiving end signal of two models FBG and DCF with different lengths of optical fiber. Figure 6 shows the Q-factor of the receiving end signal with different optical fiber lengths in three cases first without using any dispersion compensator, second with using FBGs compensator and third with using DCF compensator. From the obtained results we can notice that the Q-factor by using the DCF is better than using the FBGs but to reduce the positive dispersion of SMF

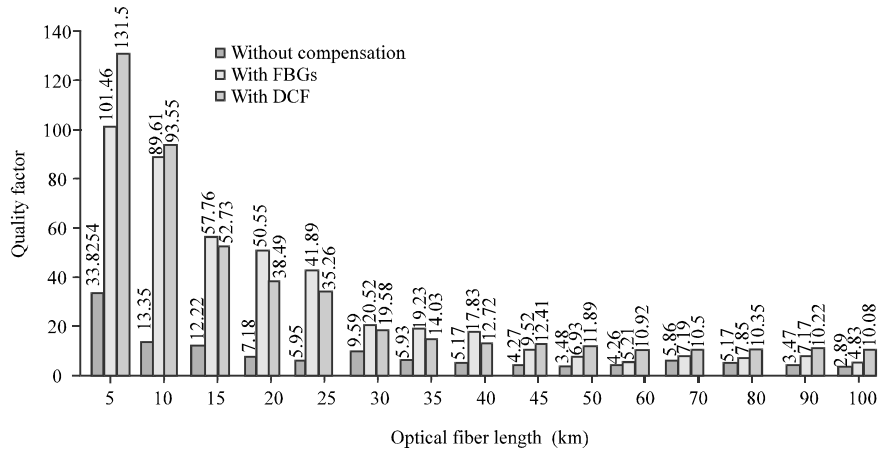


Fig. 6: Q-factor versus optical length in different cases

Table 2: Optimum parameters setting of FBGs and DCF

Parameter	Values
FBG parameters	
Frequency	193.1 (THz)
Effective refractive index	1.45
Apodization function	Uniform
Tanh parameter	4
Chirp function	Linear
Linear parameter	0.0001 (μm)
Length of grating	6 (mm)
DCF parameters	
Dispersion	-170 (ps/nm/km)
Attenuation	0.2 (dB/km)
Effective area	22 (μm ²)

Table 3: Optical fiber length and DCF length with the Q-factor results for optical fiber system with FGB and DCF

Optical fiber length (km)	DCF-length (km)	(DCF) Q-factor	(FBG) Q-factor
5	0.5	131.50	101.46
10	1	93.55	89.61
15	1.5	52.73	57.76
20	2	38.49	50.55
25	2.5	35.26	41.89
30	3	19.58	20.52
35	3.5	14.03	19.23
40	4	12.72	17.83
45	4.5	12.41	9.52
50	5	11.89	6.93
60	6	10.92	5.21
70	7	10.50	7.19
80	8	10.35	7.85
90	9	10.22	7.17
100	10	10.08	4.83

a high negative dispersion coefficient has been required from DCF. Hence, the overall cost and the non-linear effect are increased. The insertion losses also high, so, FBG is a promising approach in compensating the dispersion (Table 2 and 3).

CONCLUSION

By using the dispersion compensator FBGs in the optical system, the Q-factor of the signal is increased and the dispersion of the signal decreased. When the length

of gratings increased the Q-factor increased too with some limitation. Q-factor for 1-8 mm length of the grating are 3.48-7.49, respectively. Linear chirp function and uniform apodization function of the FBGs are the effect parameters and produce higher Q-factor of the signal than other functions. Q-factor for 100 km length is 4.83. The Q-factor of the signal by using the DCF compensator is better than using the FBGs compensator. For 100 km length, the Q-factor by using DCF is 10.08 and by using FBG are 4.83. To reduce the positive dispersion of SMF a significant negative dispersion coefficient has required from DCF. Hence, the overall cost and the non-linear effect are increased. The insertion losses are also high. FBGs are a promising approach because it is a passive optical.

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