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Performance Evaluation Of DWDM System With Dispersion Compensation

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Abstract— Fiber-optic dispersion and its effect on optical transmission system are analyzed. We have investigated the performance analysis of dispersion compensation in WDM network using EDFA. In this the variation of Q-factor and Bit error rate with respect to the system length is analysed. This simulation is done for 16-channel transmitter at 25Gbps; 30Gbps and 35Gbps data rate and various dispersion compensation schemes are analyzed for defining the optimum results

Keywords— Dispersion compensation; Optical communication; DCF; EDFA; Simulation; Q-factor; BER

1. INTRODUCTION

Optical communication systemcame into existence which uses high carrier frequencies in the visible or near-infrared region of the electromagnetic spectrum.Fiber-optic communication systems are lightwave systems that employ optical fibers for information transmission.

The core of the global telecommunication network consists of wavelength division multiplexed (WDM) optical transmission systems. A WDM transmission link transport large amount of data traffic by multiplexing a number of lower capacity wavelength channels onto a single fiber. The use of WDM therefore allows increase in the capacity of long haul optical transmission systems or, decrease in the cost of the transmitted bandwidth, i.e. the cost per transmitted bit.In long-haul WDM transmission systems there occurs nonlinear impairments. The tolerance against these impairments scales linearly, or even quadratically, with the bit rate. Hence, to build robust long-haul transmission systems at high bit rates these transmission impairments should be optimized &, if possible, compensated.

Optical amplifiers are the backbone of optical network as they directly amplify the weak signal without going through electronic process. But it also amplifies the signals which occur due to the fiber losses and many other noise sources. There are various amplifiers like S O A (Semiconductor Optical Amplifier), RAMAN and EDFA (Erbium Doped Fiber Amplifier) etc. But EDFA is the optical amplifier which is the most used amplifier because of its high capacity and low pump power.So EDFA behaviour in a WDM network needs to be studied.

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Fiber also suffers from dispersion due to fiber material nonlinearities, cut-bands in the fiber and the distance that signal travels inside the fiber. So this dispersion has to be minimized by some methods. Installing the DCF (Dispersion Compensation Fiber) is one of the methods to compensate the dispersiondue to the SMF (Single Mode Fiber).

This paper is structured as follows: Section 2 gives the detailsof simulation model of dwdm system. Section 3 gives the details of Decision Tree and SVM. Section 4 gives the details of ensemble techniques used in this paper Section 5 Conclusion.

2. MODULATION

The first step in the design of an optical communication system is to decide how the electrical signal would be converted into an optical bit stream. Modulation is the process of imposing information on an optical carrier wave. It involves varying one or more of the features that defines the optical wave, such as its amplitude, frequency, or phase. Modulation can be realized either by directly varying the laser drive current with the information stream to produce a varying optical output power or by using an external modulator to modify a steady optical level emitted by the laser. External modulation is needed for high speed systems (> 2.5 Gb/s) to minimize undesirable nonlinear effects such as chirping. There are two basic modulator technologies that are widely used; Direct Modulation and External Modulation.

2.1 TWO TYPES OF MODULATION FORMATS

1. Direct Modulation
2. External Modulation.

2.1.1 DIRECT MODULATION

Direct Modulation induces chirping that causes a signal carrier frequency to vary with time, thus causing pulse broadening or dispersion of the signal. In addition, laser phase noise and induced chirp also limit the use of direct modulation to higher capacity and higher bit rate transmission. It cannot be used at

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bit rates that are greater than 2.5-Gb/s. Moreover, direct modulation creates nonlinearity especially SPM.

2.1.2 EXTERNAL MODULATION

External Modulation avoids nonlinearities and excessive chirp. External modulation can be implemented using either Electro-Optic modulators (EOM) or Electro-Absorption Modulator (EAM). The EOM operate according to principles of electro optic effects. The change of refractive index in the solid state of semiconductor material is proportional to the applied electric effect. EOMs are utilized for modulation of either the phase or the intensity of the light wave carrier. Electro-optic phase modulator manipulates the phase of optical carrier signals under the influence of an electric field created by the applied voltage. The refractive index changes accordingly inducing varying amount of delay to the propagating light wave, when the RF driving voltage is applied on to the electrode.

2.2 NEED FOR MODULATION

1. To increase the signal's robustness against fiber transmission impairments such as chromatic dispersion (CD) and polarization-mode dispersion (PMD).
2. They are used to mitigate linear and nonlinear impairments of fiber optic transmission, as well as to achieve high spectral efficiencies in optically routed networks.

The modulation format defines the characteristics of the optical signal that is transmitted over the transmission link. It describes how the data is coded onto the optical signal. The amplitude, frequency and phase of optical signal can be modulated. Depending on which of the properties of the electric field of optical carrier is being varied, modulation schemes can be classified into the following

1. Ampliyude shift keying
2. Frequency shift keying
3. Phase shift keying

ASK encodes data by turning on or off the amplitude of light, depending on whether the symbol to be transmitted is a mark ("1") or a space ("0"), at a rate equal to the information frequency. In this modulation format, each binary symbol ("1" or "0") is represented by the presence or the absence of light The ASK modulation is characterized by the relation between the signal levels in on and off states called extinction ratio (ER). The ER value is dependent on the approach used for the signal generation: direct or external modulation of the laser source. In case of external modulation, the ER is limited by the extinction ratio of the external modulator. Typical ER values vary between 8-12 dB depending on the signal bit rate in use. The ASK based modulation formats are characterized by simple signal generation and detection, due to which all currently deployed optical transmission system employ ASK based modulation formats.

ASK scheme includes non return-to-zero (NRZ), return-to-zero (RZ), and duobinary formats. There are also a number of variations of the RZ formats. It includes simple RZ, carrier-suppressed RZ (CSRZ), chirped RZ (CRZ), vestigial sideband RZ (VSB-RZ), and dispersion-managed soliton-based RZ (DMS-RZ). The modulation formats covered are Non Return-to-Zero (NRZ), Return-to-Zero (RZ)

Non return-to-zero (NRZ) has been the dominant modulation format in intensity modulated-direct detection (IM/DD) fiber-optic communication systems for several years because it is easy to generate, detect and process. There are probably several reasons for using NRZ in early days of optical fiber communications: First, it requires a relatively low electrical bandwidth for the transmitters and receivers; second, it is not sensitive to laser phase noise; and the last, it has the simplest configuration of transmitter and receivers.

NRZ modulation is obtained by switching the output of a laser source On and Off. This can be achieved by modulating the output of the laser source using a Mach-Zehnder Modulator (MZM). The MZM is driven at the quadrature point of the modulator power transfer function with an electrical NRZ signal.

In RZ format for the 1 bit, the power level returns to 0 after half of the period, whereas for the 0 bit, the power level is 0 continuously. Binary 0 is represented by the absence of an optical pulse during the entire bit duration. There is a transition for every 1, which means that, no matter how long a sequence of ones is, clock information is always present, unless there is a long sequence of zeros. The bandwidth required by RZ is twice larger than that of NRZ as the bit transition lead to an increase in signal bandwidth . Therefore it only requires half of NRZ power in transmission and twice the switching time that required for NRZ. In addition RZ modulated signals is a relatively broad optical spectrum, resulting in a reduced dispersion tolerance and a reduced spectral efficiency. RZ modulation format is found to be less susceptible to inter-symbol interference (ISI), and typically achieves better performance compared to NRZ. Two more benefits of RZ modulation format exist, first, that this modulation method is self-synchronized, and the second, laser life time is prolonged.

3. TYPES OF FIBERS USED

Optical fibers are widely used in fiber-optic communications, which permits transmission over longer distances & at higher bandwidths (data rates) than other forms of communication. Fibers are used instead of metal wires because signals travel along them with low loss & are also immune to electromagnetic interference. Fibers are also used for illumination, & are wrapped in bundles so they can be used to carry images, thus allowing viewing in tight spaces.

Fiber can be classified according to the profile of the refractive index within the fiber as;

i. Step index Fibers - It is an optical fiber that is characterized by the uniform refractive index in the core & the cladding

ii. Graded index Fibers - It is an optical fiber that is characterized by the uniform refractive index in the core & the cladding

Both these fibers can further be classified according to the number of mode that they allow to propagate as;

i. Single-Mode Fibers (SMF)
ii. Multi-Mode Fibers (MMF)

SMF is an optical fiber that can propagate only one mode. Normally the no. of modes propagating through the fiber is proportional to its V-number. In the case of SMF, the V-number is less than 2.405. The SMF has a smaller core diameter (10 mm) & the difference between the refractive indices of the core & the cladding is very small. Fabrication of SMFs is very difficult & so the fiber is expensive. Further the launching of light into SMFs is also difficult. The manufacturing of graded index SMF is very difficult because it is not easy to fabricate a fiber with smaller core diameter and varying refractive index. Generally in SMFs, the transmission loss & dispersion or degradation of the signal are very small. So the SMFs are very useful in long distance communication.

MMF is an optical fiber that can propagate multiple modes. Here the V-number is greater than 2.405. Generally in MMFs, the core diameter & the relative refractive index difference are larger than in the SMF. In case of step index MMF, there is transit time dispersion between various modes since they take different time to travel a given length of the fiber. However, there is no transit time dispersion in case of graded index MMF. Here the light rays travel at different speeds in different paths of the fiber because of the parabolic variation of refractive index of core. As a result, light rays near the outer edge travel faster than the light rays near the centre of the core. In effect, light rays are continuously refocused as they travel down the fiber & almost all the rays reach the exit end of the fiber at the same time due to the helical path of the light propagation. Launching of light into fiber & fabrication of the fiber are easy. These fibers are generally used in local area networks.

DCF is the standard solution to compensate for the chromatic dispersion accumulated in long-haul optical transmission systems. It yields colorless, slope-matched dispersion cancellation with negligible cascading impairments. These are specially designed fibers with negative dispersion. The high value of negative dispersion is used to compensate for positive dispersion over large lengths of ordinary fiber. The total negative dispersion compensates for the total positive dispersion.DCF has a smaller core effective area ($\sim 30\mu m^2$) & different core index profile in comparison to SSMF.

4. SIMLULATION

To investigate the effect of dispersion on the 16-channel WDM system at the speed of 25Gbps; 30Gbps and 35Gbps the following model is used as shown in fig 1. The transmitter section consists of data source, Laser source and Mach-Zehnder modulator. The data source is then converted to Non-Return to Zero (NRZ) format. The Data source and laser signal are fed to the Mach-Zehnder modulator, where the inputs generated from data source are modulated with the laser signal are transmitted. The output from the modulator is now an optical signal with certain wavelength. When multiple optical signals are transmitted in a fiber they are multiplexed with wavelength division multiplexer. The multiplexed signal is then passed through the SMF fiber, then through the optical amplifier (EDFA) and then through the DCF fiber to the detector. In the detector section the de-multiplexer is used to get the different optical signals with different wavelengths which were multiplexed at the transmitter side. The Receiver side consists of photo-detector, low-pass filter and the BER analyser. The photo-detector detects the optical signal and then the signal is passed through a low pass filter. The BER analyser is used to check the Bit Error rate and the Q-factor of each signal..

4.1 Figures

Figure 1 Transmitter Section

Figure 2 Receiver Section

5. LITERATURE SURVEY

Husam Abduldaem Mohammed [9] investigated the performance DWDM system utilizing EDFA and DCF for different lengths of optical fiber and bitrates the most effective factors causing performance degradation are attenuation and dispersion .EDFA is used in the system model to encounter the effects of attenuation and scattering losses, while DCF is utilized to mitigate the effects of dispersion.

Bo-ning HU, Wang Jing,Wang Wai, Rui-Mei Zhao[2] analyzed the fiber optic dispersion and its effects on optical transmission system. Most commonly used dispersion compensation fiber technology is studied .three schemes of dispersion compensation with DCF are implemented using optisystem and various results such as Q factor and BER are analyzed.

X.YZou, M.Imran Hayee, S-M Hwang and Alan E.Willner [3] analyzed the system limitations of WDM transmission when using various types of optical fiber to manage dispersion and non linearity's .in the system 2 to 8 10gbps WDM channels are transmitted through a cascade of EDFA's experiencing dispersion, stimulated Raman scattering, self and cross phase modulation

MilivojevicB [7] elaborated that optical wireless links offer gigabit per second data rates and low system complexity. For ground space and or terrestrial communication systems, these links suffer from atmospheric loss mainly due to fog, scintillation and precipitation. The author has presented the bad weather effects such as rain, fog, snow, and scattering losses on the transmission performance of wireless optical communication systems. He also studied the bit error rate, maximum signal to noise ratio, maximum transmission optical path lengths and maximum transmission bit rates under these bad operating conditions

Raghav P. K., Renu Chaudhary [14] proposed that technology involves a new type of compact device based on magneto-optics in a fiber micro modulator. This type of modulator allows the user to inter manipulate and control the propagation of the incoming light.

Sandeep Singh [8] studied dispersion compensation system in the WDM in this paper. Based on optical transmission equation, considering the various types of nonlinear effects and the impact of EDFA, system simulation models are established. According to relative position of DCF and single-mode fiber, post-compensation, pre-compensation, mix compensation is proposed. DCF Pre-compensation scheme achieve dispersion compensation by place the DCF before a certain conventional single-mode fiber, or after the optical transmitter. Post -compensation scheme achieve dispersion compensation by place the DCF after a certain conventional single-mode fiber, or before the optical transmitter. Mix compensation scheme is consist of post compensation and pre-compensation .Different location on the system will generate different nonlinear effects. In order to improve overall system performance and reduced as much as possible the transmission performance influenced by the dispersion, several dispersion compensation scheme

6. PERFORMANCE PARAMETERS

The measurement component used is BER analyzer to measure Q-factor & BER. The graphs are taken by varying the values of global parameters at different stages of the simulation.

7. RESULTS OF SIMULATION

The performance of non return-to-zero (NRZ), return-to-zero (RZ) modulation format for WDM optical communication system is analyzed in terms of the Q-factor, Bit Error Rate (BER) The bit rates considered are 25 Gb/s, 30 Gb/s and 35 Gb/s. Results have been represented by optimizing various parameters like optical signal power for each channel, Mux/Demux filter bandwidth and also by varying the channel spacing between adjacent channels.

Various Q factor & BER Values for NRZ Modulation format:

BIT RATE(GBPS)	Q-FACTOR	BER
25 gbps	18.6002	1.3166-e077
30gbps	9.2914	5.16 e-021
35gbps	5.60825	9.6077e-009

Various Q factor & BER Values for RZ Modulation format:

Bit rate(GBPS)	Q FACTOR	BER
25gbps	22.5888	1.657e-113
30gbps	20.0115	1.024029e-089
35gbps	19.1732	1.87337e-082

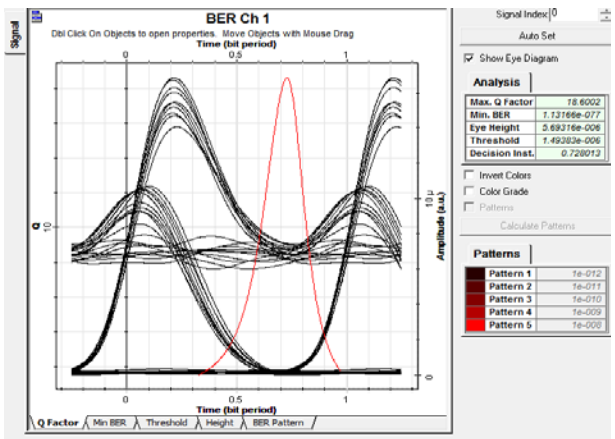

Fig. 3.The ber and eye diagram with best results at 25gbps for NRZ modulation format

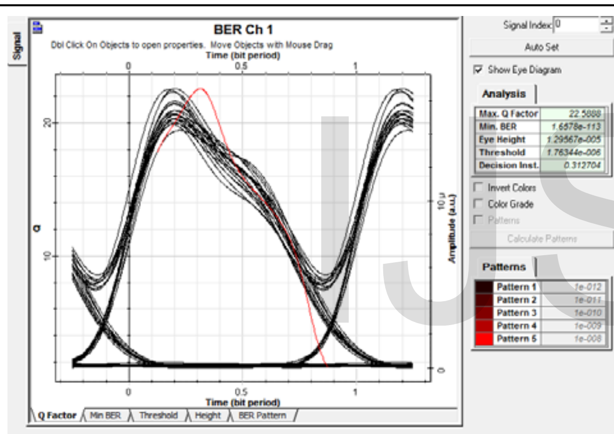

Fig. 4.The ber and eye diagram with best results at 25gbps for RZ modulation format

The results of simulation of optical system with different data rates, wavelengths and various modulation formats are shown in the above graphs . The results include the tables for different bitrates, eye diagrams and graphs for each format Eye diagram gives the simulation results at different bitrates. As we can see from different eye diagram, the effect of dispersion compensation is very good. The signal quality is high, eye's opening is very good, and the edge neat graph is symmetrical. The effect of dispersion compensation is quite good. The figure shows this system have the big decision scope under the guarantee of the condition of system bit error rate. This indicated the DCF compensate different channel's chromatic dispersion greatly.

The best result is obtained at 25gps for RZformat with a Q factor 22.558 and BER 1.657e-113 wheras for NRZ format the value of Q factor 18.6002and BER 1.3166-e077

TABLE 1
BASELINE PARAMETERS

Parameters	Symb	Baseline Value
Power	P	2 mW and 4 mW
Linewidth		0.1 MHz
Modulation Format		NRZ, RZ
Bit rate	B	25, 30 & 35 Gb/s
Effective area (SMF)	A_{eff}	80 μm^2
Dispersion (SMF)	D	17ps/nm/km
Attenuation (SMF)	α	0.2 dB/km
Length (SMF)	L	60 km/span
No. of spans	N_S	1
Effective area (DCF)	A_{eff}	22 μm^2
Dispersion (DCF)	D	-85 ps/nm/km
Attenuation (DCF)	α	0.5 dB/km
Length (DCF)	L	12 km/span
Gain (EDFA)	G	Ac.to Att. Losses
Noise Figure (EDFA)		6dB
PIN Diode Responsivity	R	1 A/W
Threshold Quality Factor	Q	6
Min Bit error rate	BER	10^{-9}
WDM Grid	C	191.6-195.9 THz
Wavelength	C	1543-1565 nm

8. CONCLUSION

16 channel DWDM light wave systems with data rates of 25 GB/s, 30 GB/s and 35 GB/s and channel spacing of 140 GHz are considered for the simulation in this dissertation. The modulation formats considered are non return-to-zero (NRZ), return-to-zero (RZ). A number of simulations have been performed and various conclusions have been drawn out of that. Conclusions of this research work are summarized as follows;

1. Optimization of Mux/Demux filter bandwidth and laser source power is essential for efficient WDM transmission.

2. NRZ modulation format for DWDM systems, optical bessel filters result in improvement in system performance through the elimination of nonlinearities like XPM and FWM and also by decreasing the amount of noise added because of ASE generated by EDFA.

3. On the basis of results for both the formats using RZ format gives the best Q factor at 25 gbps bit rate.

4. A moderate bigger value of laser of laser average power is favorable to the performance of transmission system the input fiber is taken as 9-10db, the corresponding BER performance is better.

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REFERENCES

[1] Abd El-Naser A. Mohammed, Abd El-Fattah A. Saad, and Ahmed Nabih Zaki Rashed and Mahomud M. Eid, "Characteristics of Multi-Pumped Raman Amplifiers in Dense Wavelength Division Multiplexing (DWDM) Optical Access Networks", IJCSNS International Journal of Computer Science and Network Security, Vol. 9, No. 2, pp. 277-284, Feb. 2009

[2] Bo-ningHU,Wang Jing," Analysis on dispersion Compensation with DCF based on optisystem"978-1-4244-8217-7/10/IEEE 2010

[3] Gerd Keiser, "Optical fiber communications," third edition, 2000, McGraw-Hill Higher Education, ISBN: 0-07-116468-5.

[4] Govind P. Agrawal, "Fiber-optic communication systems," Third edition, 2002, John Wiley & Sons, Inc, ISBN: 0-471-21571-6

[5] Mochida Y, Yamaguchi N, Ishikawa G, "Technology-oriented review and vision of 40Gb/s-based optical transport Networks", Journal of light-wave technology.PP. 2272-228,12002,

[6] Zhaohuaigang, "study on dispersion compensation in optical transmission system", study pn optical communications, Vol.3 ,No.141, 2007

[7] Milivojevic B.; Abas A.F.; Hidayat A.; Bhandare S.; Sandel D.; Noé R.; Guy M.; and Lapointe M., "1.6-b/s/Hz 160-Gb/s 230-km RZ-DQPSK polarization multiplex transmission," IEEE Photon TechnologyLett., vol. 17, no. 2, pp. 495–498, Feb. 2005.

[8] Sandeep singh., "Pre-, post, symmetric1 and 2 compensation techniques with RZ modulation," Recent Advances in Information Technology (RAIT), 2012 1st International Conference on , vol., no., pp.251,255, 15-17 March 2012.

[9] Husam Abdulaem mohammed "Performance Evaluationof DWDM for Radio over Fiber system with dispersion Compensation and EDFA" IJCA vol 72- no10, june 2013

[10] WuQiang,Yu Chong Xiu, "Analysis on dispersion compensation with DCF", semiconductor optoelectronics,Vol.24 No.3 pp.186- 196.June 2003

[11] Wangchen,Raomin, "the performance of the DCFTransmissionn system", Journal of applied sciences,Vol.21, No.2,pp.177-181,June 2003

[12] Killy R I, Thiele H J, Mikhailov v, ea al. Reduction of intrachannel nonlinear distortion in 40-Gb/s based WDM transmission over standard fiber [J]. IEEE Photonics Technology Letters, 2000, 12(12): 1642-1626

[13] John M. Senior, "Optical Fiber Communications: Principles and Practice," Third edition, 2009, Prentice Hall, ISBN: 978-0-13-032681-2.

[14] Raghav P. K., Renu Chaudhary, " Compensation of Dispersion in 10 Gbps WDM System by Using Fiber Bragg Grating", IJCEM International Journal of Computational Engineering & Management, Vol. 15 Issue 5, September 2012

[15] Zou X Y, Hayee M I, H wang S M, et al. Limitations in 10 GB/s WDM optical-fiber transmission when using a variety of fiber types to manage dispersion and nonlinearities [J]. Lightwave Technol., PP: 1144-1152, June,1996.

[16] Wangchen, Raomin, "the performance of the DCF Transmissionn system", Journal of applied sciences, Vol.21, No.2,pp.177-181,June 2003.

[17] Jianjun Yu, Bojun Yang,"Dispersion-allacated soliton technology with long amplifier spacing and long distance," IEEEphoton technol lett, vol 9, pp. 952-954, No.7, 1997.

[18] M.A.Othman , M.M. Ismail R.," Erbium Doped Fiber Amplifier (EDFA)for C-Band Optical Communication," 1214104-8383-IJET-IJENS © August 2012 IJENS

[19] Dr. Neena Gupta Inderpreet Kaur, "A Novel approach for performance improvement of DWDM systems using TDFA-EDFA configuration," IJECT, vol. I, no. 1, December 2010.

[20] E. Desurvire, "Erbium-Doped Fiber Amplifiers: Principles and Applications", Wiley, (1994).

[21] J. Hansryd, P.A. Andrekson, M. Westlund, J. Li, P.-O.Hedekvist, S,A,"Fiber-Based Parametrics and their Applications", IEEE Selected Topics in Quantum Electronics, 8 (3), 506-520, (2002)

[22] Y. Sun, A. K. Srivastava, J. Zhou and and J. W. Sulhoff, "Optical fiber amplifiers for WDM optical net works', *Bell Labs Tech.* J., vol. 4, pp.187–206, 1999.