COMPARING DISPERSION COMPENSATION METHODS FOR 120 GB/S OPTICAL TRANSMISSION: PRE, POST, AND SYMMETRICAL SCHEMES

Ammar M. Odeh
QC Auditor, Nokia Networks, Rafiq Al Hariri Ave, Amman, Jordan

ABSTRACT: One of the major factors that limit the performance of an optical fiber communication system is dispersion. In order to get a high transmission range with high data rates, techniques must be in place to compensate for the dispersion caused by fiber nonlinearity. Dispersion Compensating Fiber (DCF) and Fiber Bragg Grating (FBG) are the trending dispersion compensation techniques in optical fiber communication. The use of DCF and FBG as a method of dispersion compensation can notably enhance the overall performance of the system. Broadening is a function of distance as well as the Dispersion parameter (D). The dispersion parameter is given in ps/nm/km and changes from fiber to fiber and also is a function of wavelength. In this paper, we investigate pre-, post-, and symmetrical compensating schemes in three different compensating models: DCF, FBG, and DCF cascaded to FBG. The system performance was evaluated in terms of Q-factor and Bit Error Rate (BER) for one optical channel communication system at 120 Gbps Return to Zero (RZ) signal launched over Single-Mode Fiber (SMF) of 100 km by using OptiSystem 7.0 software.

Keywords: Bit-Error Rate, Dispersion Compensating Fibers, Dispersion Compensation, Fiber Bragg Gratings, Q-factor

مقارنة أداء طرق تعويض التشتت لناقل بصري ذو قناة واحدة بسرعة 120 جيجابت/الثانية باستخدام نظم مسبقة، مؤخرة، ومتناظرة

عمار عودة

الملخص: يعد التشتت أحد العوامل الرئيسية التي تحد من أداء نظام اتصالات الألياف الضوئية. من أجل الحصول على نطاق إرسال عالي بمعدلات بيانات عالية، يجب وضع تقنيات للتعويض عن التشتت الناجم عن الألياف اللاخطية. تعد الألياف المعوضة للتشتت (DCF) وشبكة الألياف الضوئية (FBG) من تقنيات تعويض التشتت الشائعة في اتصالات الألياف الضوئية. يمكن أن يؤدي استخدام DCF و FBG كطريقة لتعويض التشتت إلى تحسين الأداء العام للنظام بشكل ملحوظ. اعتبر التوسيع دالة للمسافة ومعامل للتشتت .(D) يتم إعطاء معلمة التشتت بوحدة ps / nm / km وتتغير من ألياف إلى أخرى وهي أيضًا دالة لطول الموجة. قمنا في هذا البحث بدراسة مخططات التعويض السابقة واللاحقة والمتناظرة في ثلاثة نماذج تعويضية مختلفة: DCF و FBG و DCF المتتالية إلى FBG. تم تقييم أداء النظام من حيث عامل Q ومعدل خطأ البت (BER) لنظام اتصال قناة بصرية واحد بسرعة 120 جيجابت في الثانية لإشارة العودة إلى الصفر (RZ) التي تم إطلاقها عبر الألياف أحادية الوضع (SMF) لمسافة 100 كم باستخدام OptiSystem 7.0 برمجة.

الكلمات المفتاحية: معدل الخطأ في البت؛ ألياف تعويض التشتت؛ تعويض التشتت؛ حواجز الألياف الزجاجية ؛ معامل Q.

Corresponding author's e-mail: ammarm.odeh@gmail.com

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NOMENCLATURE

β	Fiber propagation constant, in (radians/meter).
Γ	Attenuation between two amplifiers, in (dB).
γ	Effective nonlinear coefficient, in (rad/km/W)
Δf	The bandwidth that measures the NF, in (nm or Hz).
Λ	FBG grating period, in (μm).
λ	Optical wavelength, in (nm).
λ_B	The central wavelength of the reflected spectrum satisfies the Bragg condition, in (μm).
π	Math constant = 3.14159265
τ	Time delay, often in (ns)
ω	Angular frequency, in (radians/second or Hertz).
B_t	System bit rate, in (Gbps).
c	Speed of light, in (m/s).
D_{DCF}	Chromatic dispersion coefficient for DCF, in (ps/nm/km).
D_{SMF}	Chromatic dispersion coefficient for SMF, in (ps/nm/km).
f	Signal center frequency, in (Hz).
k_0	Free-space wavenumber.
L_{DCF}	Dispersion compensating fiber length, in (km).
L_{SMF}	Single mode fiber length, in (km).
N	Number of amplifiers in the fiber link.
NF	Noise figure of amplifier, in (dB).
n_e	The grating effective refractive index.
P_r	Optical received power by the photodetector, in (dBm).
P_s	Average source signal power into the first span.
P_t	Optical transmitted power by CW laser, in (dBm).
Q	Q-factor.

1. INTRODUCTION

Optical fiber is the key component in various types of telecommunications networks, due to the intensive demands for high bandwidth, transmission speed and distance. Such characteristics make an optical fiber a preferred means of transmission. When information-carrying light pulses propagate through an optical fiber, they suffer from attenuation, temporal broadening, and even interact with each other through nonlinear effects in the fiber. (Ramaswami, R., Sivarajan, K., & Sasaki, G, 2009), (Thyagarajan, K., & Ghatak, A., 2006).

Correct functioning of an optical data link depends on modulated light reaching the receiver with enough power to be demodulated correctly. Attenuation is the reduction in power of the light signal as it is transmitted (JuniperNetworks, 2022). With the recent development of practical Erbium-Doped Fiber Amplifiers (EDFAs), attenuation has become no longer a capacity-limiting issue.

But dispersion is still a major concern that corrupts the signal quality. Dispersion is one of the critical barriers to an increase in the transmission capacity of an optical fiber, particularly in a single-mode fiber, causes an optical pulse to broaden as it travels along the fiber cable. The broadening is so severe that adjacent pulses begin to overlap to the degree that a photo-detector can no longer distinguish clear boundaries between pulses. As a result, reduces the effective bandwidth which further escalates the error rate due to an increasing Inter-Symbol Interference (ISI) (Sharma, A., Singh, I., Bhattacharya, S., & Sharma, S., 2019).

In order to widen bandwidth of optical fiber transmission systems, techniques for dispersion compensation over transmission bandwidth for the accumulated chromatic dispersion of Standard SMF must be in place for mitigating signal deterioration caused by dispersion and nonlinearities. (Kaler, R. S., Sharma, A. K., & Kamal, T. S, 2002).

There are three basic limitations in modern optical transmission systems: the optical signal-to-noise ratio (OSNR), dispersion, and nonlinear effects (Gruner-Nielsen, L., Wandel, M., Kristensen, P., Jorgensen, C., Jorgensen, L. V., Edvold, B., ... & Jakobsen, D., 2005). This paper will discuss how the limitations due to dispersion can be dealt with by the use of dispersion compensating fiber and fiber Bragg grating. Another proposed model is applied by combining DCF with FBG in a manner that contributes to improving performance at a certain level of input power and makes the comparison with other methods.

Our analysis is based on the chromatic dispersion which is dominant in the single mode fiber. This raises the question of how well the DCF and FBG outperform one another is compared in a practical approach by varying the input optical power intensity with constant modulation scheme while keeping tab on the Q-factor for measuring how dispersion poses a serious problem in optical communication link.

2. BASIC THEORY:

2.1 Dispersion

When the optical signal strength is low, the dispersion can be seen in the linear range, but if the input light intensity is high enough, it may exhibit nonlinear properties (Ahmed, 2017). Fiber dispersion plays an essential part in the propagation of short pulses as all the pulses with different spectral components travel at different speeds. This is the essence of Chromatic Dispersion (CD). Chromatic dispersion is a phenomenon in an optical fiber that results in the temporal broadening of optical pulses as they pass through the fiber due to the dependency of group index on wavelength (Kaler, R. S., Sharma, A. K., & Kamal, T. S, 2002). Inside SMF, chromatic dispersion can be classified into two parts: waveguide dispersion and material dispersion. Material dispersion is a function of the source spectral width, which contains components, namely modes, at different wavelengths. These wavelengths propagate at different velocities depending on the refractive index of the silica, the material used to make optical fiber. The core of the fiber is not the only place where the modes can exist; they also extend slightly into the cladding material (Sharma, A., Singh, I., Bhattacharya, S., & Sharma, S., 2019). The power distribution of a mode between the fiber's core and cladding is a function of wavelength; the longer the wavelength, the more power in the cladding. This power distribution alters with a change in wavelength, affecting the effective index or propagation constant of the mode. This phenomenon is classified as waveguide dispersion. (Ramaswami, R., Sivarajan, K., & Sasaki, G., 2009). The dispersion is related to the second derivative of the propagation constant (β):

$$D = -\frac{2\pi c}{\lambda^2}\frac{d^2\beta}{d\omega^2} \tag{1}$$

where c is the light velocity in the vacuum, L is the wavelength and ω is the frequency.

As a result of dispersion, different delay times will be generated between different spectral components of the optical signals. For a single-mode fiber of length (L), the specified wavelength components at the angular frequency (ω) would arrive at the receiver terminal with a time delay (τ):

$$\tau = \mathrm{L}/v_g \tag{2}$$

where v_g is the group velocity, calculated as follows:

$$v_g = d\omega/d\beta \tag{3}$$

where β is the propagation constant.

The propagation constant is a measure of changes in the amplitude and phase of the electromagnetic wave as they travel through a medium. The propagation constant can be written in terms of the free space wave number and the effective index:

$$\beta = k_0\, n_e = \frac{\omega}{c}\, n_e \tag{4}$$

and the effective index as

$$n_e = n_0 + \Delta n_e \tag{5}$$

where n_0 is the refractive index of the cladding and Δn_e is the effective index difference.

2.2 *Dispersion Compensation Techniques*

The data rate of the fiber optic communication link cannot be increased beyond a certain limit due to inter-symbol interference. To achieve high data rates, dispersion compensator is the most crucial part to sustain link robustness against the impairments imposed on the light-wave optical system. Dispersion compensating fiber, fiber Bragg gratings, Electronic Dispersion Compensation (EDC), and Digital Filters are the most available techniques for dispersion compensation. (Hossain, M. B., Adhikary, A., & Khan, T. Z., 2020). This study is limited to DCF and FBG. The alternative techniques are outside the scope of this paper.

(a) Dispersion compensation fiber

Dispersion compensation fiber is a sort of optical fiber that has dispersion characteristics opposite those of transmission link fibers. The dispersion of the fiber can be controlled by varying the refractive index profile and the relative index value. The transmission fiber is a Standard SMF (SSMF) having zero dispersion at a wavelength of 1310 nm and a dispersion of 17 ps/nm/km at a wavelength of 1550 nm (Chen, W., Li, S., Lu, P., Wang, D., & Luo, W., 2010). For narrowband externally modulated lasers, the bandwidth of the signal is governed by the modulation. Increased modulation speed leads to increased bandwidth. On the other hand, increasing the optical bit rate leads to an increased signal distortion effect. A popularly used criterion for the maximum allowed fiber distance limited by fiber dispersion (without an amplifier) is given by:

$$L_{max} = \frac{K}{B^2|\mathrm{D}|} \tag{6}$$

where D is the dispersion coefficient of the transmission fiber, B is the system bit rate and K is a constant depending on many details, such as laser spectral width, modulation method, and the wavelength of the optical signal.

Therefore, as B increases, L decreases with the square root of B (Gruner-Nielsen, L. and Wandel, M. and Kristensen, P. and Jorgensen, C. and Jorgensen, L.V. and Edvold, B. and Palsdottir, B. and Jakobsen, D., 2005) (MapYourTech, 2014).

To cancel out the accumulated dispersion of the link road, the following principle will be obeyed:

$$\mathrm{L_{DCF}\,D_{DCF} + L_{SMF}\,D_{SMF}} = 0 \tag{7}$$

where $\mathrm{D_{SMF}}$ is the dispersion coefficient of the transmission fiber, $\mathrm{L_{SMF}}$ is the length of the transmission optical fiber, $\mathrm{D_{DCF}}$ is the dispersion coefficient of the DCF, and $\mathrm{L_{DCF}}$ is the length of the DCF.

The higher the dispersion coefficient of the compensating fiber, the smaller the required length of the of the compensating fiber.

The effective core area of the DCF is much smaller than that of transmission fiber, 20 μm^2, compared to the 85 μm^2 of SMF, and hence exhibits higher nonlinearities. The wavelength of operation is an important consideration, in which small increases in wavelength leading to relatively large changes in mode size, where the propagation in the less dense media (the cladding) provides an increase in propagation than of the dense media (the core). This, in the nutshell, creates a large negative dispersion value. (Willner, A. E., Song, Y-W, Mcgeehan, J., Z Pan, & Hoanca, B. , 2005). By reducing the optical power, the influence of Non-linear Optical Effects (NOE) can be reduced. The DCF takes a long length of fiber to compensate for a span, about one-fifth of the length of the transmission fiber, entailing a large amount of space and a relatively large insertion loss. Additionally, the DCF can only accept a limited signal power because the small-mode field of the fiber and the long propagation length result in nonlinear pulse distortions at high signal intensity (Kaminow, I. P., & Li, T. (Eds.), 2002).

Again, a DCF is a fiber that causes dispersion opposite to conventional single-mode fibers. DCF has negative dispersion over the same range of wavelengths in which SMF has positive dispersion. Multiple wavelengths are used to transmit data in a single fiber using Wavelength Division Multiplexing (WDM). WDM is a technique that enables the use of different data types over fiber networks in the form of light. A single virtual fiber network is produced by allowing many light channels, each with a unique wavelength, to be sent simultaneously over an optical fiber network; hence, a single fiber can be shared for several services.

DCF provides fixed negative dispersion for all channels in the WDM system and considered as a good compensating device for its reference wavelength where all optical channels are not compensated to the same degree, which results in residual dispersion. This leads to dispersion slope mismatch, the term used to describe how residual dispersion goes up and down (T. Duthel, S. Jansen, P. Krummrich, M. Otto, and C. Schäffer, 2005). On the other hand, fiber gratings, the other technique used in this paper, offer an alternative approach that overcomes the problems.

(b) Fiber Bragg grating

It is one of the most flexible and evolved techniques for dispersion compensation. The principle behind FBG is to reflect wavelengths that satisfy the Bragg condition and transmit the desired wavelengths. The unwanted wavelengths are selected by changing the grating period. The simple model of this fiber-based device and the possibility that a single parameter can be changed to alter dispersion are two of its primary advantages (T. Duthel, S. Jansen, P. Krummrich, M. Otto, and C. Schäffer, 2005).

FBG consists of a periodic modulation of the refractive index in the core of a single-mode optical fiber. The Bragg wavelength also varies along the grating length, thus different frequency components of an incident optical pulse are reflected at different points depending on where the Bragg condition is satisfied. This can be easily expressed as follows:

$$\lambda_B = 2 n_{eff} \Lambda \qquad (8)$$

where λ_B is called the Bragg wavelength, n_{eff} is the grating effective refractive index and Λ is the grating period.

Compared to DCF, FBG-based dispersion compensators can be made to be very compact, with potentially lower insertion loss and reduced optical nonlinearity (P.S. Westbrook, B.J. Eggleton, 2005). The low insertion loss of the FBG allows a significant reduction in the amplification requirements. This feature lowers the system cost and can improve the Optical Signal-to-Noise Ratio (OSNR).

Most applications need a dispersion tuning range that includes both positive and negative values. This is the key benefit of FBG technology that can't be met by DCF. Changing the physical parameters of the fiber grating allows us to obtain a narrow or wide bandwidth or other special characteristics (Sharma, A., Singh, I., Bhattacharya, S., & Sharma, S., 2019).

2.3 OSNR and BER:

The number of amplifiers affects the quality of the transmission line. Hence, the performance of the transmission line must be determined using a measurement technique called the optical signal-to-noise ratio. OSNR is used to identify the signal quality in the optical domain. It is the amount of difference between the signal power and noise power in the unit (dB) somewhere within the modeled system. While EDFA amplifies the optical signal, the OSNR is reduced because such an amplifier adds unwanted Amplified Spontaneous Emission (ASE) noise into the optical signal (Sajjan, S. M., Seshasai, V., & Sadashivappa, G, 2015), (Ramaswami, R., Sivarajan, K., & Sasaki, G., 2009). OSNR is one of the most diagnostic metrics for monitoring the optical network, as the BER is directly linked to the OSNR signal. The OSNR value depends on many factors, including data rate for a specific modulation format, location in the network and the target BER level. A low OSNR value indicates that the receiver will probably not detect or recover the signal (Tassé, 2012). The OSNR value can be calculated as:

$$\begin{aligned} OSNR_{F,dB} = 158.9 + P_{s,dBm} - \Gamma_{dB} - NF \\ - 10\log(\Delta f) \\ - 10\log(N) \end{aligned} \qquad (9)$$

where $OSNR_F$ is the final OSNR value that faced the receiver (in dB), P_s is the average input source signal power (in dBm), NF is the amplifier noise figure, (in dB), Δf is the bandwidth measures NF (in Hz), N is the number of amplifiers used in the transmission system, Γ is the span loss (in dB).

Therefore, OSNR, BER, and Q-factor are major indicators of the quality of the overall system in digital communication systems. The Q-factor, the criterion for measuring the quality of the received signal investigated at the receiver, limits the BER to be below10^{-9}(one error in 10^9 bits), and is approximated as follows:

$$\mathrm{BER} = \frac{1}{2}\mathrm{erf}\left[\frac{Q}{\sqrt{2}}\right] \approx \frac{e^{-Q^2}/2}{Q\sqrt{2\pi}} \quad (10)$$

whereby erf(x) is the error function (special function) widely used in statistical computations.

3. SIMULATION SETUP

In this study, three dispersion compensation methods (DCF, FBG, and the combining of both in one model) with various configurations (i.e., Pre, Post, and Symmetrical scheme) are considered for dispersion compensation using OptiSystem 7.0 software for single-channel optical communication. The simulation setups of the proposed optical system are shown in figures from Fig.1 to Fig.9.

At the transmitter end, the simulation setups consist of a Continuous Wave (CW) laser used as a source of light, a return to zero modulation format, and a Mach–Zehnder (MZ) modulator to externally modulate the input RZ signal with an extinction ratio of 30dB. All the optical pulses are sent at a transmission rate of 120 Gbps. The laser source is a CW type at a frequency of 193.1 THz and the output power is varied from -5 dBm to 20 dBm.

The loop control system has two loops for all models except for DCF and DCF-FBG models in symmetrical mode. The reason behind it is to equalize the transmission length. To adequately compensate for the dispersion slope and cumulative dispersion in the transmission fiber (SMF), each span is made up of 100 km of transmission fiber and 20 km of DCF. However, since the symmetrical design only has one loop, the overall length of the fiber channel is still 240 km.

At the receiver terminals, an Avalanche Photodiode (APD) detector is used to detect the optical pulses and then convert them to electrical signals.
Simulation parameters, optical fiber properties, and FBG fiber parameters are tabulated in Tables 1, 2, and 3, respectively.

4. RESULTS AND DISCUSSION

Single-channel nonlinear effects are caused mainly by Self-Phase Modulation (SPM), It causes optical pulses to have a wider spectral range by interacting with the medium that passing through and imposing a phase modulation on itself.

The RZ modulation format is used for three simulation models, which is preferred in high bit rate systems at a higher input of power compared to NRZ, as it can help in providing great results in reducing dispersion distortion and Inter-symbol Interference. We have analyzed the effects of SPM for three cases: DCF, FBG, and DCF cascaded to FBG, using performance metrics: Q-factor, BER, and eye diagrams. The comparative value of the Q-factor for different models is given in Tables 4, 5, and 6. According to the simulation results for the three compensation models, DCF in a symmetrical scheme provides the best Q-factor of 23.2824 and BER of 2.41855e-120 at an input power of 15 dBm compared to all other model configurations in this study. Figure 16 depicts the case.

Generally, DCF performs well in a mid-power range between 10 and 15 dBm, among all other DCF schemes. On the other hand, the cascaded system performs better in the low-power region of less than 10 dBm and achieves the highest Q-factor of 10.8361 and BER 9.15197e-028 in pre-compensation mode at an input power of 5 dBm, as shown in Fig. 17.

At an input power of 15 dBm and above, FBG performs better compared to other models and achieved satisfactory results, and gives almost identical values, 7.508, 7.65518, and 7.63105 for the three compensation modes, pre-, post-, and symmetrical, respectively. The reason behind this is that the system involved with DCF exhibits nonlinearities at high power intensity. Which is considered one of the suggested solutions to use the FBG, so that it does not require additional cables to compensate for dispersion and thus fewer amplifiers, which achieves the highest possible OSNR value along the link.

Table 1. Simulation parameters

Parameters	Values
Reference wavelength [THz]	193.1
Channel type	Single-channel transmission
Channel data rate [Gbit/s]	120
Sequence Length [bit]	128
Samples per bit	128
Signal Format	Unipolar (single polarity) RZ
Optical External Modulator. ER [dB]	30
Receiver Bandwidth [Hz]	0.75 * Rb

Table 2. Optical fiber parameters

Parameters	Values	
	SMF	DCF
Length [km]	100	20
Attenuation [dB/km]	0.2	0.5
Dispersion [ps/(nm.km)]	17	-85
Dispersion slope [ps/(nm^2 . km)]	0.075	-0.375
Effective area [micro m^2]	85	20
Kerr coefficient, n2 [m^2/W]	2.6E-020	2.6E-020

Table 3. FBG parameters

Parameters	Values	
	FBG	DCF-FBG
Bandwidth [THz]	1	1
Frequency [THz]	193.1	193.1
Dispersion [ps/(nm.km)]	-1720	-860
Insertion Loss [dB]	2	2

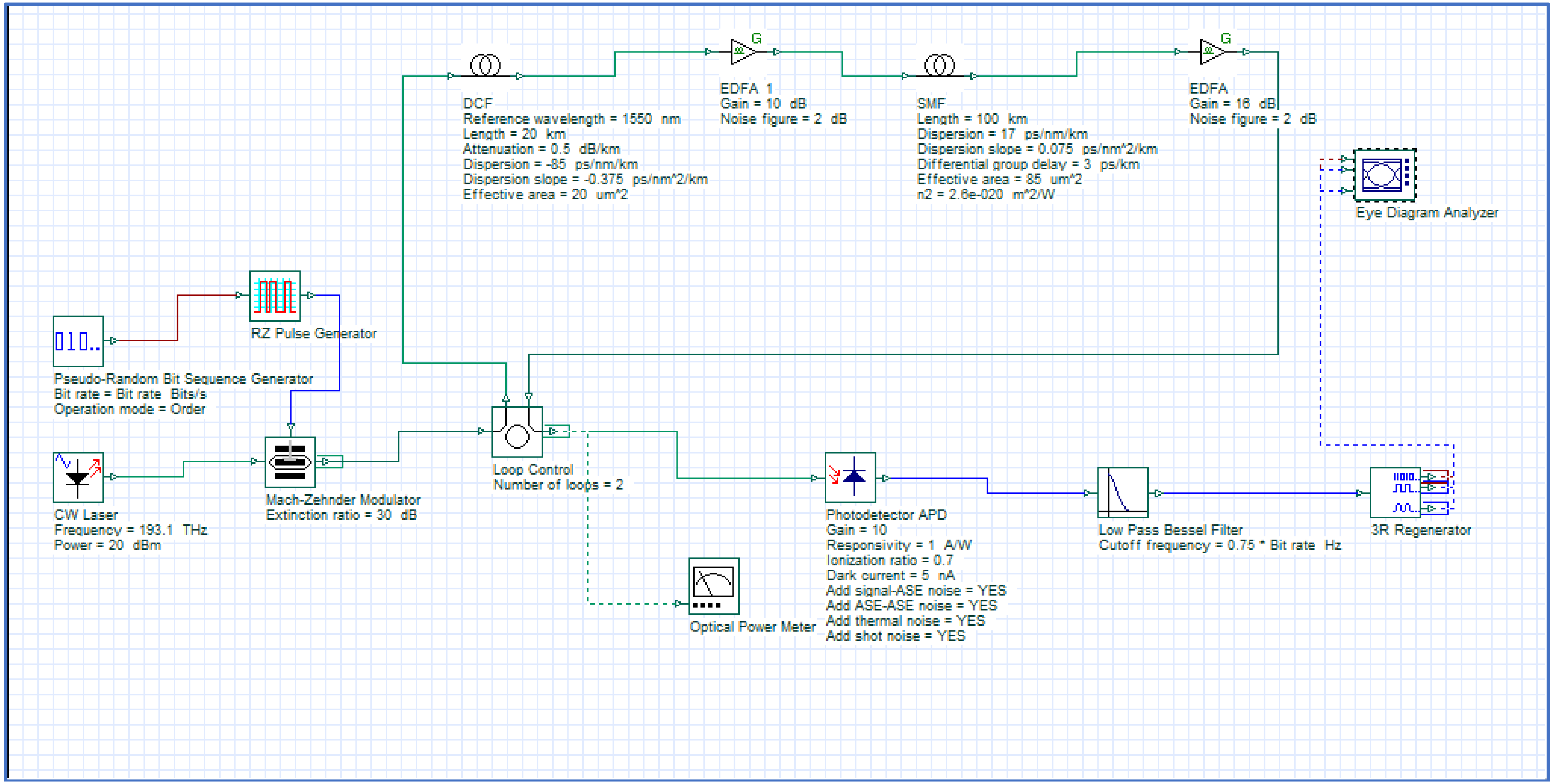

Figure1. Pre-compensation using DCF simulation model.

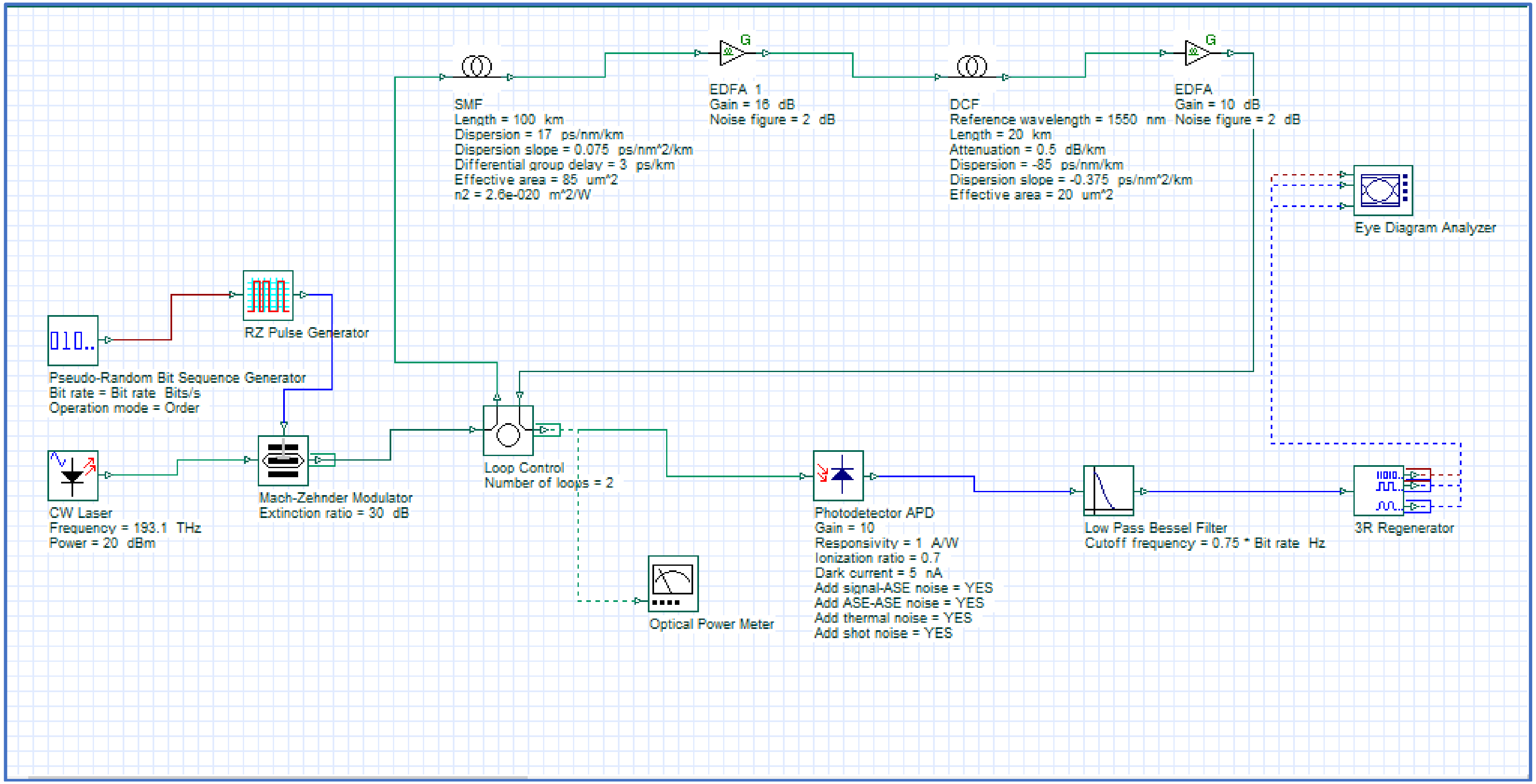

Figure 2. Post-compensation using DCF simulation model.

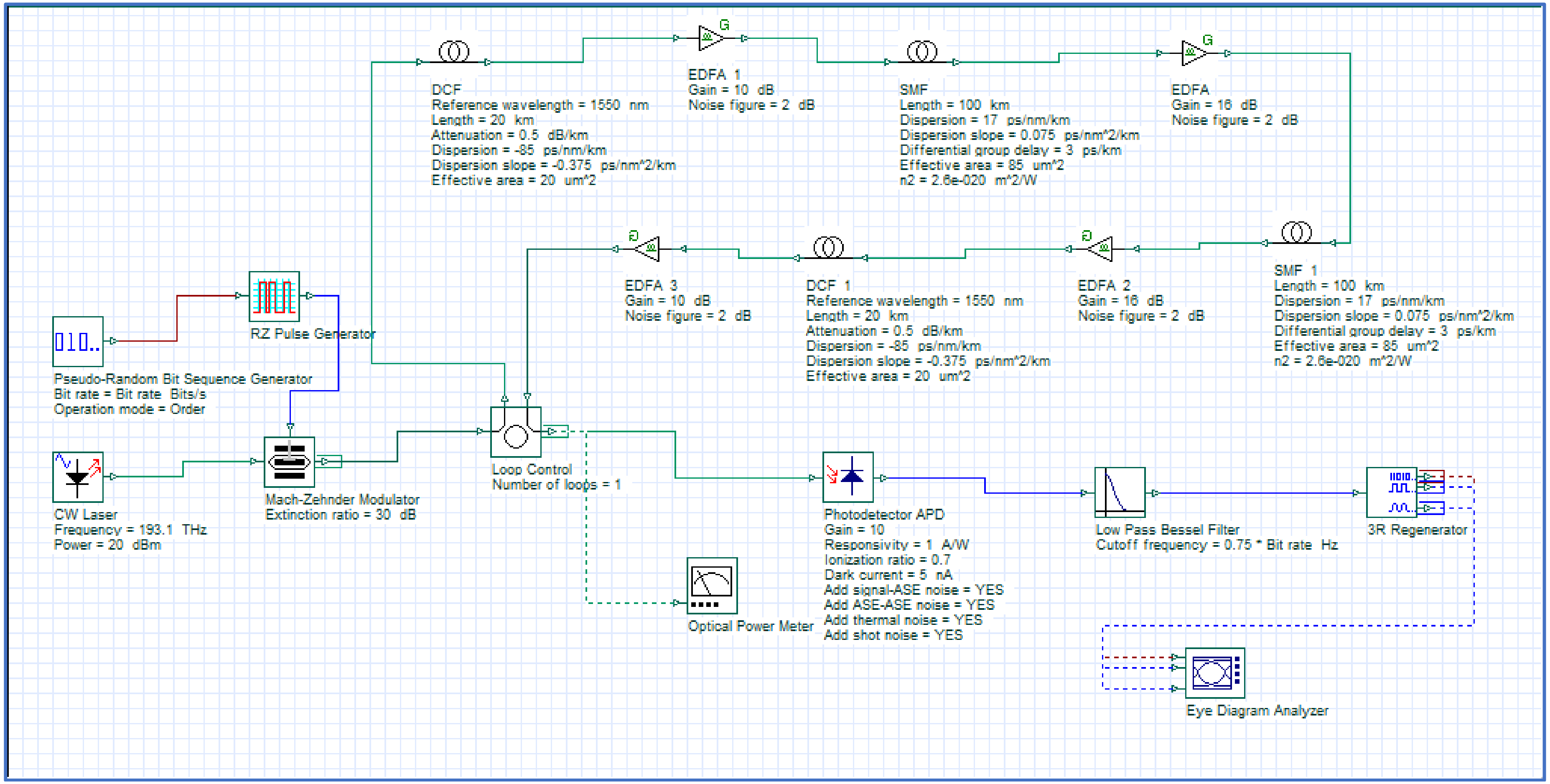

Figure 3. Symmetrical compensation using DCF simulation model.

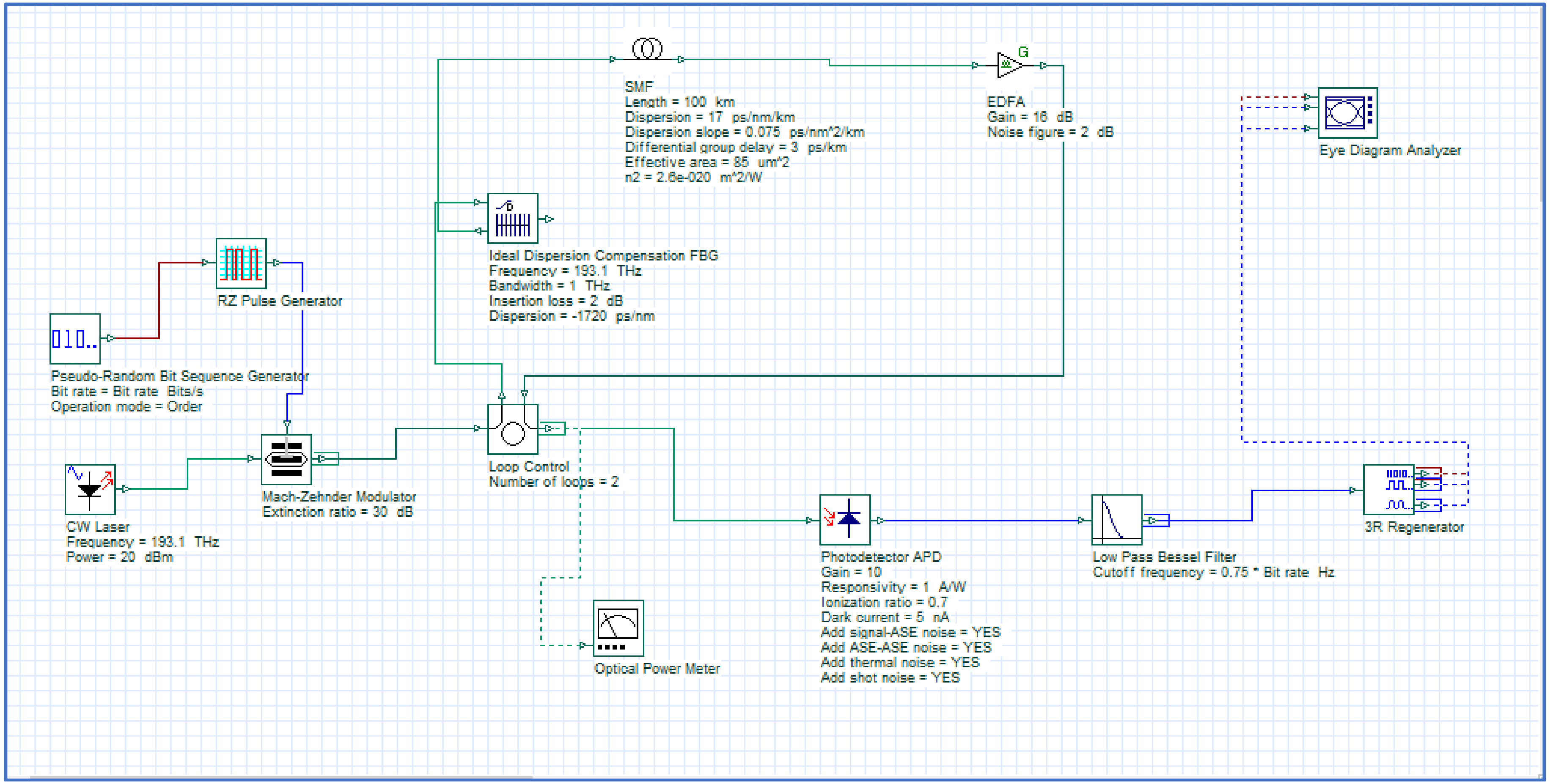

Figure 4. Pre-compensation using IDCFBG simulation model.

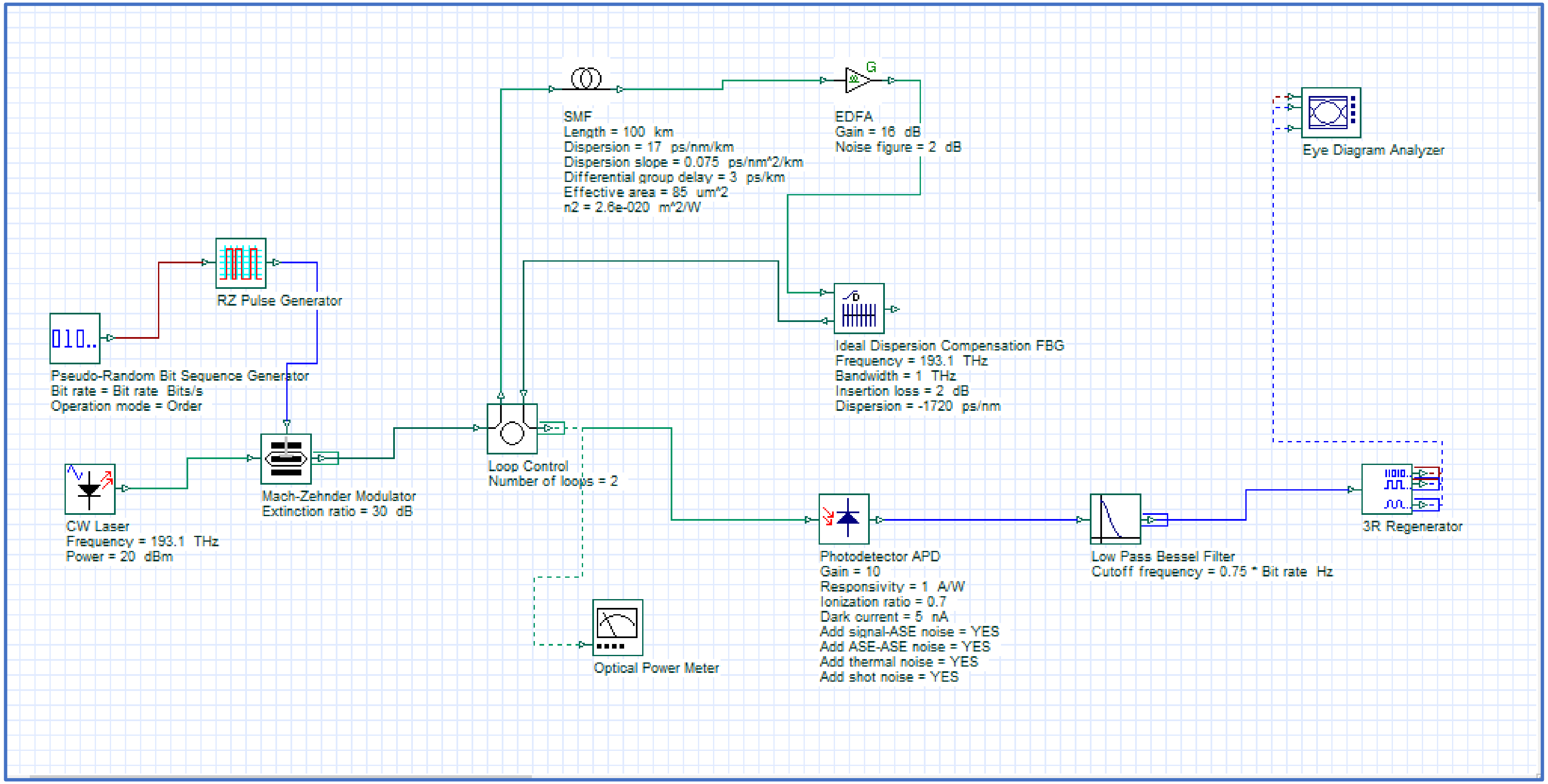

Figure 5. Post-compensation using IDCFBG simulation model.

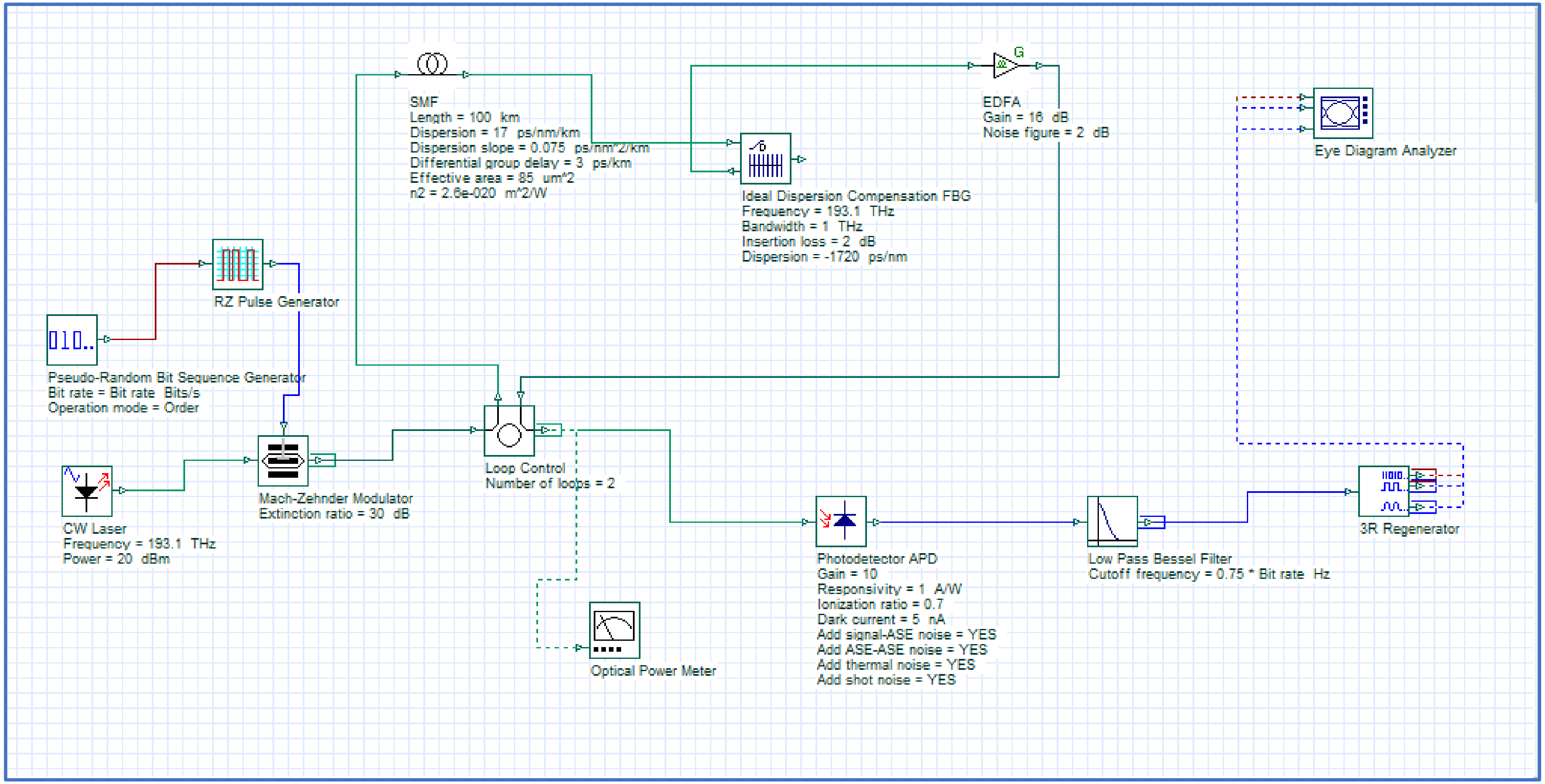

Figure 6. Symmetrical compensation using IDCFBG simulation model.

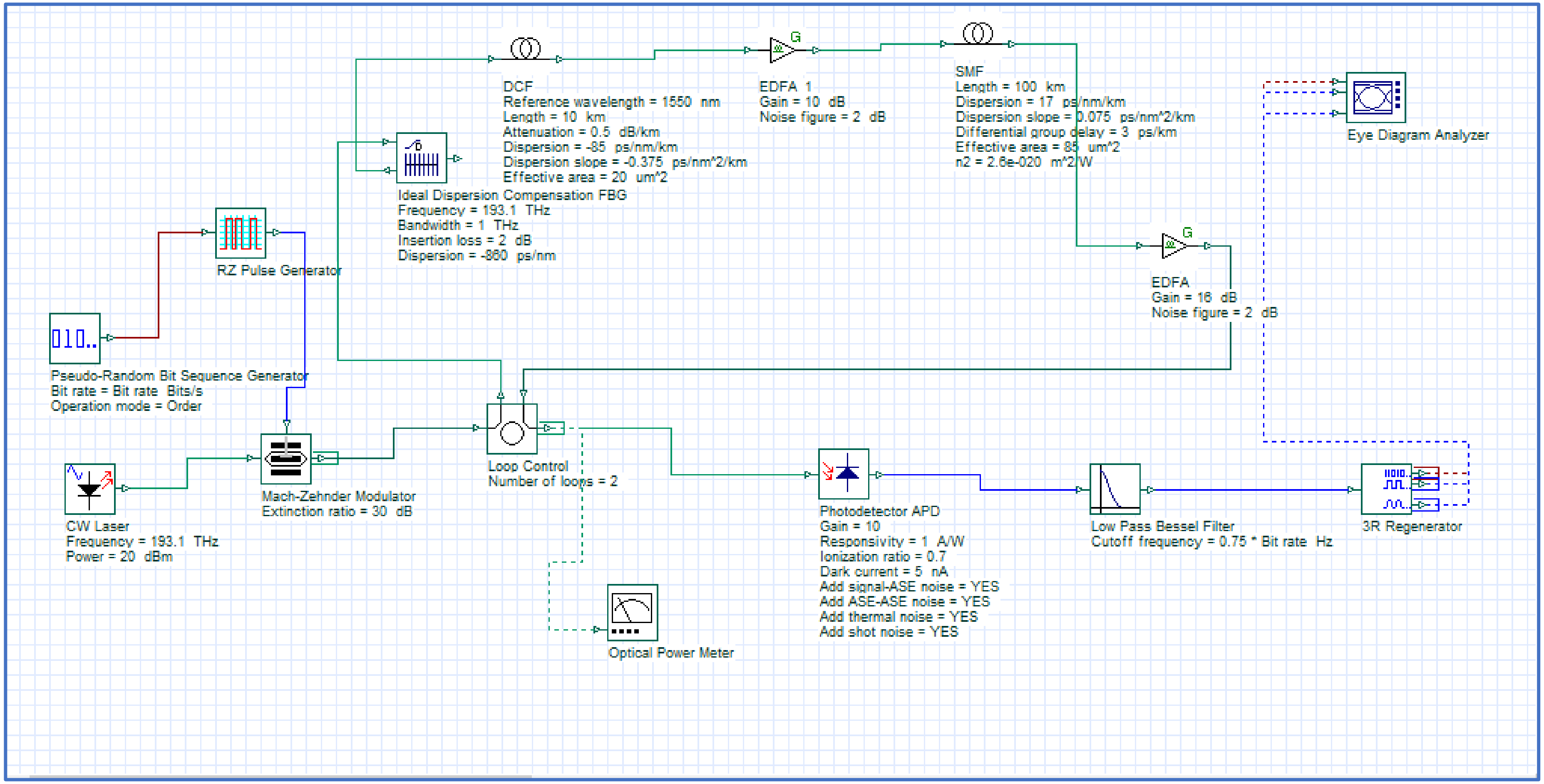

Figure 7. Pre-compensation using DCF-FBG simulation model.

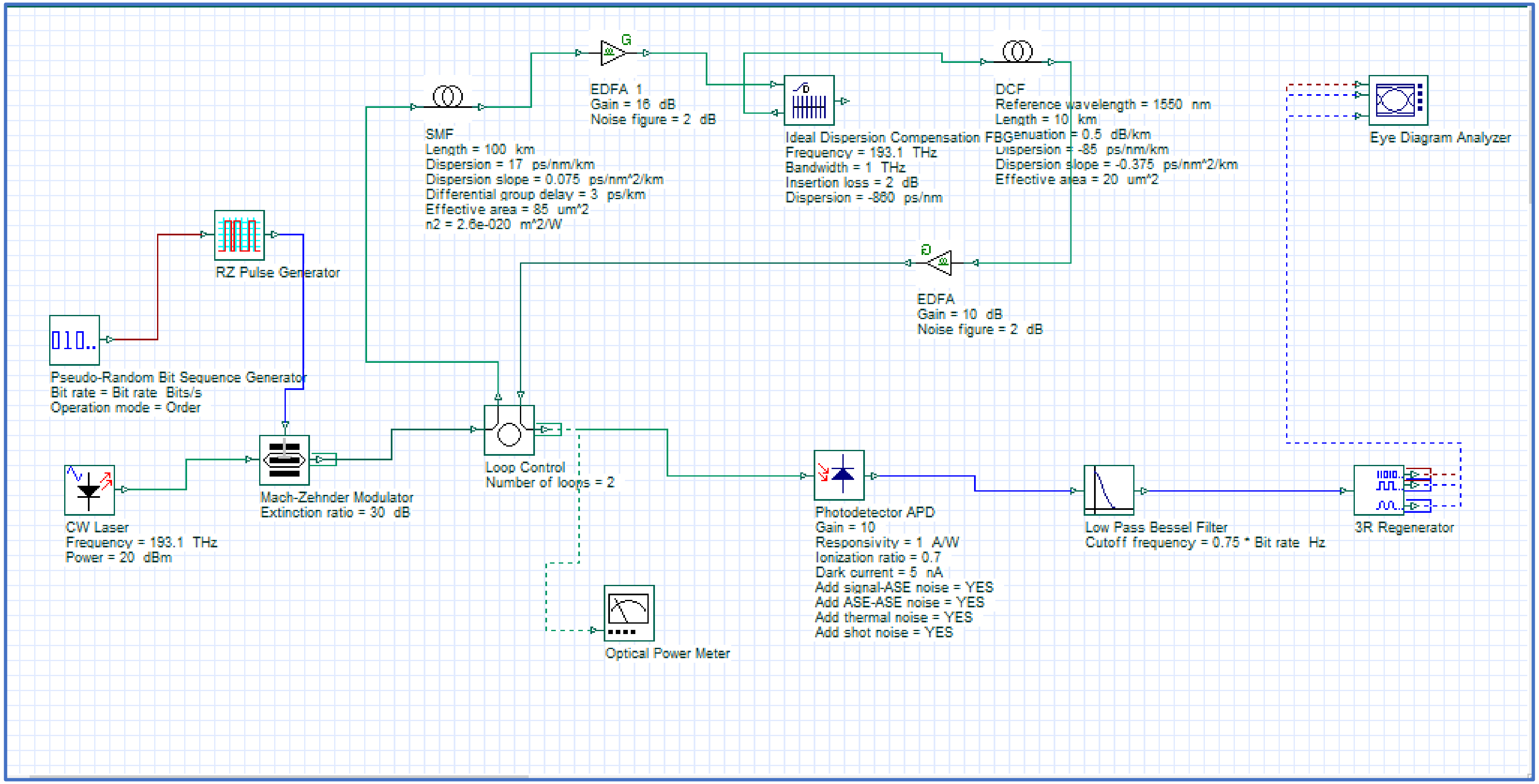

Figure 8. Post-compensation using DCF-FBG simulation model.

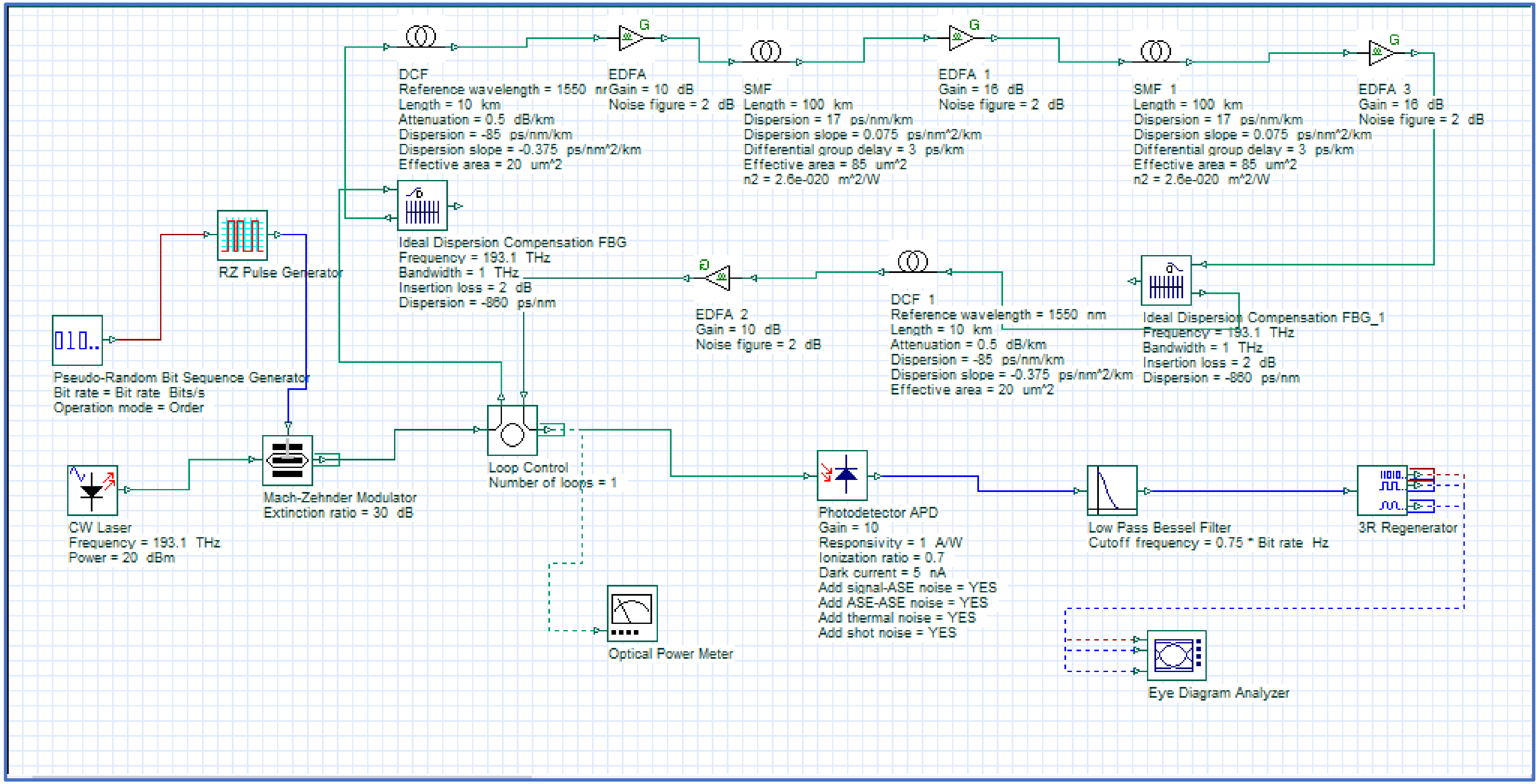

Figure 9. Symmetrical compensation using DCF-FBG simulation model.

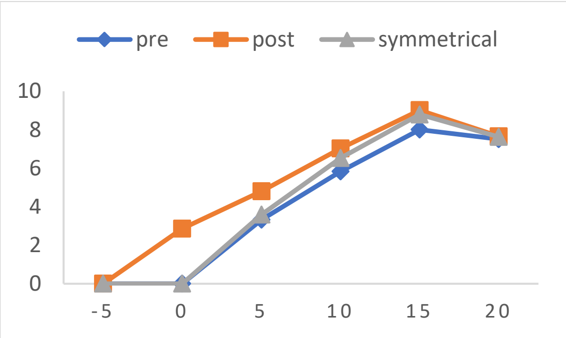

Figure 10. Comparison of Transmission power vs Q-factor influence of FBG simulation model.

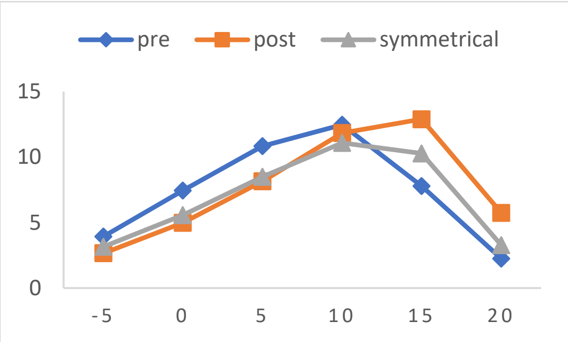

Figure 11. Comparison of Transmission power vs Q-factor influence of DCF-FBG simulation model.

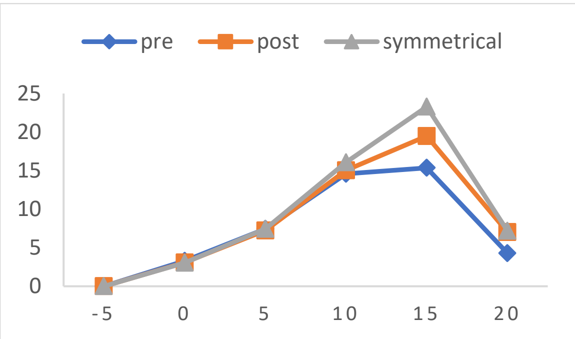

Figure 12. Comparison of Transmission power vs Q-factor influence of DCF simulation model.

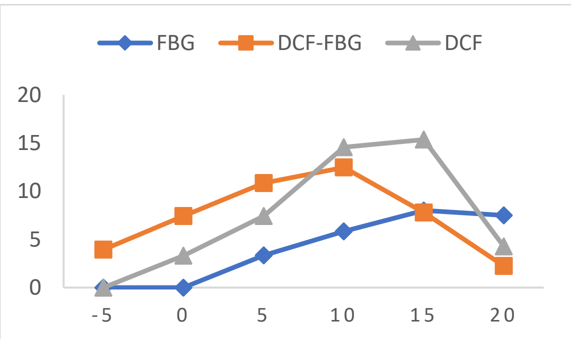

Figure 13. Comparison of Transmission power vs Q-factor influence in pre-compensation mode.

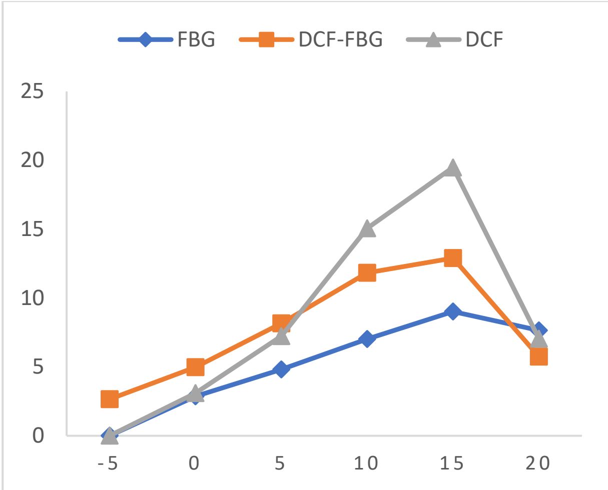

Figure 14. Comparison of Transmission power vs Q-factor influence in post-compensation mode.

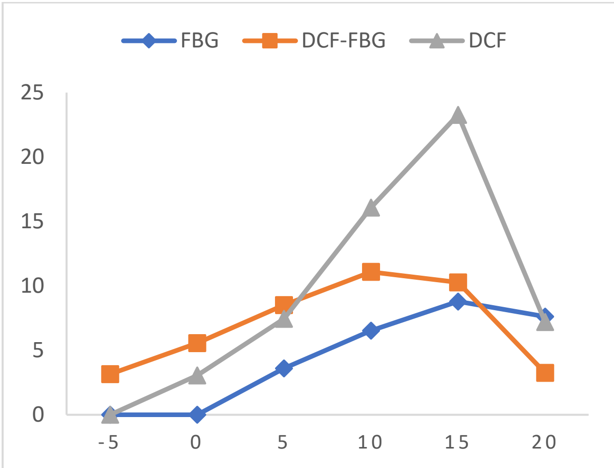

Figure 15. Comparison of Transmission power vs Q-factor influence in symmetrical mode.

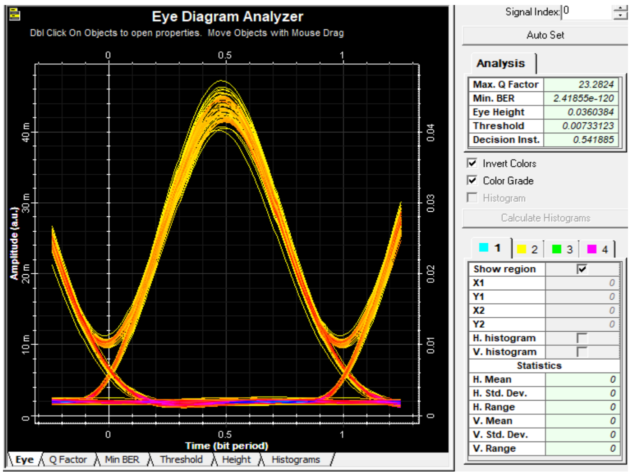

Figure 16. Eye diagram for DCF symmetrical compensation simulation result at -15 dBm input power.

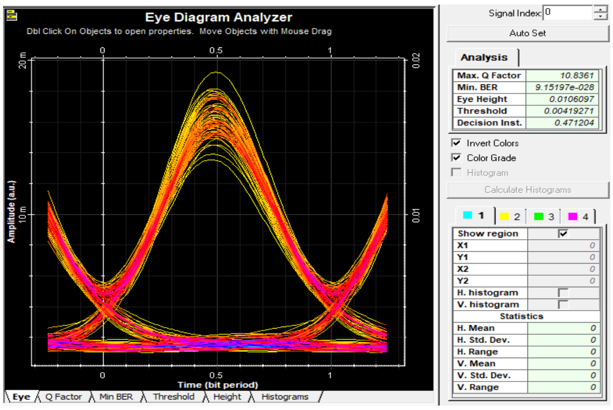

Figure 17. Eye diagram for DCF-FBG pre-compensation simulation result at 5 dBm input power

Table 4. Simulation results of the FBG model

Transmitted SignalPower	Q-Factor		
	Pre	Post	Symm.
-5	0	0	0
0	0	2.87013	0
5	3.33472	4.80579	3.59826
10	5.84047	7.02279	6.53683
15	8.005	9.01556	8.79573
20	7.508	7.65518	7.63105

Table 5. Simulation results of the DCF-FBG model

Transmitted SignalPower	Q-Factor		
	Pre	Post	Symm.
-5	3.9294	2.65284	3.15258
0	7.43716	4.98011	5.57083
5	10.8361	8.162	8.50435
10	12.4673	11.8314	11.0831
15	7.79289	12.8964	10.2684
20	2.2428	5.74072	3.26283

Table 6. Simulation results of the DCF model

Transmitted SignalPower	Q-Factor		
	Pre	Post	Symm.
-5	0	0	0
0	3.31692	3.09557	3.05317
5	7.43216	7.22034	7.43353
10	14.574	15.0505	16.0879
15	15.3546	19.4849	23.2824
20	4.28873	7.05111	7.19432

5. CONCLUSION:

The performance of each setup was reported in terms of Q-factor and BER. The evaluations of the systems depend on the best value of the Q-factor, which corresponds to BER. This paper focuses on the single-channel optical transmission system. After analyzing the results and graphs, it is clear that FBG compensation has the lowest Q-factor when compared to other simulation models in the low- and mid-power region (less than 20 dBm). DCF experiences the best performance at an input power of 10 and 15 dBm. To prevent nonlinear impairments, in which DCF is limited in optical input power and has a fairly large insertion loss, FBGs might take over from DCF as the preferred method for in-line dispersion compensation. The proposed DCF-FBG system shows its advantage in the low power region of 5 dBm and lower, and surpasses the FBG system by up to 15 dBm. This approach combines the benefits of both DCF and FBG as an effective way for dispersion compensation and loss reduction, respectively. This, in comparison to other models, has a significant contribution in providing the best Q factor in the low-power region. There is a key demand for longer fibers, which leads to higher costs associated with the positioning of amplifiers along the fiber routes. Also, dispersion increase with higher bandwidth, and the emphasis is strong on dispersion compensation points. Therefore, FBG can be focused at a single location and tends to have fewer compensation points and amplifiers.
So, for overall consideration, DCF and the cascaded system for their best Q-factor are the promising approaches, but a significant negative dispersion coefficient from DCF is required for the reduction of positive dispersion in SMF. This leads to an increase in the non-linear effect and overall cost. In addition, since it only corrects the center wavelength of the pulse, in which shorter wavelengths will be overcompensated and longer wavelengths will be undercompensated.

Unlike DCF, the FBG device can compensate for chromatic dispersion at multiple wavelength variations. As a result, FBG is the preferred option for compensating for chromatic dispersion.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding this article.

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