IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 4, April 2016

Effect of Four Wave Mixing at different Channel Allocation Schemes for DWDM Communication System

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Abstract: In this research paper, the effect of four wave mixing (FWM) has been analyzed and compared for different channel allocation schemes such as equal space channel allocation (ESCA) and unequal space channel allocation (USCA) schemes for a Dense Wavelength Division Multiplexing (DWDM) system. The simulated results have been analyzed for fixed numbers of channels (N=8). We have evaluated the Quality-factor (Q-factor) of the DWDM system for different parameters such as optical fiber length, laser power, channel spacing and data rates. In the ESCA and USCA schemes, the Q-factor varies from 27.72 dB to 5.95 dB and from 40.47 dB to 6.25 dB respectively as the distance increases from 25Km to 125 Km at a bit rate of 8×10 Gbps. The results of simulative observation revealed that the unequal channel spacing provided better Q-factor for DWDM system than equal space channel allocation scheme Further, it has been observed that on decreasing the channel spacing between input channels, their mutual interference increases and thus, the effect of four wave mixing also increases. Similarly, as the channel spacing increases, the FWM effect decreases for the DWDM system.

Keywords: FWM, ESCA, USCA, DWDM system, Channel spacing, Q-factor.

I. INTRODUCTION

Ever since ancient times, one of the principle needs of people was to communicate. This need created interest in inventing communication system for sending message from one place to another. Many forms of communication systems have been appeared over years [1]. The basic motivation behind each new form was to improve fidelity, to increase data rate and to increase the transmission distance between two locations. As internet traffic increases day by day, optical network has been considered as the only mean to ensure delivery of large capacity links in a flexible, dynamic and reliable way [2]. Dense Wavelength Division Multiplexing is a fiber optic transmission technique that employs light wavelength to transmit multiple signals [3] and to make an effective usage of the fiber bandwidth and achieve high system capacity [4]. Dispersion and fiber nonlinearities are the parameters which restrict the transmission distance and bandwidth of DWDM system [5]. Fiber nonlinearities become a problem when several channels are co-propagating in the same fiber [6]. The interaction between propagating light and the fiber can lead to interference, distortion or excess attenuation of the optical signal [7]. The fiber nonlinearities fall into two categories, one is the stimulated scattering and another is Kerr effects. The most important types of nonlinear scattering within optical fiber are stimulated Brillouin and Raman scattering, both of which are usually only observed at high optical power densities in long single mode fiber [8]. A considerable amount of optical power is radiated in the opposite direction which destabilize the laser at the transmitter is known as Stimulated Brillouin Scattering [9]. Stimulated Raman Scattering is responsible for transferring a small fraction of power energy from one channel to another where photon of certain energy is destroyed and new photon at lower energy is generated which limit the performance of DWDM system [10]. Nonlinear effects which can be readily described by the intensity dependent refractive index of the fiber are commonly referred to as Kerr nonlinearities [11]. The Kerr nonlinearities leads to different effects such Self Phase Modulation (SPM), Cross Phase Modulation (XPM) and Four Wave Mixing (FWM) [12]. The change of phase in the optical signal due to change in the refractive index caused by the power fluctuation of the same signal is called Single Phase Modulation [13] and change of phase in optical signal due to change in refractive index caused by other channel optical power fluctuation is called Cross Phase Modulation [14]. FWM is one of the dominating degradation effects in WDM systems with dense channel spacing and low chromatic dispersion on the fiber. If in a WDM system, the channels are equally spaced, the new waves generated by FWM will fall at channel frequencies and thus, will give rise to crosstalk [15]. When wavelength channels are located near the zero-dispersion point, three optical frequencies (V_i, V_j,V_k) will mix to produce a fourth inter modulation product V_{ijk} as shows in equation (1).

$$V_{ijk} = V_i + V_j - Vk \qquad (1)$$

The impact of FWM on a communication system depends on the fiber parameters (A_{eff} and L_{eff}), the number of

IJARCCE

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International Journal of Advanced Research in Computer and Communication Engineering
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channel, channel spacing and power transmitted. The most straightforward method to reduce FWM effect is to space channel unequally [16]. Vishal Sharma et al. [17] demonstrated an 80 Gbps dispersion compensated DWDM system to evaluate BER, Q-factor and received power after an optical span of 100 Km in the presence of FWM under the impact of equal and unequal channel spacing. Simulation results showed an efficient improvement in Q-factor and received power with unequal channel spacing in high speed DWDM system. Amarpal Singh et al. [18] modified techniques equal and unequal channel spacing with polarization, equal channel spacing with alternate channel delay, optical coupling and varied laser power to reduce the impact of FWM in DWDM system.
Surinder Singh et al. [19] analyzed the FWM effect in different spectral efficient orthogonal modulation format at equal spacing of 50 GHz and 100 GHz to design long haul WDM system. Jian Guo Zhang et al. [20] proved that unequal channel spacing scheme is treated as one of the most effective method to suppress FWM waves from falling into the desired signal channel. Bassem K. Abd et al. [21] integrated unequal channel spacing and duo binary modulation format (NRZ) to suppress FWM crosstalk in a four 10 Gbps channel WDM system and result showed that performance is better by using unequal channel spacing with duo binary modulation.
Till now, many simulative communication models have been proposed to reduce the FWM effect. Comparison between equal and unequal channel spacing with eight numbers of users is rarely considered in the literature studied by us. In this paper, the effect of FWM at the system output is considered for different values of optical distance, channel spacing, laser power and bit rate.

This paper is further divided into five different sections. In section 1, the introduction of four wave mixing effect is presented. In section 2, the schematic model is proposed. Section 3; describes the simulation setup for an eight channel DWDM communication system. In section 4, results, discussions and comparison of equal and unequal channel spacing has been presented. Section 5 covers the conclusion of this research work.

II. SCHEMATIC MODEL

An optical transmission system has three basic components: Transmitter, Transmission medium and Receiver as shown in Fig.1. The schematic model for optical communication network implementing the four wave mixing effect for various value of spacing between different input channels/users. The transmitter section consists of CW laser, modulator driver, PN-sequence generator. The signal transmitted from each of transmitter is combined together using a multiplexer. The combined signal is amplified so that it can be transmitted over long distance without its degradation. Then the multiplexed signal is sent over the fiber which adds the nonlinear effect like four waves mixing in the transmitted signal. Then the signal is de-multiplexed at the receiver side, the receiver contains the PIN photodiode, a Bessel low pass filter, 3R generator and Bit Error Rate (BER) analyzer.

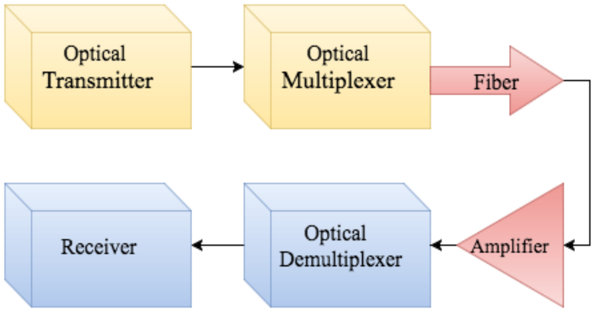

Fig.1 Model for the Communication System

III. SIMULATIVE SETUP

This DWDM system is set up by the simulation software Optisystem™. In this simulation model, the effect of four wave mixing is implemented on changing spacing between the input channels. The optical transmitter T1-T8 is used to setup the simulation model. The continuous wave laser L-1 to L-8 is used to create the carrier signal. The Number of channel are used by carrier generator are eight at different channel spacing of 25 GHz, 50 GHz, 75 GHz and 100 GHz. Bit sequence generator is used to generate pseudo random bit sequence (PRBS) data format (NRZ) at different bit rate of 1 Gbps, 2.5 Gbps, 5 Gbps, 10 Gbps and 20 Gbps. Afterword's, the output of laser is modulated with a $LiNbO_3$ Mach-Zehnder Modulator (MZM). Table 1 shows the value of various simulation parameters used in the DWDM system setup. The extinction ratio of MZM is taken as 10 dB. The reference frequency of CW source is 193.1 THZ and power varies from 0dBm to 10dBm for this model as shown in Fig.2. The modulated data from the entire channel is combined with the help of multiplexer. The transmitted optical signals have been over single mode fiber (SMF) with different length varies from 25 Km to 125 Km. All the attenuation, dispersion and nonlinear effects are activated. The erbium-doped fiber amplifier (EDFA) amplifies the signal in the transmission medium to avoid losses. At the receiver section, the combined signal is de multiplexed into eight number of user

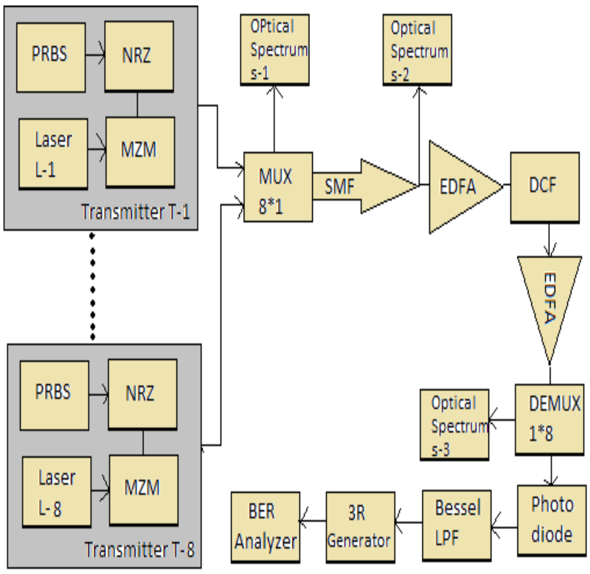

Fig.2 Simulation setup for the DWDM System

IJARCCE
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Table. I Simulation Parameters for the experiment setup of DWDM communication system

Parameter	Value
Reference Wavelength	1552.52 nm
Attenuation	0.25 dB/km
Dispersion	16.75 ps/nm/km
PMD Coefficient	0.5 ps/km^2
Effective Fiber Core Area	80
EDFA Power	10 dBm
No. of Channels	8
Line Width	10 MHz
Extinction Ratio	10 dB
Modulation Type	NRZ
PIN Responsivity	1 A/W

The optical signal is detected by a PIN photodiode having responsively of 1 A/W. Then the signal is passed through the low pass Bessel filter having an insertion loss of 0dB. The original bit sequence and electrical signal are recovered with the help of 3R generator for all the DWDM channels. An optical spectrum analyzer (S_1) is placed at the output of multiplexer to analyze the input signal. Other optical spectrum (S_2) and (S_3) are attached at the output of SMF and de-multiplexers respectively to investigate the four wave mixing effects. An electrical BER is kept at the receiver output to compute BER, Q-factor and eye opening.

IV. RESULTS AND DISCUSSIONS

The performance of a DWDM system has been measured at the receiver output with the help of BER analyzer and Q-factor is analyzed. Different channel allocation schemes i.e. equal and unequal space channel allocation schemes are considered. Fig.3 shows the graph between Q-factor and fiber length which reveals that for fixed power 0dBm and NRZ modulation format for ESCA scheme. The graph shows that Q-factor decreases as distance increases but increase in Q-factor with increases in channel spacing.

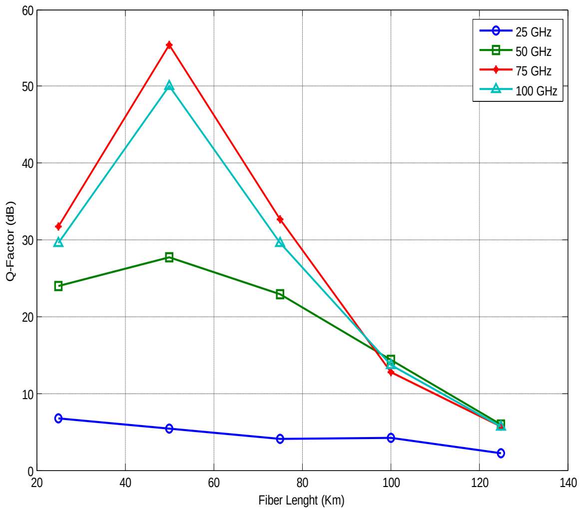

Fig.3 Comparison of Q-factor and fiber length for ESCA scheme for DWDM system at different channel spacing

In Fig.4, the graph has been drawn between Q-factor and distance which shows the comparison between ESCA and USCA schemes. ESCA scheme, the Q-factor varies from 27.72 dB to 5.95 dB as the distance increases from 25 Km to 125Km and with USCA scheme Q-factor varies from 40.47 dB to 6.25 dB as the distance increases from 25Km to 125 Km. It has been observed that USCA scheme implemented for the DWDM system shows the better result than ESCA scheme.

Further, the system is investigated under the influence of equal and unequal channel spacing by evaluating the input power which varies from 0dBm to 10dBm as shown in Fig.5 and Fig.6. It has been observed that with increases in input power, Q-factor decreases an optical span of 50 Km in the presence of four wave mixing effect. FWM effect increases with increase in input power but the increase is not same for equal and unequal channel spacing. FWM effect is less for USCA as compare to ESCA scheme. Eight channel DWDM system with equal channel spacing varies from 25 GHz to 100 GHz distributed among the 8 channel in the presence of four wave mixing effect as shown in Fig.5.

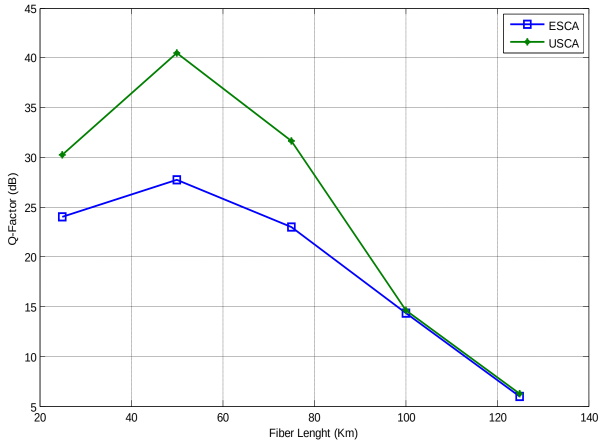

Fig.4 Comparison of Q-factor and optical fiber length between ESCA and USCA schemes for DWDM system

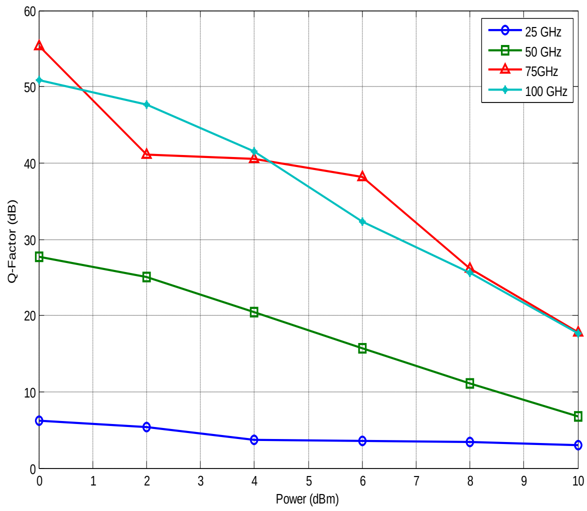

Fig.5 Comparison of Q-factor at different channel spacing with respect to laser power for ESCA scheme.

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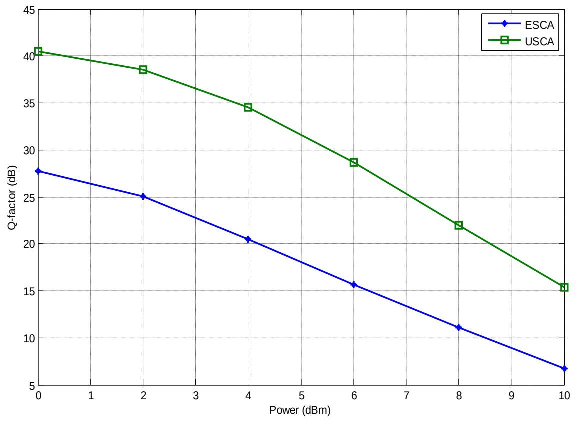


Fig.6 Comparison of Q-factor and laser power between ESCA and USCA schemes for DWDM system

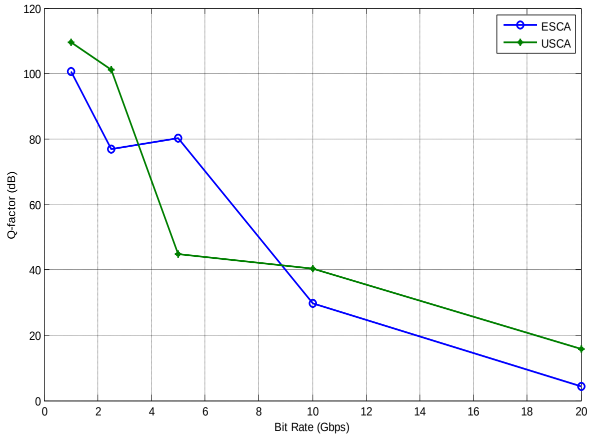


Fig.8 Comparison of Q-factor at different bit rate for ESCA and USCA schemes for DWDM system

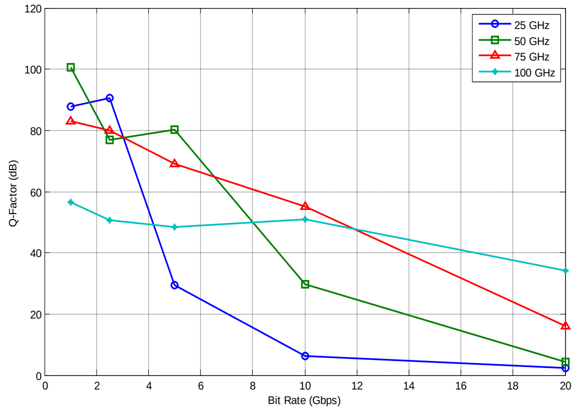


Fig.7 Comparison of Q-factor and bit rates for ESCA scheme at different channel spacing.

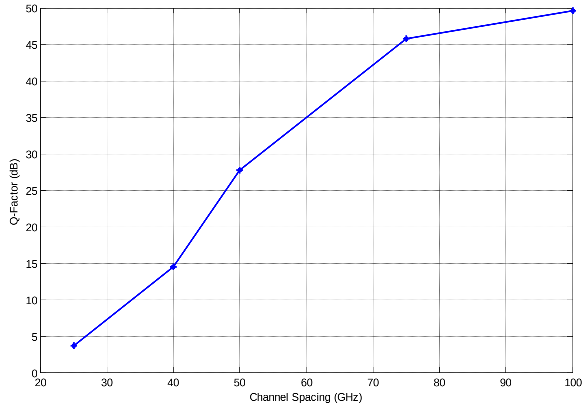
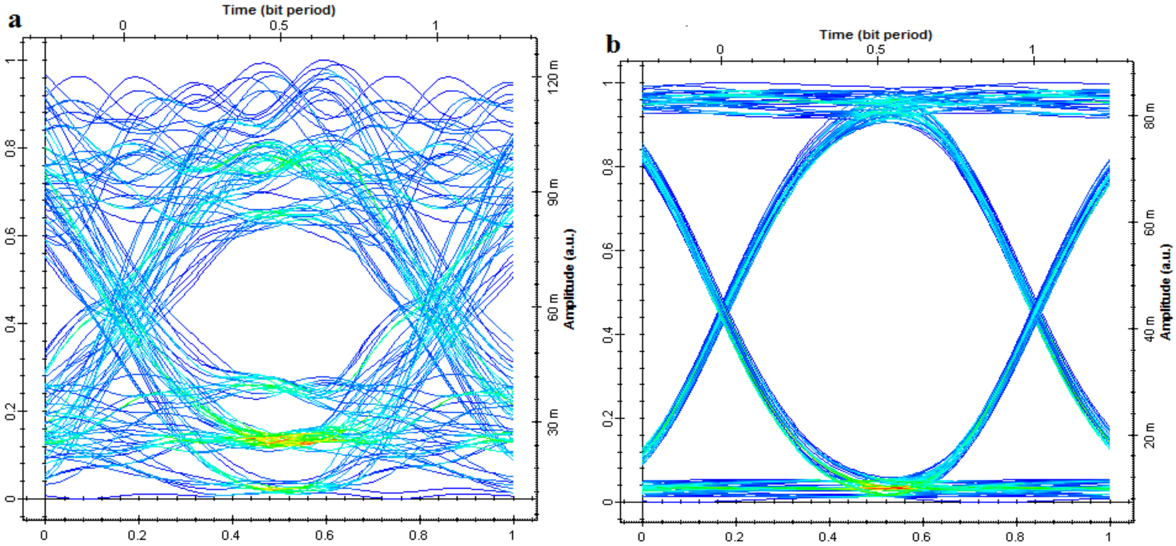


Fig.9 Variation of Q-factor with respect to channel spacing

Table II Q-factor/BER comparison of ESCA and USCA channel schemes for DWDM System at a bit rate of 8×10Gbps.

Channel Scheme	Max. Value of Q-factor (dB)	Min. Value of Q-factor (dB)	Min. BER	Max. BER
ESCA	27.72	5.95	1.8×10^{-169}	1.2×10^{-09}
USCA	40.47	6.25	1.4×10^{-261}	1.9×10^{-10}



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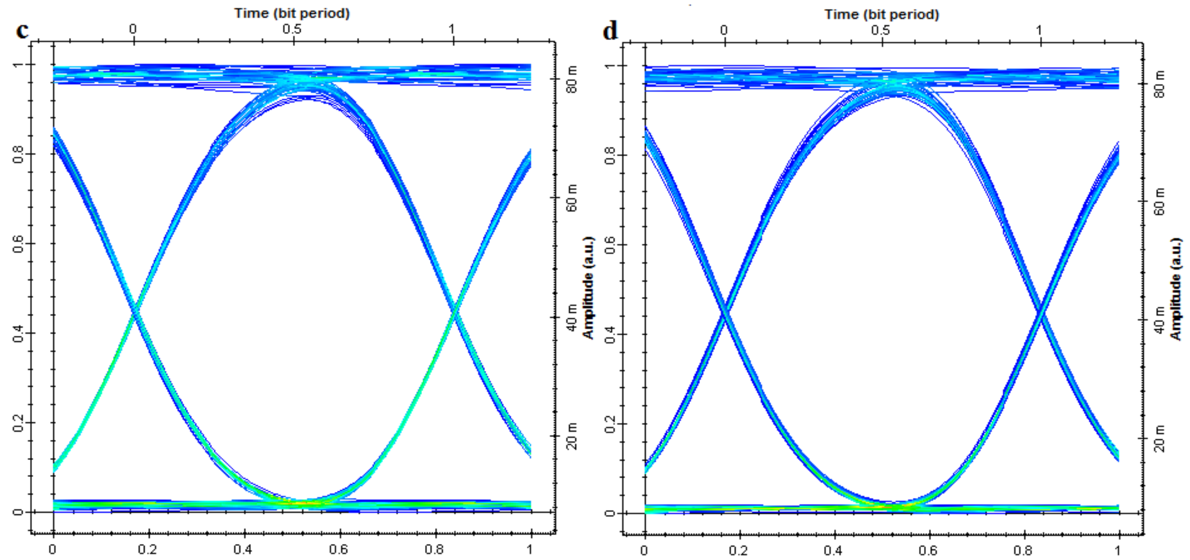

Fig.10 Eye diagram patterns of (8×10) Gbps DWDM system for different channel spacing of (a) 25 GHz (b) 50 GHz (c) 75 GHz (d) 100 GHz at an optical fiber length of 50 km in the presence of FWM mixing.

Then the comparison has been done between ESCA for 0.4 nm spacing and USCA for 50 GHz slot width. It has been observed that the USCA scheme of channel allocation in WDM system is the better allocation scheme as shown in Fig.6. The simulation setup shown above is also used to analyze the effect of change of bit rate on the equal and unequal space channel allocation scheme. Here SMF of fixed length 50 Km has been used with input power of 0dBm and NRZ modulation format for eight numbers of users. Hence, the effect of changing the bit rate as showed in Fig.7 and Fig.8. Fig.7 shows the variation of Q-factor as bit rate changes from 1 Gbps to 20 Gbps with different channel spacing between the users for equally spaced channel allocation scheme.Fig.8 shows the variation of Q-factor from 100.6 dB to 4.44 dB for equally spaced allocation scheme and from 109.5 dB to 15.9 dB for unequally spaced channel allocation schemes. The results show that with increase in bit rate Q-factor decreases. Table 2 shows the different values of Q-factor and BER obtained for the DWDM system for ESCA and USCA schemes. The maximum value of Q-factor is 40.47 dB for USCA scheme has been achieved which is 12.75 dB enhanced from ESCA scheme at the data rate of 8×10 Gbps. Fig.9 shows the variation of Q-factor with the spacing between the input channels. The graph shows that the Q-factor increases as the spacing between input channels increases. Q-factor is maximum, when the channel spacing is 100 GHz and Q-factor is minimum, when the channel spacing is 25 GHz. Fig.10 shows the eye diagram of the receiver output for the various values of channel spacing. As the channel spacing is less, the interference between input channels is large and thus, the eye diagram is poor in amplitude and shape as shown in Fig.10a. The eye diagram shown in Fig.10d is unambiguous than as shown in Fig.10a. Hence, it has been observed that on increasing the channel spacing from 25 GHz to 100 GHz, the inference between the adjacent channel decreases and thus, the FWM effect also decreases.

V. CONCLUSION

In this paper, we have investigated the effect of four wave mixing on eight channel (N=8) DWDM system at different parameters such as optical distance, laser power, channel spacing and bit rate. The performance has been evaluated in terms of Q-factor under the impact of equal and unequal channel spacing for the DWDM system. It has been observed that reduction in channel spacing to accommodate more interference between the channels in the presence of four wave mixing, which degrade the performance of the DWDM system. The simulation results show an efficient improvement in Q-factor with unequal channel spacing as compared to equal channel spacing for the present simulative DWDM system. A maximal value of Q-factor of 40.47 dB has been obtained for USCA channel scheme based DWDM system, which is enhanced by 12.75 dB than ESCA based DWDM system. Further, it has been concluded that on increasing the channel spacing between input channels, the effect of four wave mixing decreases.

ACKNOWLEDGMENT

I wish to express my sincere indebtedness and a deep sense of gratitude to my supervisor **Er. Satbir Singh,** Assistant Professor, Guru Nanak Dev University, Regional Campus Gurdaspur for his generous inspiration, guidance, continuous encouragement and supervision throughout the course of present work. I am highly thankful for his most valuable suggestions, constructive critiques and valuable time spared throughout this venture. The perseverance, dedication and understanding of subject matter showed by his are a class in itself. I am indeed indebted to my parents who encouraged me to take up this endeavor. The references, internet sites that have been consulted in carrying out this work and software like OptiSystem and Matlab for drawing graphs for writing this manuscript are also greatly acknowledged.

IJARCCE

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ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
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I shall feel my labor amply rewarded if this work proves to be useful for those who are working in the field of optical fiber communication.

REFERENCES

[1] Gerd Keiser, "Optical Fiber Communication", Tata McGraw Hill Higher Education, Edt. No.9, 2000.
[2] Monika, Amit Wason, R.S. Kaler, "Investigation of four wave mixing effect with different number of input channels at various channel spacing", Optik, vol. 124, pp. 4227-4230, 2013.
[3] Edward Mutafungwa, Seppo J. Halme, "On the use of optical spreading codes to design DWDM system to reduce FWM crosstalk", Optics Communications, vol. 198, pp. 339-350, 2001.
[4] Takahiro Numai, "Analysis of repeated unequally spaced channels for FDM lightwave Systems", Journal of Lightwave Technology, vol. 18, no. 5, pp.656-664, 2000.
[5] Satbir Singh, Amarpal Singh, Shashi B. Rana, "Simulative analysis of the influence of continuous wave laser power on different data formats for a bi-directional radio over fiber communication system", Journal of Optics, vol. 41, pp. 25-32, 2012.
[6] Yan Ling Xue, "FWM and XPM in Er^{3+} doped silica and tellurite fibers", Optics Communications, vol. 281, pp. 1558-1567, 2008.
[7] Govind P. Agrawal, "Nonlinear Fiber Optics", Optics and Photonic, 2006.
[8] John M. Senior, "Optical Fiber Communications", Pearson, 2011.
[9] J. Hansryd, F. Dross, M. Westlund, P. A. Andrekson, S. N. Knudsen, "Increase of the SBS threshold in a short highly nonlinear fiber by applying a temperature distribution", Journal of Lightwave Technology, vol. 19, no. 11, pp. 1691-1697, 2001.
[10] Ajay K. Sharma, Sandeep K. Arya, "Improved analysis for SRSand XPM-induced crosstalk in SCM-WDM transmission link in the presence of HOD", Optik, vol. 120, pp. 773-781, 2009.
[11] Rajneesh Kaler, R.S. Kaler, "Investigation of four wave mixing effect at different channel spacing", Optik, vol. 123, pp. 352-356, 2012.
[12] Forghieri, F., Tkach, R.W., Chraplyvy A.R., Marcuse D, "Reduction of four wave mixing crosstalk in WDM systems using unequally spaced channels", Photonics TechnologyLetters, vol. 6, pp. 754-756, 2002.
[13] Anamika, Vishnu Priye, "XPM and SPM induced crosstalk in WDM system employing distributed Raman amplifier for DPSK and OOK modulation format", Optical FiberTechnology, vol.19, pp. 75-82, 2013.
[14] Zhenning Tao, Weizhen Yan, Weizhen Yan, "Simple fiber model for determination of XPM Effects", Journal of Lightwave Technology, vol. 29, no. 7, pp. 974-986, 2011.
[15] Prithipal Singh, Satbir Singh, "Survey of four wave mixing with different number of channels under the impact of different channel spacing", An International Journal of Engineering Sciences, vol. 17, pp. 409-414, 2016.
[16] Djafar K. Mynbaev, Lowell L. Scheiner, Fiber-Optics Communication Technology, Pearson education, 2011.
[17] Vishal Sharma, Ramandeep Kaur, "Implementation of DWDM system in the presence of four wave mixing under the impact of channel spacing", Optik, vol. 124, pp. 3112-3114, 2013.
[18] Amarpal Singh, Ajay K. Sharma, T.S. Kamal, "Investigation on modified FWM suppression methods in DWDM optical communication system", Optics Communications, vol. 282, pp. 392–395, 2009.
[19] Surinder Singh, Sukhbir Singh, "Investigation on four wave mixing effect in various optical Fibers for different spectral efficient orthogonal modulation Formats", Optics & Laser Technology, vol. 76, pp. 64–69, 2016.
[20] Jian Guo Zhang, A.B. Sharma, "Notes on use of strict optical orthogonal codes to design unequal channel spacing frequency sequences for DWDM systems with reduced FWM crosstalk", Optics Communications, vol. 281, pp. 5574–5579, 2008.
[21] Bassem K. Abd ElRazak, M. Bashir Saleh, "Duobinary Modulation Format and Unequal Channel Spacing Integration to Suppress Four-Wave Mixing Crosstalk in WDM Systems", IEEE Photon. Technology, vol. 69, no.11, pp. 978-982, 2011.

BIOGRAPHY

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