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ADVANCED OPTICAL COMMUNICATION SYSTEM DESIGN WITH FBG DISPERSION COMPENSATION TECHNIQUE

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Abstract-**This paper emphasized on advanced optical communication system with Fiber Bragg Grating (FBG) dispersion compensation technique. Fiber Bragg Grating (FBG) plays most vital role in compensating the pulse spreading technique due to overlapped output pulses. In this paper, we have focused on the design of advanced optical communication system with and without Fiber Brag Grating dispersion compensation technique represented by system design models 1 & 2. Also we developed simulation and analysis of advanced optical communication system with parameters such as Q-Factor (dB), output power (dBm), optical fiber length (km) and FBG length (mm). This advanced optical communication system design model 2 has advantage of 5dBm EDFA gain, 80 dB high Q-Factor (dB) and 0.118464 dB Eye Opening Pattern (EOP). Here the analysis and simulation of the advanced optical communication system has been developed by using OPTISYSTEM software.**

Keywords—Dispersion compensation; Fiber Bragg Grating (FBG); Optisystem software;Q-Factor(dBm).

I. INTRODUCTION

The development of optical communication system has enabled high bandwidth for long-distance transmission system with data rate of 10Gb/s. When the information transmitted through the optical fiber at the transmission side, some error generates at receiver side for computation of final output data [1]. The dispersion compensation technique generally used in optical communication system to avoid the errors and signal losses. The Fiber Brag Grating is the most crucial element in order to remove the spreading of the optical light pulses in dispersion compensation technique [7]. The Fiber Bragg Grating applies the photosensitive grating within the fiber. The Fiber Bragg Grating (FBG) [15] is also utilized for optical sensors [8]. It helps to achieve good performance of optical communication system in terms of output power (dBm) with good eye pattern diagram.

In this paper, we have developed simulation and analyzation of basic/advanced optical communication system with and without Fiber Bragg Grating (FBG) dispersion compensation technique. The advanced optical communication system with FBG dispersion compensation technique also has advantage of Erbium doped fiber amplifier (EDFA) gain for better Q-Factor with good eye pattern. Here the transmitter section simulation and analyzation developed with the fundamental parameters such as input power (dBm), optical fiber length (km) and Fiber Bragg Grating (mm). And receiver section simulation and analyzation includes the fundamental parameters based on output power (dBm), gain (dB) and Q-Factor (dB). Advanced /basic optical communication systesm simulation has been developed in OPTISYSTEM software. The OPTISYSTEM software is advanced design tool. It is very useful to learners for different levels of components design applications such as WDM/TDM, CATV etc. [3, 12]. This software provides lots of library functions and fundamental illustrations for beginners [2]. This paper includes following sections as given. Section II gives a brief description of components. Section III includes dispersion compensation technique required to maintain a good quality factor for fiber optic communication system. Next section IV is focused on the analysis and simulation of all designs. And Section V compares the effect of analysis and

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simulation results of all designs. Finally in last section VI conclude the summaries of all designs.

II. DSCRIPTION OF COMPONENTS

1. Continues laser diode(CW)

It gives the input power supply to the next component Mach-Zehnder modulator. It has 193.1 THz default frequency, 10MHZ line width and 1550 nm wavelength. The CW laser is utilized to produce high frequency optical signal [4].

2. Mach-Zhender modulator

It depends on the principle of interferometer. It has two input ports. One port is used as non-return to zero (NRZ) pulse generator. Other port is used for generation of input optical signal. It has 30 dB extension ratio[5].

3. Pulse genrator

Here two types of pulse generators are included – one return to zero (RZ) and other non-return to zero (NRZ). These are the bit sequence generators. It has two ports. One is used for binary input port. Another one is output port used for Mach-Zehnder modulator We have developed system design models 1 & 2 by use of NRZ pulse generator. [5].

4. Optical fiber

This is essential part of our system design. It is suitable for long distance communication. Here we use single mode fiber in three design system design models [6].

5. EDFA

EDFA gain amplifier used to avoid the losses in basic/advanced optical communication system [16]. The EDFA gain amplifier is added between the optical fiber and photodiode at receiver part. By use of EDFA gain amplifier, we get better quality of the received signal in term of Q-Factor (dB) and eye pattern diagram.

6. Photodetector(PIN photodiode)

It is used for detection of light (photons) at the receiver side [5]. The electric current generates from the detection of light by photo detector. The results observations have been done with the help of visualizer.

III. DESIGN OF BASIC/ADVANCED OPTICAL COMMUNICATION SYSTEM MODELS

The basic/advanced optical communication system design models are given below.

1. Design analysis of basic optical communication system without losses & dispersion compensation technique.
2. Design analysis of advanced optical communication system with losses & dispersion compensation technique utilization with the Fiber Bragg grating (FBG) single EDFA gain amplifier.

1. Design analysis of basic optical communication system without losses & with dispersion compensation technique.

The simulation and analyzation of basic/advanced optical communication systems performed with OPTISYSTEM software. Here all two optical communication system design models are developed by single channel transmission link with 10 Gb/s data rate. The basic optical communication system design model 1 block diagram is mention in figure 1 [3]. It consists electrical signal generator i.e. light source (CW), optical fiber cable and detector section i.e. photodiode [12]. The simulation and optimization of optical system has been performed in 1550 nm wavelength transmission window. It uses the CW laser source with 10 MHZ line width and 5 dBm transmitting power [15]. The single mode 10 km long fiber is placed between the Mach-Zehnder modulator and photo detector PIN diode as mention in Fig 2.The quality of received signal checked with visualizers such as eye opening Pattern (EOP) and Bit Error Rate (BER) analyzer. The Bit Error Rate (BER) is theoretically calculated from equation 1.

$$BER = Nc/Nb \quad (1)$$

Nc = Number of bits received in error.
Nb = Total number of bits introduced defined time interval.

The optical system design 1 basic parameters are shown in table 1.

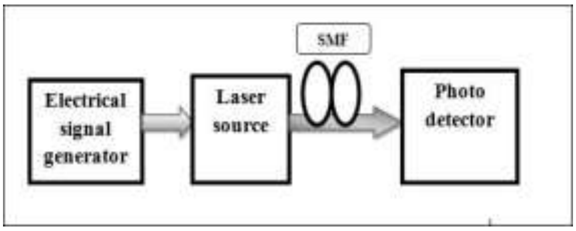

Fig. 1: The basic optical communication system block diagram.

TABLE 1 Simulation parameters of system design model 1.

Parameters	Values
C/W Laser power	5 dBm
C/W Laser frequency	193.1 THZ
Reference wavelength	1550 nm
Fiber length	10 km
PRBS data rate (NRZ)	10 Gbp/s
Attenuation coefficient	0.2 dB/km
Mach-Zehnder modulator with of extension ratio	30 dB

In optical system design model 1 with case 1.1 is considered for different optical fiber length (km).

Case 1.1

Here simulation has been performed at different optical fiber length from 5 km to 100 km. We also have analyzed the Q-Factor (dB) and total output power (dBm) for different optical fiber length (OFC) (km) [4].
The simulation of optical system design model 1 is shown in figure 2 given below.

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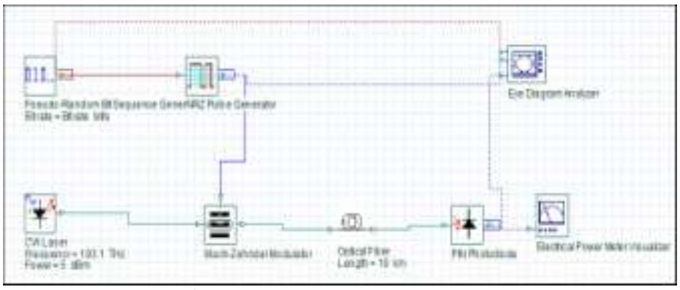

Fig 2. Simulation of optical communication system design model 1 by using OPTISYTEM software.

2. *Design analysis of advanced optical communication system with losses & dispersion compensation technique utilization with the Fiber Bragg grating(FBG) single EDFA gain amplifier.*

The system design model 2 basic block diagram is shown in figure 3 [4]. First the CW laser optical source is connected to Mach-Zehnder modulator. The CW laser source uses 1550 nm wavelength with 5 dBm input power (dBm). The transmitter section modulator is connected to pin diode receiver section by use of single mode fiber with 10 km length. In system design model 2 the dispersion compensation technique is applied with single EDFA gain amplifier. The Fiber Brag Gratting (FBG) length (mm) and EDFA gain (dB) are theoritically calculated from equation 2 and 3 respectively.

$$\lambda B = 2\, neff\, \Lambda \qquad (2)$$

where λB = Bragg Wavelength;
Λ= Grating Period.

neff = Effective refractive index of the transmitting medium.

$$\text{Optical Gain(dB)} = 10 \log[\, P\,out / P\,in] \qquad (3)$$

P out = Output power.

P in = Input power.

The distortion in system design model 2 is less in compare to system design model 1 with moderate Q-Factor (dB). The advanced optical communication system model design 2 simulation and analyzation parameters are given below in table 2.

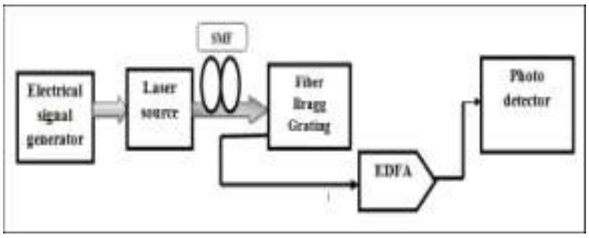

Fig. 3: The advanced optical communication system block diagram.

TABLE 2 Simulation parameters of system design model 2.

Parameters	Values
C/W Laser power	5 dBm
PRBS data rate (NRZ)	10 Gbp/s
C/W Laser frequency	193.1 THZ
Fiber length	10 km
Attenuation coefficient	0.2 dB/km
FBG length	7 mm
Mach-Zender modulator with of extension ratio	30 dB
EDFA length	5m

The advanced optical communication system design model 2 classified in two cases. These are discussed as under.

Case 1.2

The simulation and analyzation results of system design model 2 have been performed at different fiber optic length from 5 km to 100 km. We also have analyzed the high Q-Factor (dB), high total output power (dBm) and eye opening penalty (EOP) for one particular optical fiber length.

Case 1.3

The Simulation and analyzation results of system design model 2 have been performed at various Fiber Bragg Gratings (FBG) (mm) from 1 mm to 7 mm. We also have analyzed the high Q-Factor (dB), high total output power (dBm) and eye opening penalty (EOP) for one particular FBG length (mm).

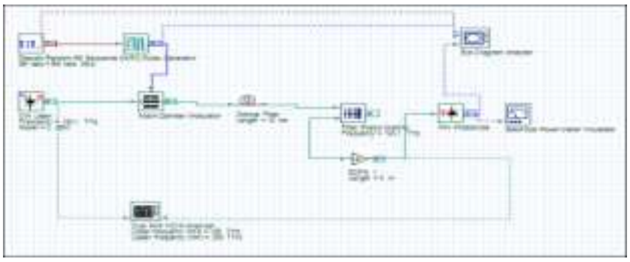

Fig. 4: Simulation of optical communication system design model 2 by using OPTISYTEM software.

IV. RESULTS AND DISCUSSIONS

The simulations of basic/advanced optical communication systems design models are produced in OPTISYSTEM software. The results are observed along with Bit Error Rate (BER) analyzer. Here the Bit Error Rate (BER) analyzer is consider with 10^(-9) bit error rate. These results are mainly focused on parameters such as Q-Factor (dBm), output power (dB), OFC length (km) and FBG length (mm). The best design system model gives high Q-Factor (dB) corresponds to better system performance. The different simulated and analyzed values of Q-Factor (dB) with dispersion compensation technique are listed in table 3 to 6.

1) Design and simulation analysis of basic optical communication system without losses and dispersion compensation technique.

Case 1.1: Simulation at different optical fiber length (km)

The output readings of Q-Factor (dB) along with variations of 5km to 100 km OFC length (km) are tabulated. From these tabulated values we plotted graph 5 for different Q-Factor (dB) values verses OFC length (km). In this graph we observed that

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OFC length (km) is inversely proportional to the Q-Factor (dB) values.

TABLE 3 Output readings of Q-Factor (dB) verses OFC length (km).

OFC length (km)	Q-Factor (dB)	EOP
5	**37.124**	**0.0023**
10	12.547	0.0076
20	8.4320	0.00086
30	8.3298	0.00055
50	3.7136	7.395e-005
70	3.2678	4.662e-005
100	2.2729	-5.914e-006

Generally Bit Error Rate (BER) analyzer with 10^(-9) bit error rate gives Q-Factor value upto 5.99. The Q-Factor results below 5.99 are not considered for system design models.

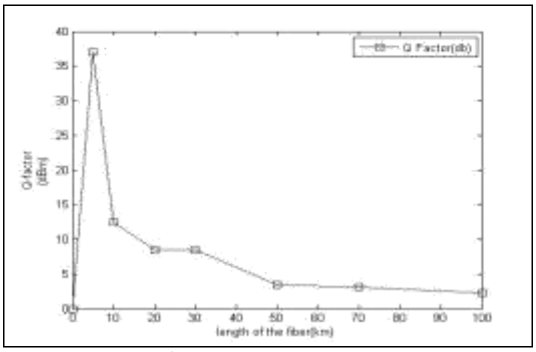

Fig 5. Graph of Q-Factor (dB) verses OFC length (km)

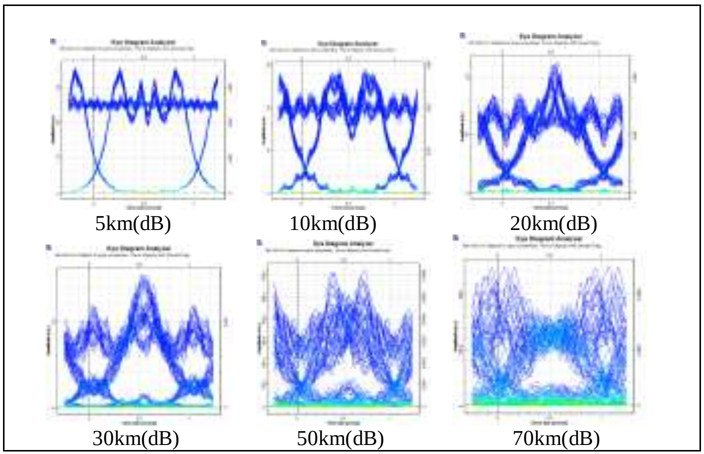

Fig.6: Analyzation of eye diagram by using different values of OFC length (km).

The received signal strength is observed by eye pattern diagram. We get best result of eye pattern diagram (eye opening case) at 5 km OFC length (km) with 37.124 dB Q-Factor (dB) value as shown in above fig.7.

2) Design and simulation analysis of advanced optical communication system with losses & dispersion compensation technique utilization with the Fiber Bragg Grating (FBG) single EDFA gain amplifier.

Case 1.2: Simulation at different optical fiber length (km).

The output power readings with Q-Factor (dB) along with variations of OFC length (km) are tabulated. From these tabulated values, we plotted graph 8 of different Q-Factor (dB) values verses OFC length (km). In this graph we observed that OFC length (km) is inversely proportional to the Q-Factor (dB).

TABLE 4 Output power readings (dBm) with Q -factor (dB) verses OFC length (km).

OFC length (km)	Q-Factor (dB)	Output power (dBm)	EOP
5	**80.50**	**8.32**	**0.118464**
10	54.28	8.31	0.116983
20	28.43	7.87	0.107345
30	12.47	7.62	0.0981207
50	8.779	6.80	0.073981
70	7.554	5.345	0.0468138
100	3.654	0.36	0.00756109

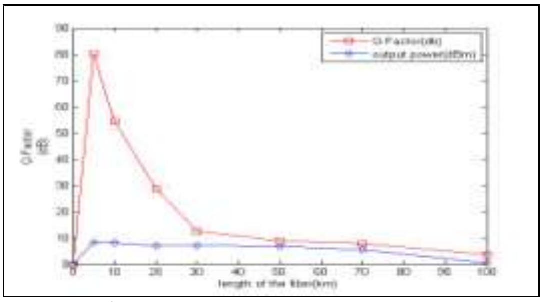

Fig.7: Graph of output power (dBm) with Q-Factor (dB) verses OFC length (km)

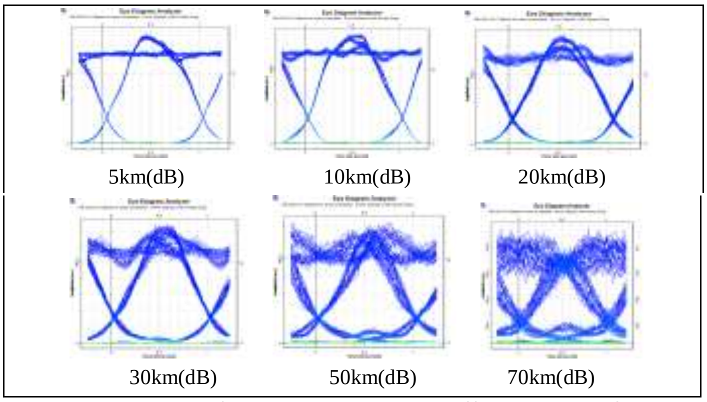

Fig.8: Analyzation of eye diagram by using different values of OFC length (km)

Case 1.3: Simulation at different Fiber Bragg Grating (FBG).

Here we observed the different values Q-Factor (dB) and output power (dBm) by changing the Fiber Brag Garting (FBG) (mm). From tabulated values, it is clear that only one particular 7 mm FBG length value gives high Q-Factor (dB).

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We also plotted graph 9 of output power with Q-Factor (dB) verses FBG (mm).

TABLE 5 Output power readings (dBm) with Q –factor (dB) verses FBG (mm).

FBG (mm)	Q-Factor (dB)	Output power (dBm)	EOP (dB)
1	13.33	5.12	0.0661955
2	30.68	7.24	0.0976007
5	49.75	7.99	0.109379
7	**64.64**	**8.07**	**0.116047**

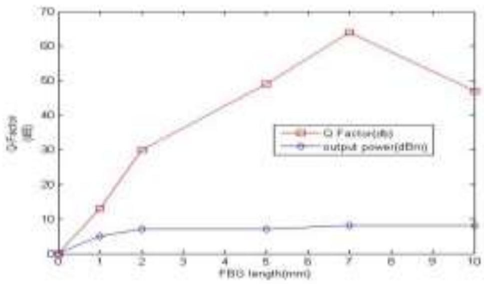
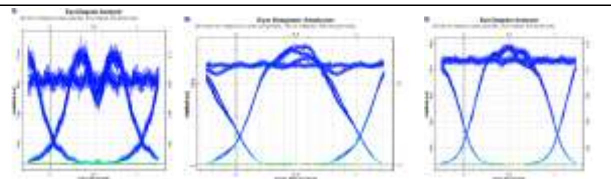


Fig.9: Graph of output power (dBm) with Q-Factor (dB) verses FBG (mm)



1mm (dB) 7mm (dB) 5mm (dB)

Fig.11: Analyzation of eye diagram by using different values of FBG (mm).

V. COMPARATIVE ANALYSIS

Here we have simulated and analyzed basic/advanced optical communication system design models 1 & 2. By comaparing these two system design models, we conclude that system design model 2 gives the best result in terms of parameters such as output power (dBm), Q-Factor (dB) and eye pattern. Finally we summarized the results of these two system design models on the basis of changes in the Q-Factor (dB) values with respect to OFC length (km) as shown in table 6. We also plotted a graph 10 of Q-Factor (dB) values verses OFC length (km) of tabulated data.

Comparision of system design models Q-Factor (dB) verses OFC length (km)

By comparing two system design models, we conclude that system design model 2 gives the best result in terms of output power (dBm), Q-Factor (dB) and eye pattern.

TABLE 6 Output readings of Q-Factor (dB) verses OFC length (km)

OFC length (km)	Design 1 Q-Factor (dB)	Design 2 Q-Factor (dB)
5	37	**80**
10	12	54
20	8	28
30	8	12
50	3	8
70	3	7
100	2	3

From the above tabulated data it is clear that system design model 2 has highest Q-Factor (dB) i.e. 80 value. From below graph we have analyzed that system design model 1 has worst Q-Factor (dB) curve. The system design model 2 has best performance in terms of Q-Factor (dB) curve.

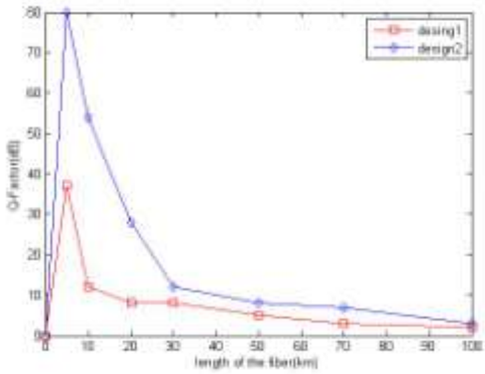


Fig.10: Graph of OFC length (km) verses Q-Factor (dB)

VI. CONCLUSION

We have simulated and analyzed basic/advanced optical communication system design models 1 and 2 by using OPTISYSTEM software with certain parameters such as Q-Factor (dBm), output power (dBm), and OFC length (km). The system design model 1 has analysis of basic optical communication system without losses & dispersion compensation technique. The system design model 2 has focused on the analysis of advanced optical communication system with losses & dispersion compensation technique utilization with the Fiber Bragg grating (FBG) EDFA gain amplifier. From the simulated and analyzed results of basic/advanced optical communication system design models, we conclude that system design model 2 gives best result in terms of 80.50 dB Q-Factor, 8.32 dBm output power, 5 km OFC length with 7mm FBG length and good eye pattern diagram.

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