DWDM based Optical Fiber Communication Link using Different Modulation Formats and Dispersion Compensating Fiber

Mehtab Singh[1], Rajveer[2]

[1]Assistant Professor,ECE Department, Satyam Institute of Engineering and Technology, Amritsar, India

[2]Assistant Professor, ECE Department, Satyam Institute of Engineering and Technology, Amritsar, India
Email: [1]mehtab91singh@gmail.com (corresponding author), [2]rajveerbhagat@yahoo.co.in

Abstract- Dense Wavelength Division Multiplexing (DWDM) is a technique that can be used to increase the channel capacity and meet with the growing demand of bandwidth in Optical Fiber Communication system. In this technique multiple information signals are transmitted using a composite optical signal. Each of the information signals is transmitted at a particular optical wavelength in an optical fiber. The presence of non-linear effects in optical fiber namely Four Wave Mixing (FWM), Self Phase Modulation (SPM), Cross Phase Modulation (CPM), Stimulated Raman Scattering (SRS), Stimulated Brillouin Scattering (SBS) degrades the performance of the DWDM transmission system. In this paper, investigation of a DWDM transmission system is performed using different modulation formats, power levels, data transmission rates and number of information channels in the link. A single mode fiber of length 100 km at 1550 nm wavelength is used along with a dispersion compensating fiber in order to reduce dispersion. The performance of the signal received at the receiver is analyzed on the basis of quality factor and bit error rate (BER).

Keywords- DWDM, four wave mixing, self phase modulation, cross phase modulation, stimulated raman scattering, stimulated brillouin scattering, dispersion compensating fiber.

1. Introduction

Information from different sources can be transmitted simultaneously by using optical signals of different wavelengths (850nm-1650nm). The technique which combines multiple information signals from different sources over a single optical fiber is called Wavelength Division Multiplexing (WDM). Each information source transmits its signal in the optical fiber at a distinct wavelength. With the development of Erbium Doped Fiber Amplifier, the concept of WDM was taken to next level, DWDM. Without EDFA the implantation of DWDM would have not been possible. EDFA operate at 1550 nm wavelength range which is also the range in which dispersion in single mode fiber is minimum, hence EDFA are compatible with optical fibers [1], [10]. In order to implement DWDM in an optical fiber communication link, special optical devices and modules such as multiplexers, low chirp integrated lasers, EDFA and demultiplexers are required. A multiplexer couples light from different sources and launches it in the transmitting fiber. At receivers end an optical demultiplexer is used to separate different information signals in the optical transmitted signal. In order to prevent entry of spurious optical signal into received signal, a narrow spectral width demultiplexer is used having sharp wavelength cutoff value [3]. The acceptable range of cross talk is about -30 dB [2], [4]. Some of the main features in DWDM transmission link are enhanced system capacity, transparent network, wavelength routing and switching [12]. But transmitting multiple optical signals at high power levels in a single optical fiber link introduces many non-linear effects in the optical fiber which degrades the performance of the system. Rest of the paper is organized as follows- In section 2, dispersion compensating fiber are discussed briefly. In Section 3, simulation setup is presented and in section 4, results are observed and discussed. Conclusion to this investigative study is given in section 5.

2.Dispersion Compensating Fiber (DCF)

In Dispersion Compensating Fiber technique, the dispersion of optical signal travelling in a single mode fiber is reduced by passing the signal through a DCF having negative value of coefficient of dispersion. DCF is utilized in conjunction with SMF. A few hundred meters of DCF is capable of compensating dispersion of hundreds of kilometer long single mode fiber. In order to achieve high value of negative dispersion on DCF, the core of DCF fiber is highly doped as compared to that in conventional fibers [11]. The condition representing case of dispersion compensation using DCF is given by below given equation.

$$D_1L_1 + D_2L_2 = 0 \quad (1)$$

Where $D_1$and D_2represents the coefficient of dispersion of single mode fiber and dispersion compensating fiber respectively and $L_1$and L_2 represents lengths of single mode fiber and dispersion compensating fiber respectively.

3. Simulation Setup

In this investigative study, performance of a DWDM transmission system has been evaluated under different transmitting power levels, modulation formats and number of channels using Optisystem simulation software. The system proposed in this paper consists of a WDM transmitter followed by a WDM multiplexer, a single mode fiber followed by a dispersion compensating fiber, an EDFA, a WDM demultiplexer, an optical receiver and a BER analyzer as shown in Fig. 1.

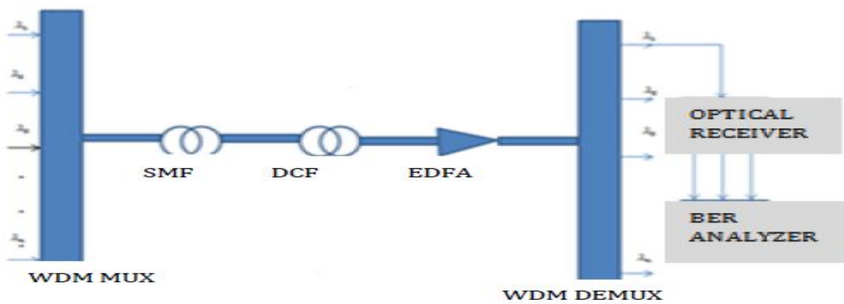


Fig.1 WDM transmission link [10]

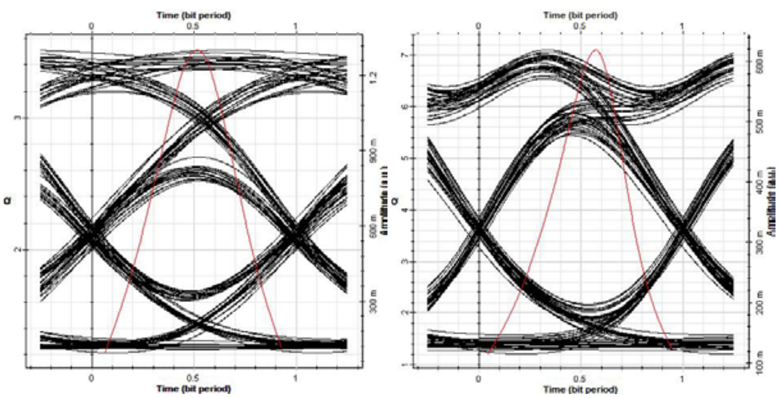
The WDM transmitter consists of 32 channels having starting frequency of 193.1 THz and with frequency spacing of 100 GHz. It consists of 32 different optical channels carrying information signal each transmitted with power of 15 dBm. RZ and NRZ are two types of modulation formats used in this paper. The bandwidth of WDM multiplexer is 10 GHz. The length of dispersion compensating fiber used is 100 km and value of dispersion coefficient is 20 ps/nm/km. On the other hand the DCF is of length 20 km and value of dispersion coefficient of -100 ps/nm/km. An Erbium Doped Fiber Amplifier (EDFA) has been utilized having gain of 40 dB and no noise figure. The information transmission rate is 10 Gbps.

4. Results and Discussions

In this paper, performance of a Dense Wavelength Division Multiplexing (DWDM) has been observed and analyzed on basis of different modulation formats, transmission power levels, number of channels and data transmission rates using Optisystem simulation software.

4.1 Effect of different Modulation Formats

Firstly, comparison has been done for a 32 channels DWDM transmission system, transmitting at a power level of 15 dBm for each optical channel at a data rate of 10 Gbps and NRZ and RZ modulation formats. Figure No.2 (a) and (b) shows Eye Diagram of signal received at the receiver end in case of NRZ and RZ modulation formats respectively.



(a) (b)

Fig.2 Eye Diagram of signal received at receiver for (a) NRZ modulation format (b) RZ modulation format

In case of NRZ modulation format used at the transmitter, the received signal observed at the receiver end showed max Q Factor value of 3.51485 with bit error rate (BER) value of 0.000205613. On the other hand, in case of RZ modulation format used at the transmitter, the signal received at the receiver end showed maximum Q Factor value of 7.09949 and BER value was found to be 6.04159 e-013. By observing these values, it can be clearly seen that RZ modulation format has better performance than NRZ modulation format in case of DWDM transmission system as Q Factor is higher and value of BER is smaller in case of RZ modulation format.

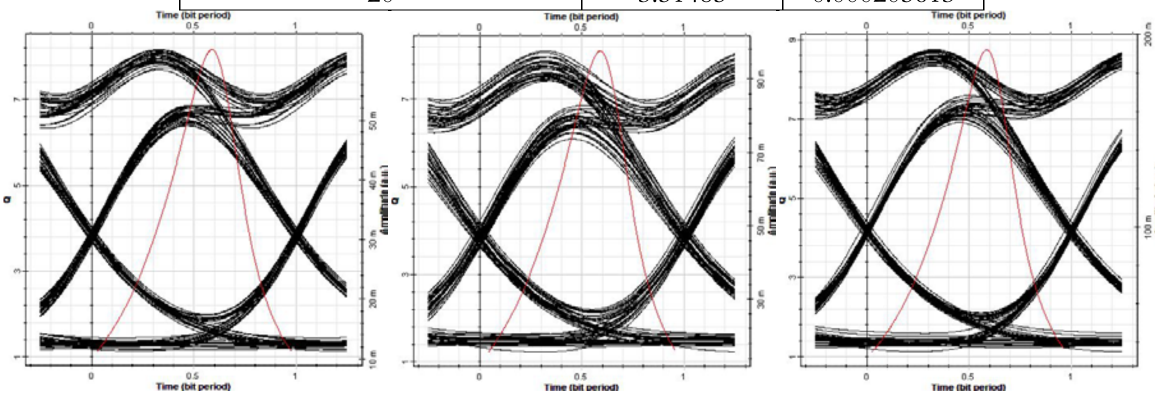
4.2 Effect of Transmission Power Levels

Next, the comparison of performance of DWDM communication system using RZ modulation format with 32 channels at 10 Gbps data rate at different levels of transmission power varying from 5 dBm to 20 dBm has been done. Table.3 shows the value of BER and Q Factor of signal received at receiver end for each simulation.

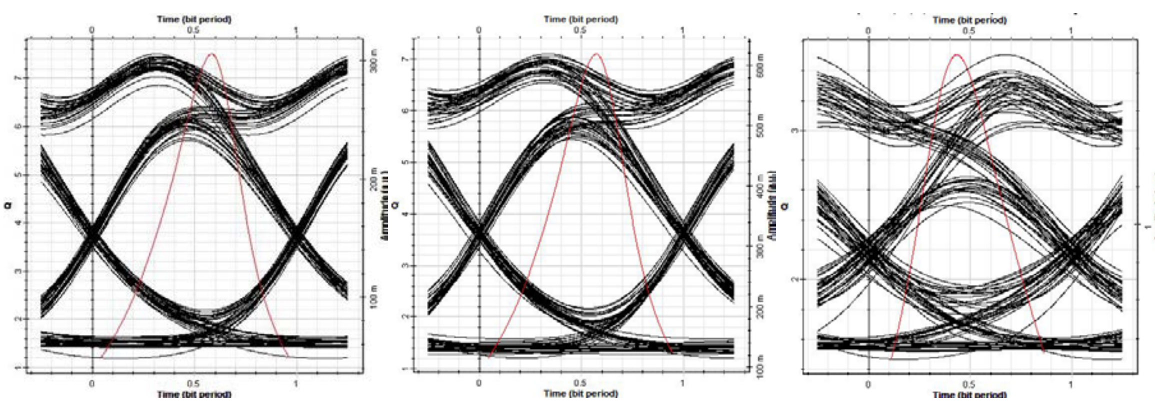
Table.3 Performance Comparison at different transmission power levels

Transmission Power Level (dBm)	Q Factor	BER
5	8.16919	1.4823 e-016
8	8.09812	2.71307 e-016

10	8.74845	1.0487 e-018
12	7.50212	2.9857 e-014
15	7.09949	6.04159 e-013
20	3.51485	0.000205613



(a) (b)(c)



(d) (e) (f)

Fig.3 Eye Diagrams for received signal for transmitting power level of (a) 5 dBm (b) 8 dBm (c) 10 dBm (d) 12 dBm (e) 15 dBm (f) 20 dBm

Fig.3 shows Eye Diagram of received signal for each simulation result presented in Table 3. From the above presented results, it can be seen that as the power of optical signal at transmitter end is increased from 5 dBm to 10 dBm, the quality of signal receives improves. This can be seen from the fact that as the transmitting power is increased, the value of Q factor increases and BER value decreases till transmitting power level of 10 dBm. As the transmitting power level is further increased from 10 dBm to 20 dBm, it can be seen that the value of Q Factor of received reduces and BER value increases and hence the quality of received signal degrades. This is due to the fact that as the value of transmitting power level is increased up to 10 dBm, the non-linear effects are almost negligible. But as the transmitting power level is increased further, the efficiency of non-liner effects increases and thus the quality of received signal degrades. Hence it can be observed that the quality of received signal in case of this particular simulation is best when transmitting power level is around 10 dBm.

4. 3 Effect of Number of Channels

Performance of DWDM transmission system has also been analyzed on basis of different number of transmitting channels varying from 8 to 32 for a 10 Gbps transmitting systemusing RZ modulation format and 10 dBm of transmitting power level of each optical channel. Table.4 shows value of Q Factor and BER value of received signal for different number of input channels.

Table.4 Performance Comparison for different number of channels

Number of channels	Q Factor	BER
8	8.5936	4.06099 e-018
16	8.35905	3.02962 e-017
24	8.28778	5.5365 e-017
32	8.74845	1.0487 e-018

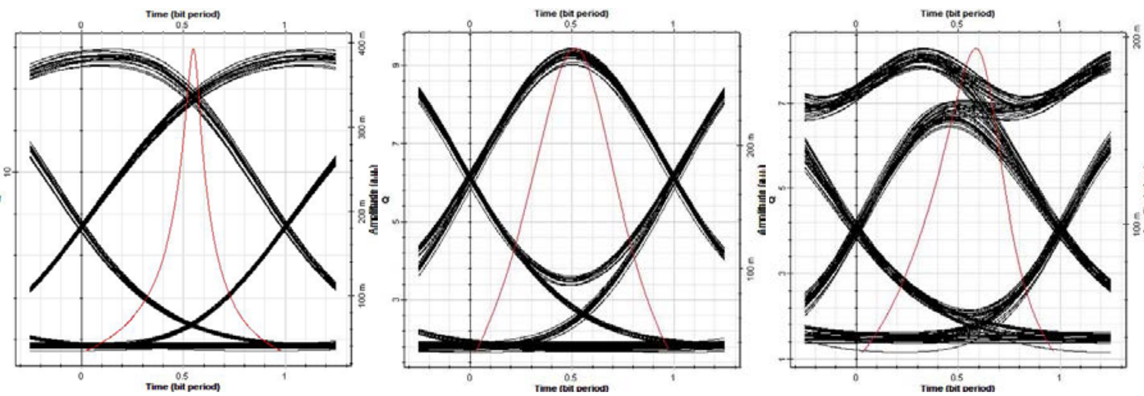
From the above presented results, it can be seen that by varying the number of input channels, there is a negligible variation in the Q Factor and BER values of received signal. Hence it can be seen that number of channels in a DWDM system does not play a significant role in determining the quality of received signal.

4.4 Effect of Data Transmission Rates

In this paper, the performance comparison of DWDM system has been done on basis of data transmission rates by varying it from 2.5 Gbps to 10 Gbps for a 32 channel transmission system at 10 dBm transmitting power level and RZ modulation format. Table.5 presents Q Factor and BER value of received signal for different values of data transmission rates.Fig.4 shows Eye Diagram of received signal for each simulation result presented below.

Table.5 Performance Comparison for different data transmission rates

Data Transmission Rate (Gbps)	Q Factor	BER
2.5	15.9197	2.31232 e-057
5	9.44278	1.77311 e-021
10	8.74845	1.0487 e-018



(a)(b)(c)

Fig.4 Eye Diagram of receives signal for data ransmission rate of (a) 2.5 Gbps (b) 5 Gbps (c) 10 Gbps

From the above results, it can be seen that as the value of data transmission rate is increased, the value of Q Factor of received signal and BER value of received signal falls and hence the quality of received signal degrades.

5. Conclusion

In this paper, performance analysis of a DWDM transmission system is performed using different modulation formats, power levels, data transmission rates and number of information channels at the input. From the results presented in this paper, it can be concluded that RZ modulation format shows a better performance as compared to that of NRZ modulation format as the quality of signal received in case of RZ modulation format is better than that of NRZ modulation format. Also from the above results it can be concluded that by varying the number of input channels in a DWDM system, the quality of signal receives at the receiver end remains same and shows negligible degradation. Also it can be concluded that as the transmission power level is increased up to 10 dBm, the quality of received signal improves, but as the transmission power level is further increased the quality of received signal degrades due to increase in efficiency of non-linear effects. Increasing the data transmission rates degrades the performance of received signal. Thus, it can be concluded that for faith full transmission in case of DWDM transmission system, RZ modulation format must be used and the transmitting power levels should be kept close to 10 dBm for each input channel.

References

[1]. Harold Kolimbiris "Fiber optics communications".

[2]. Ivan P. Kaminow, Tingye Li, Alan E. Wilner "optical fiber telecommunication".

[3]. C.Peuchere t, N.Hanik, R.Freund, L.Molle, P.Jeppesen , IEEE Photonics Technology Letters, Volume 12, Issue 8, 2000, 992.

[4]. Muhammad AnisuzzamanTalukder, Mohammed Nazrullam "A long haul wavelength division multiplexed system using standard single mode fiber in presence of self-phase modulation", Optik 120, 356-363, (2009).

[5]. Rajani , Raju Pal, Vishal Sharma, "Comparison of Pre-, Post- and Symmetrical-Dispersion Compensation Schemes for 10/15Gbps using Different Modulation Formats at Various Optical Power Levels using Standard and Dispersion Compensated Fibers", International Journal of Computer Applications (0975 – 8887) Volume 50– No.21, July 2012

[6]. Ravi Prakash Shukla, Mukeshkumar, A.K. Jaiswal, RohiniSaxena, "Performance Analysis of Dispersion in Optical Communication link Using Different Dispersion Compensation Fiber (DCF) Models", International journal of recent technology and Engineering, ISSN:2277-3878,Vol. 1,june 2012.
[7]. Ramesh Pawase, R.P.Labade,.S.B.Deosarkar, "Dispersion PostCompensation Using DCF at 10Gbps", Global Journal of Computer Science and Technology, Volume 11, Issue Version 1.0, March 2011.
[8]. Chaya S, RamjanKhatik, "Comparison of Fiber Based Dispersion Compensation in RZ and NRZ Data Modulation Formats", International Journal of Electronics Communication and Computer Technology (IJECCT), Volume 3, Issue 1, January 2013.
[9]. Monajkumar, Ajay K. Sharma, T.S.Kamal , etc, " Comparative investigation and suitability of various data formats for 10Gb/s optical Soliton transmission links at different chirps", volume120, Issue7, March 2009 , pg- 330-336.
[10]. Djafer K. Mynbev and Lowell, L. Scheiner "Fiber-optics communications Technology".
[11]. John M Senior,"Optical fiber communications", Pearson publications 2010
[12]. Manpreet Kaur, HimaliSarangal, "Analysis on Dispersion Compensation with Dispersion Compensation Fiber (DCF)," SSRG International Journal of Electronics and Communication Engineering (SSRG-IJECE), ISSN: 2348 – 8549 – vol. 2 issue 2, 56-59, Feb 2015.