

PERFORMANCE INVESTIGATION OF OPTICAL TRANSMISSION SYSTEM USING DCF-EDFA TECHNIQUES

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Abstract

In this paper, a single channel optical system is proposed with dispersion compensation fiber techniques. Dispersion compensation method restricts the pulse broadening consequence of transmitted pulse in optical systems. To overcome dispersion trouble; dispersion compensation scheme modeled for investigate the performance of optical system. The proposed model is designed for 10Gbps with non-return-to-zero (NRZ) modulation format with erbium doped fiber amplifier (EDFA) over a length of 15km single mode fiber (SMF) and 3km dispersion compensation fiber (DCF). The performance of designed model is analyzed in terms of output power (dBm), gain (dB), noise figure (dB), Q-factor, BER and Eye-diagrams by varying the fiber length (km), input power (dBm) and attenuation constant (dB/km). The simulation is carried out in Opti-System7.0 simulator.

Keywords:

Bit Error Rate, Dispersion Compensation Fiber, Erbium Doped Fiber Amplifier, Non-Return-to-Zero

1. INTRODUCTION

Recently, the demand of optical fiber technology is increased day by day in telecommunication industry due to large bandwidth, high data rate and low cost reliable optical communication links. The transmission in optical network is mainly effected, when different wavelength signals are transmitted over an optical fiber, these optical signals travel with different speeds due to the variations in core and cladding refractive index. Therefore, the optical signals are overlap/broaden/spread out after travel a long distance through fiber. Hence the broadening of pulse causes dispersion and losses in transmitted signals which lead to error signal at receiver end [1]-[3]. Therefore, attenuation loss and dispersion are the major factor that affect optical network. In order to overcome the attenuation problem, erbium doped fiber amplifier (EDFA) is introduced as shown in Fig.1. To amplify the optical signal, EDFA is the most frequently used optical amplifier (OA) because it works on low loss 1550nm wavelength window of silica based fiber [4]-[6].

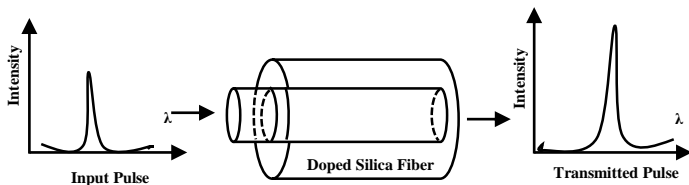


Fig.1. Basic principal of EDFA amplifier

In optical transmission system, dispersion is the key issue to restrict the long distance optical fiber communication [7], [8]. To overcome dispersion issue, the most efficient technique that is Dispersion Compensation Fiber (DCF) is introduced having

negative dispersion coefficient to compensate the effect of positive dispersion in an optical fiber communication link [9]. However, DCF technique increases insignificant nonlinear effects but it is low cost, simplicity, highly reliable and easy to upgrade of already installed links of single mode fiber (SMF) in an optical network [10]-[16].

In this paper, we investigate the performance of 10Gbps optical transmission system using dispersion compensation fiber technique. The optimized parameters of SMF and DCF are identified and after simulation, performance parameters of the proposed model are analyzed for single channel in terms of output power (dBm), gain (dB), noise figure (dB), Q-factor, BER and Eye-diagram for NRZ modulation scheme. Main aim of presented work is to improve the performance of proposed model by reducing dispersion and attenuation phenomena through DCF techniques and EDFA amplifier, respectively. The designed optical configurations are modeled and simulated using advanced tools of Opti-System7.0 simulator.

2. DISPERSION COMPENSATION TECHNIQUES

Dispersion supervision plays an important role for designing of optical transmission systems because; dispersion degrades the performance of longer optical transmission link due to the fiber nonlinearity. So, dispersion compensation fiber (DCF) is the most universal technique to reduce the impact of dispersion. For this purpose, a special single mode fiber is designed to reverse the deleterious consequence of dispersion and improve the transmission quality of optical fiber. Therefore, the DCF has a higher negative dispersion coefficient around -80ps/nm-km fibers can be linked to the SMF having positive dispersion coefficient of 16ps/nm-km to compensate the dispersion effect as shown in Fig.2.

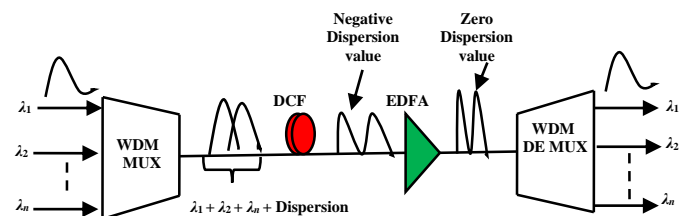


Fig.2. Basic principal of DCF Technique with EDFA optical transmission system

Hence, dispersion compensation fiber is competent to compensating the group velocity dispersion (GVD) and insignificant nonlinear effect inside the fiber if optical power is kept small. The pulse propagation equation for optical signal

propagates through the segments of SMF and DCF at L transmission distance can be given as [9]:

$$V(L,t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \tilde{V}(0,\omega) \exp\left(\frac{i}{2}\beta\omega^2 L - i\omega t\right) d\omega \quad (1)$$

where $\tilde{V}(0,\omega)$ is Fourier transform of pulse amplitude $V(0,t)$ and β is GVD parameter, which is related to dispersion. Dispersion induced deficiency of optical signal is cause by the phase aspect, $\exp\left(\frac{i}{2}\beta\omega^2 L\right)$, which can be acquired by signal during its transmit throughout the optical fiber. If the length of two fiber segments LSMF, LDCF are due to SMF and DCF, respectively then from the Eq.(1):

$$V(L,t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \tilde{V}(0,\omega) \exp\left(\frac{i}{2}\omega^2 \left(\beta_{SMF} L_{SMF} + \beta_{DCF} L_{DCF}\right) - i\omega t\right) d\omega \quad (2)$$

where, overall length of fiber segments is $L=L_{SMF}+L_{DCF}$ and β_{SMF} , β_{DCF} are GVD parameters for the segments of fiber length LSMF and LDCF, respectively. If we choose DCF then ω^2 term disappear thus original pulse shape can be recover. Therefore, perfect condition for dispersion compensation beside DCF can be given as:

$$\beta_{SMF} L_{SMF} + \beta_{DCF} L_{DCF} = 0 \quad (3)$$

or

$$D_{SMF} L_{SMF} + D_{DCF} L_{DCF} = 0 \quad (4)$$

and

$$D = -\frac{2\pi c}{\lambda^2} \beta \quad (5)$$

where, λ is wavelength of pulse signal, C is the light speed. Because in case of SMF, $D_{SMF} > 0$, Eq.(4) shows that dispersion coefficient D_{DCF} (in ps/nm.km) (at certain wavelength λ in nm) of DCF should be negative for dispersion compensation and length L_{DCF} (in km) of DCF must be satisfy as,

$$L_{DCF} = -L_{SMF} \left(\frac{D_{SMF}}{D_{DCF}}\right) \quad (6)$$

Further, to overcome remaining dispersion in very high speed optical transmission systems, the dispersion slop S_{DCF} of DCF must be satisfy as,

$$S_{DCF} = -S_{SMF} \frac{L_{SMF}}{L_{DCF}} = S_{SMF} \frac{D_{DCF}}{D_{SMF}} \quad (7)$$

where, S_{SMF} is dispersion slope of SMF. According to above analysis, the components/mechanisms of DCF are wide bandwidth performance, more stable and negligible temperature effect. Hence, DCF is the most appropriate technique for dispersion compensation. Therefore, the physical arrangement of SMF, DCF and EDFA can be situated at different positions in optical transmission system for dispersion as well as attenuation compensation. In section 3 and section 4, we discussed the proposed optical transmission model and evaluate its performance in terms of output power (dBm), gain (dB), noise figure (dB), Q-factor, BER and Eye-diagrams at different fiber length, input power and attenuation constant.

3. PROPOSED SIMULATION MODEL

A single channel optical communication system is designed for 10Gbps per channel transmission speed based on DCF-EDFA compensation techniques. The proposed model is simulated by software Optisystem7.0 using NRZ modulation format to investigate how dispersion altered the performance of optical transmission system. The basic principal of single channel optical transmission system model is shown in Fig.3. A single channel transmitter is constructed by data source, to produce a pseudo random sequence, NRZ pulse generator, to convert binary data into electrical pulse, continuous wave laser (CW) and Mach-Zehnder (MZ) modulator to modulate the CW laser signal. The central frequency of channel is choosing on 193.1THz according to recommendation of ITU-TG.694.1.

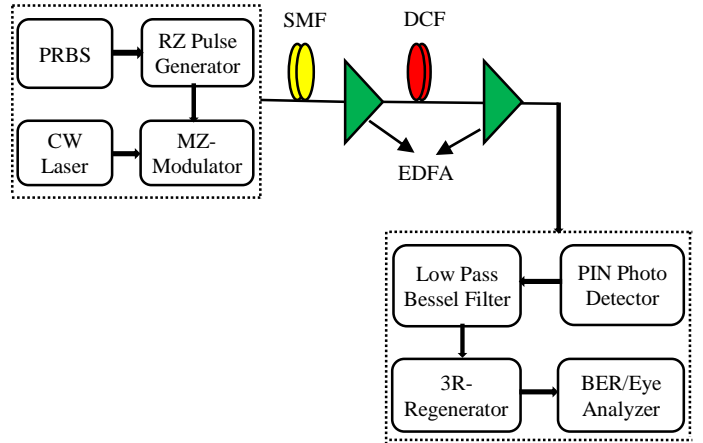


Fig.3. Principal of proposed optical transmission system using DCF-EDFA compensation techniques

The CW laser source is used for generating wavelength optical signal. The optical input signal is combine/spread over a single optical fiber consisting of SMF and DCF. The length of SMF and DCF are 15km, 3km, respectively. Therefore, total transmission length of channel is 18km. Further, relative arrangement of DCF, SMF and Erbium doped fiber amplifier (EDFA) are preferred according to dispersion compensation techniques. EDFA is introduced to amplify the transmitted signal as shown in Fig.3. The received optical signal is given to PIN photo-detector and pass through low pass electrical Bessel filter and BER/Eye analyzer. The whole simulation model of 10Gbps optical transmission system is shown in Fig.4 and parameters of simulation model components are given in Table.1.

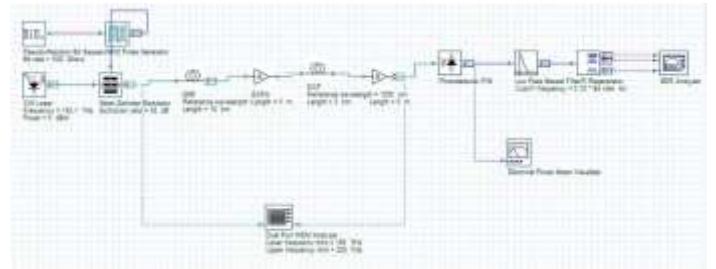


Fig.4. Proposed simulation model of 10Gbps optical transmission system using DCF-EDFA techniques

Table.1. Basic components with parameter values of simulation model

Components	Parameters
Data source	Data rate: 10Gbps
Line coder	NRZ
CW Laser	Output power: 5dBm FWHM line width: 10MHz Channel central frequency: 193.1THz
Mach-Zehnder (MZ) Modulator	Extinction ratio: 30dB
DCF	Length: 3km Attenuation Loss: 0.2dB/km Dispersion: -80ps/nm.km Dispersion slop: -0.37ps/nm ² /km Core effective area: 25μm ²
SMF	Length: 15km Attenuation Loss: 0.2dB/km Dispersion: 16ps/nm.km Dispersion slop: 0.08ps/nm ² /km Core effective area: 85μm ²
EDFA Gain	Variable Gain (10-30dB)
Receiver	Photo-detector: PIN Diode Sensitivity: -100dBm Error probability: 10 ⁻⁹
Low Pass Bessel Filter	-3dB Bandwidth: 10GHz

4. RESULTS AND DISCUSSIONS

The performance of proposed optical transmission model is simulated on Optisystem7.0 simulator and with satisfactory standards of quality factor (Q-factor), bit error rate (BER) are measured by BER analyzer. Hypothetically, $Q > 6$ and $BER \leq 10^{-9}$ are the acceptable values for enhanced optical communication system. Therefore, higher value of Q-factor and lower value of BER authenticate the low noisy and better optical transmission system. Performance of optical transmission system is investigate by varying the length of optical fiber (SMF), input power and attenuation coefficient parameters in comprehensive to pact with optimized subsequent parameters value as given in Table1. Initially, the performance of proposed model is investigated by varying the length of SMF with DCF-EDFA techniques. Different Eye-diagrams are evaluated from simulated model with different values of SMF length as shown in Fig.5. It can be observed that, when the length of SMF increases, closing of eye remains nearly same with slightly distorted while we compare the Eye-diagrams. The output readings of optimized performance parameters with corresponding fiber length are given in Table.2 in terms of Q-Factor, gain, min BER, noise figure, and output power.

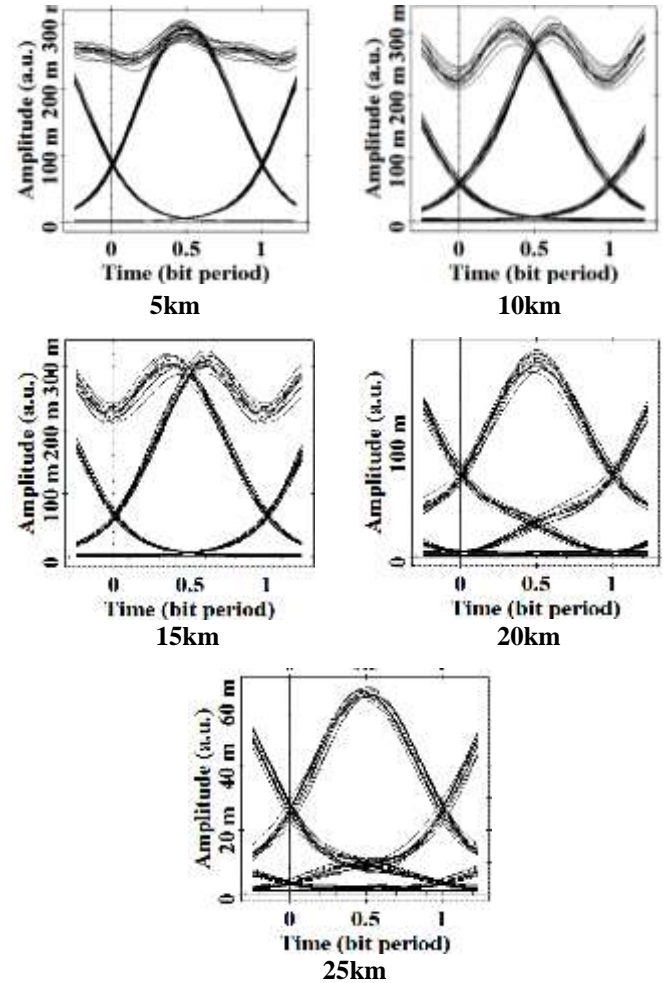


Fig.5. Eye-diagrams of received signals from proposed optical fiber transmission system with different values of SMF length

Table.2. Performance parameters of simulated model by varying SMF length

Length (km)	Max Q-factor	Min BER	Gain (dB)	Noise Figure (dB)	Output Power (dBm)
5	160.1183	1.09166×10^{-174}	18.975819	4.37252	16.432
10	140.4693	1.14862×10^{-133}	18.567038	5.29250	16.079
15	145.5749	1.47701×10^{-119}	18.499858	6.40983	16.223
20	130.8367	2.18905×10^{-019}	17.818290	7.88650	15.697
25	110.7412	2.63383×10^{-037}	16.284000	8.12069	15.450
30	100.6543	3.53383×10^{-040}	15.965430	9.12045	14.987

Secondly, the performance of proposed system is investigated by varying the input power with SMF-DCF-EDFA techniques. The different Eye-diagrams are evaluated from simulated model with different values of input power as shown in Fig.6. It can be observed that, when input power increases, closing of eye remains distorted while we compare the Eye-diagrams and clearly opening of eye-diagram is obtained at 5dBm input power. Therefore, we choose the optimized output power of CW laser at 5dBm. Further, the output readings of optimized parameters with corresponding input power are given in Table.3.

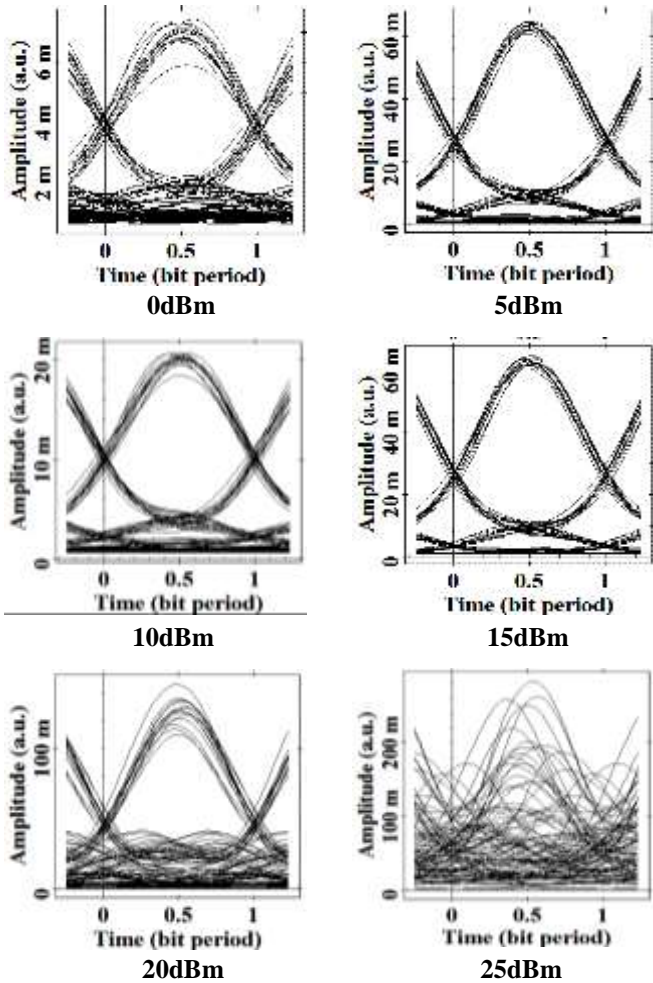


Fig.6. Eye-diagrams of received signals from proposed optical fiber transmission system with different values of input power

Table.3. Performance parameters of simulated model by varying input power

Input Power (dBm)	Max Q-Factor	Min BER	Gain (dB)	Noise Figure (dB)	Output Power (dBm)
0	160.2819	6.16003×10^{-14}	25.8706	6.1839	13.817
5	149.895	1.93068×10^{-23}	20.7409	6.1526	13.987
10	125.741	1.63383×10^{-37}	12.2840	6.1269	13.450
15	110.885	1.03539×10^{-09}	8.19702	6.1481	13.438
20	95.1751	0.2006002	6.20725	7.5311	14.876
25	89.7461	0.1606002	5.45020	8.6321	14.950

Lastly, the performance of proposed system is investigated by varying the attenuation coefficient with SMF-DCF-EDFA techniques. The different Eye-diagrams are evaluated from simulated model with different values of attenuation coefficient as shown in Fig.7. It can be observed that, when attenuation increases, closing of eye remains distorted while we compare the Eye-diagrams and higher eye opening is obtained at attenuation coefficient of 0.2dB/km. Therefore, we choose a minimum attenuation coefficient of optical fiber for the proposed optical system to obtain the finest value of performance parameters.

Further, the output readings of optimized parameters with corresponding attenuation coefficient are given in Table.4.

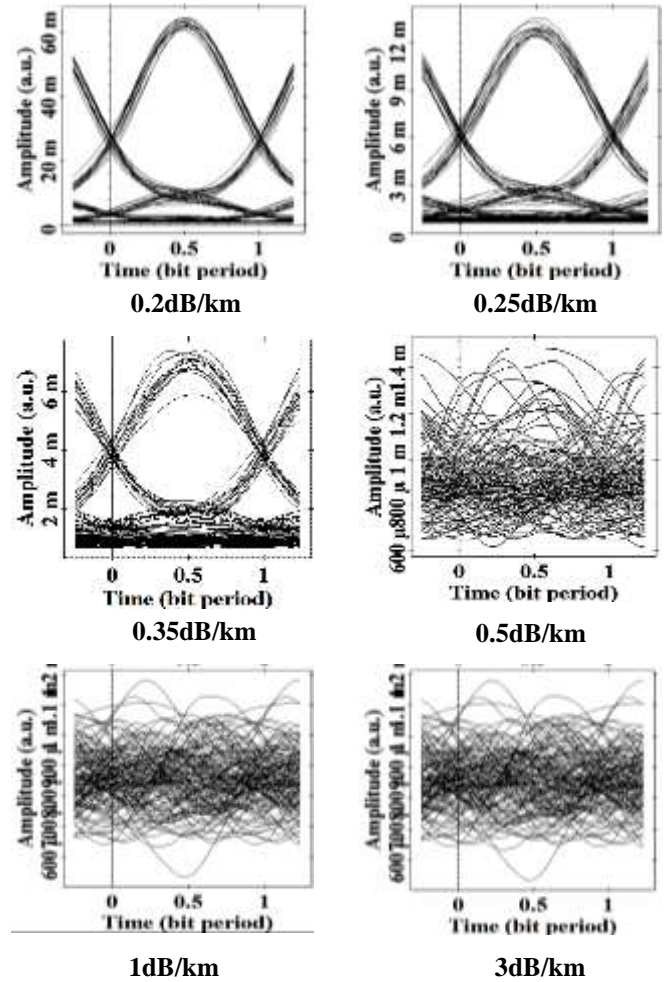


Fig.7. Eye-diagrams of received signals from proposed optical fiber transmission system with different values of attenuation coefficient

Table.4. Performance parameters of simulated model by varying attenuation coefficient

Attenuation (dB/Km)	Max Q-Factor	Min BER	Gain (dB)	Noise Figure (dB)	Output Power (dBm)
0.2	145.7412	1.63383×10^{-37}	18.2840	6.1269	15.011
0.25	135.8914	2.46648×10^{-28}	15.6949	17.6911	15.990
0.35	70.2253	3.46648×10^{-20}	10.5693	36.6955	15.890
0.5	0.00243	5.46648×10^{-20}	-14.0321	30.3560	9.346
1	0	1	-12.0654	48.1966	7.734
3	0	1	-8.1695	56.2974	-5.734

It can be concluded from the above discussions; the quality of eye opening of received signal is much clear by applied SMF-DCF-EDFA compensation techniques with optimized parameters and provides the best possible performance for dispersion compensation. Furthermore, the Table.5 summarized the comparative analysis of the proposed work along with similar research work reported earlier [12]-[16].

Table.5. Comparative analysis of proposed work with similar research work reported previously using deliberated DCF-EDFA techniques

Technique or Parameters	Proposed Work	[12]	[13]	[14]	[15]		[16]
	DCF	FBG	FBG	CFBG	FBG	DCF	DCF
Max Q-Factor	145.5749	50.2712	40.209	81.4650	-	-	33.7767
Min BER	$1.47701 e^{-119}$	$4.02312 e^{-014}$	-	$3.08032 e^{-017}$	-	-	$1.80195 e^{-027}$
Gain (dB)	18.4998	14.4298	10.920	25.4509	8.23	1.45	-
Output Power (dBm)	16.223	12.205	12.094	16.807	7.40	2.94	2.453
Noise Figure (dB)	6.40983	8.0812	24.342	5.275	-	-	37.320
DCF Length (km)	18	-	-	-	-	22	30
CFBG Length (mm)	-	75	85	90	50	-	-

5. CONCLUSIONS

The presented work is highlighted on performance analysis of optical transmission system over a fiber length of 18km (15km-SMF+3km-DCF) for 10Gbps data speed. The proposed model is designed and simulated using dispersion compensation (DCF-EDFA) schemes having EDFA amplifier in order to compensate the dispersion and attenuation effects. The performance of designed optical system is investigated in terms of parameters Q-factor, BER gain, output power, noise figure and Eye-diagrams for NRZ modulation format by varying the fiber length (km), input power (dBm) and attenuation constant (dB/km). In future, the proposed techniques can be applied to a complex optical system with large number of channels to compensate the dispersion and attenuation complications.

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