I J C T A, 9(28) 2016, pp. 399-406

QOS BASED DWDM SYSTEM WITH OPTIMUM FWM PARAMETERS FOR FTTH APPLICATIONS

S. Sugumaran* G. Suresh and P. Arulmozhivarman*****

Abstract: The integration of optical networks is a potential solution for the increasing capacity and mobility. The bandwidth hungry applications like Video-on-Demand [VoD], Games on Demand [GoD], 3G/4G Mobile services are putting burden on the fiber-optic trunk lines for the transmission rate of Peta bits per second. The increasing user's data traffic increases number of wavelengths which necessitates Dense Wavelength Division Multiplexing (DWDM), a cost effective method to increase the capacity of existing fibers without replacement. Nonlinearities arises as a limiting factor as light intensity inside a fiber is getting increased. Among various nonlinearities Stimulated Raman Scattering (SRS), Four Wave Mixing (FWM) and Stimulated Brillouin Scattering (SBS) in DWDM are dealt in this paper. The effect of dispersion and wavelength spacing on FWM are analyzed. This research aims at optimizing the dispersion, channel spacing and spectral width values for minimizing the FWM, thereby increasing the overall capacity of fiber optic trunk line. The growing importance of high-speed communication is creating a demand for ever faster information transfer rates, particularly in fiber-optic communication systems. Dense Wavelength Division Multiplexing (DWDM) can both significantly enhance transmission capacity and provide more flexibility in optical networks design.

Keywords: DWDM; Four Wave Mixing; OptiSystem; Simulation; Bit Error Rate; FTTH.

1. INTRODUCTION

The expansion and advancements in the field of communication has resulted in the need for an efficient design of communication systems. The huge amount of data transfers leads to the necessity of a large bandwidth with high efficiency without compromising the cost. Fiber optic communication has changed the world with its ability to meet the rising demands for fast internet connection, video-based multimedia, peer to peer communication, file transfer, HD gaming etc [4]. The fiber technology has played a vital role in medical field with its reliability, high data rate and lower attenuation rates. FTTH (Fiber To The Home) or also known as FTTP (Fiber To The Premises) is where the communication between the transmitter and receiver takes place with fiber optical cables till the building or premises of the end user [2]. FTTH is capable of delivering digital data, telephony, video etc. at high data rates. A fiber can carry more than 2.5 million phone calls simultaneously whereas it is 6 calls in the case of the conventional coaxial cables.

The concept of WDM allows data to be multiplexed in to different wavelengths such that it can be transmitted through a single mode fiber. Dense Wavelength Division Multiplexing has significantly increased the number of wavelengths to be transmitted through a single fiber by multiplexing more number of wavelengths through a single fiber. This has given rise to nonlinear effects in the fiber. The nonlinear effects are SRS (Stimulated Raman Scattering), SBS (Stimulated Brillouin Scattering) [7], SPM (Self Phase Modulation), XPM (Cross Phase Modulation) and FWM (Four Wave Mixing) [2]. Four Wave Mixing plays a very important role in the fiber nonlinearities in a DWDM system. FWM has to be reduced so that the system designed becomes efficient so as to be implemented [5].

* Research Scholar, School Of Electronics Engineering, VIT University,Vellore, T.N **Email:** sugudeep@gmail.com
** Professor CAHCET Melvisharam
*** Professor School of Electronics Engineering, VIT University, Vellore, T.N

In this paper, a DWDM system is simulated and the FWM and Q-factor are analyzed by varying the input power, optical gains, number of channels and channel spacing [1]. An efficient system is designed by choosing the optimum parameters obtained from the analysis and is implemented on an FTTH system and simulated to analyze the FWM and Q-factor.

The paper is organized into three sections. Section I deal with the introduction to fiber optic communication, FTTH, WDM and DWDM. Section II deal with the block diagrams of the DWDM system as well as the FTTH system. Section III includes the results obtained from analyzing the parameters by varying the input power, optical gains, number of channels and channel spacing. It also includes the results obtained from the analysis of the FTTH system along with the optical spectrum and eye diagrams. The paper concludes with the result obtained from the analysis of the DWDM system and its implementation in an FTTH system.

2.1 Study on Proposed Research:

A proper node architecture design capable to support different network protocol enhances the data transport capability of a DWDM system. In this research a simple node architecture model has been analyzed to simulate the node throughput based on media access control protocols for bursty data traffic of variable time slot duration and data rate, an appropriate mathematical model has been derived to evaluate different types of traffic reservation protocols used in DWDM networks. The Observations from the work done in this research was that the network performance is well controlled through implemented protocols and network design parameters.

Dense Wavelength division multiplexing (DWDM) can both significantly enhance transmission capacity and provide more flexibility in optical network design. Through the use of EDFAs (Erbium doped fiber amplifiers), it is possible to build long-distance transport optical transmission links without electrical regenerators. In such systems, fiber nonlinearities are likely to impose a transmission limit due to increased total interaction length.

There are a number of optical nonlinear effects in optical fibers, such as stimulated Raman scattering (SRS), stimulated Brillouin scattering (SBS), and four-wave mixing (FWM). Out of these SRS and FWM are the dominant effects. This research work also consists of an algorithm to study the effect of FWM. It has been found from literature survey that to maximize the signal-to-noise ratio of the transmitted signal in a DWDM system FWM noise needs to be reduced as this is the dominant noise factor; it also shows the dependency of capacity, system performance in terms of node throughput of the network with Optical signal-to-noise ratio which is affected by fiber nonlinearities.

The main objective of this research is to analyze the FWM (Four Wave Mixing) efficiency for different fiber lengths and channel spacing and nonlinear Schrödinger equation solution. In this thesis, I have simulated the FWM design for two and three waves.

I have also analyzed the influences of non-linear refractive index on the four-wave mixing (FWM) characteristics in semiconductor optical amplifiers (SOAs).It has been shown that the generated FWM signal characteristics can be modified due to the variation of non-linear refractive index of the SOA's medium. The wave propagation in the SOA has been modeled using the nonlinear Schrodinger equation. Simulation of Schrödinger equation is carried out using split step Fourier method. The FWM design was simulated with the OPTISYSTEM tool and analyzed using the eye pattern method with respect to bit error rate and Q factor. In this paper, FWM efficiency is analytically simulated for two wave and three wave fiber transmission. The results obtained show that the efficiency decreases with the increase of both the frequency spacing and the fiber length, which can be explained using the phase-matching condition. All the efficiency and power equations have been numerically simulated in MATLAB. The FWM efficiency is also analyzed for variation in chromatic dispersion and the results show that the chromatic dispersion should be high for FWM effect to be less.

2. PILOT PROJECT AND ARRANGEMENTS

Here the Dense WDM System as well as the FTTH system is simulated in OptiSystem and the simulation results is depicted.

2.1 Simulation of Dense Wavelength Division Multiplexing Experiment

PRBS (Pseudo-Random Bit Sequence) is used to represent the data transmitted. The data is represent using a NRZ (Non Return To Zero) coding. A CW (Continuous Wave) laser operating at 193.1 THz is used as carrier. The PRBS along with a continuous laser is multiplexed using a Mach-Zehnder modulator. The PRBS, continuous wave laser and the Mach-Zehnder modulator represents the transmitter block. Figure 1 depicts the transmitter block diagram for the NRZ line-coding technique.

The optical span consists of SMF (Single Mode Fiber), DCF (Dispersion Compensated Fiber), amplifiers etc. to account for the losses that occur during the transmission of through the fiber. The EDFA amplifiers are used; as they do not require an opto-electric conversion to amplify the signals instead they can be done in the optical domain itself. The optical gain is varied at this point to account for the four wave mixing. A typical optical span block diagram is represented in figure 2.

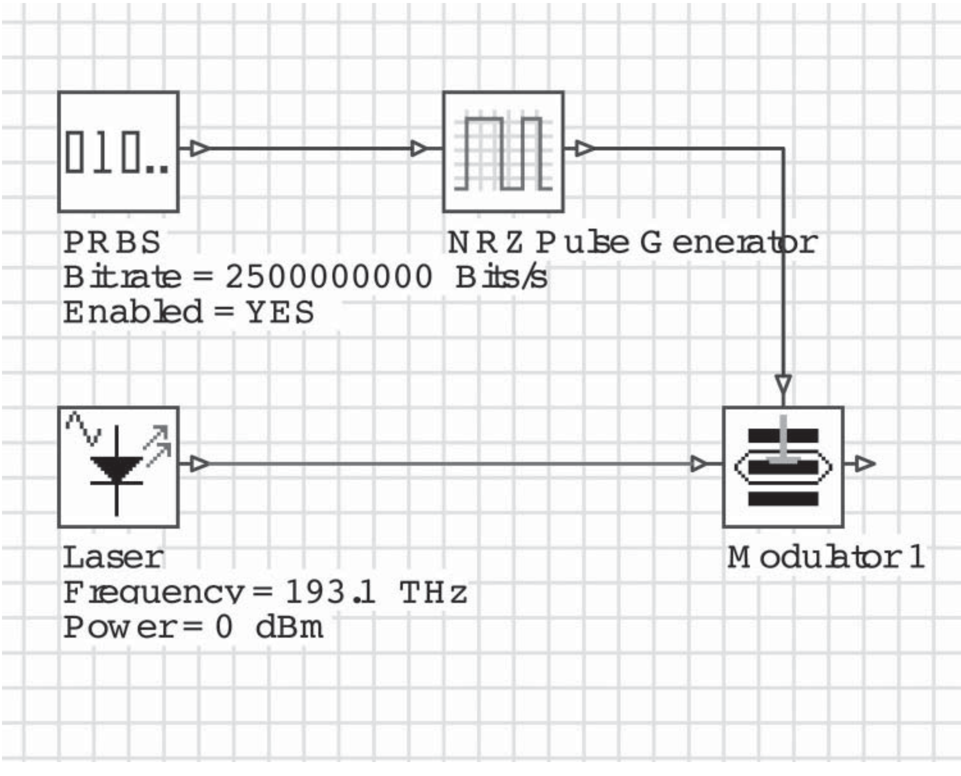

Figure 1. Transmitter Block diagram of NRZ Line Coding

SMF stands for single mode fiber [10]. DCF stands for dispersion compensation fiber [7]. The length of fiber in one loop is 50 + 10 = 60 km. the DCF length is 10 km.

The gain of EDFA placed after a fiber is such that it compensates the losses of the preceding fiber [6] [3]. Let the length of SMF be L km, the attenuation be A dB/km. The Gain of the first EDFA be G_1, that of the second be G_2. The above-mentioned parameters have to be selected such that the values satisfy the following conditions. The values are chosen based on the conditions given below. Gain of first EDFA

$G_1 = L * A$, gain of the second EDFA in the simulation $G_2 = L_2 * A_2$ and that of the gain of the third EDFA is $G_3 = L_1 * A_1$.

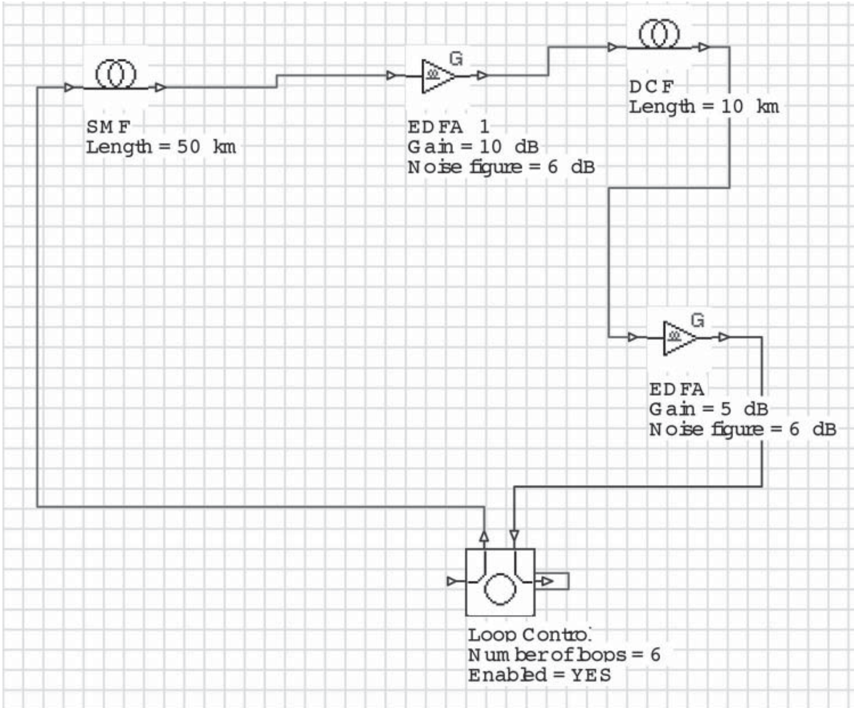

Figure 2. The Block Diagram of a Typical Optical Span

A sample calculation of the parameters is given below. Let us take L = 10 km, A = 0.2 dB/km, L_2 = 10 km and A_2 = 0.5 dB/km. [1]

The attenuation due to SMF at 50 km is calculated to be 50 *0.2 = 10 dB

This is neutralized by gain G1 = 10 dB

The receiver is an optical receiver used at the end taken from the output of a de-multiplexer. The receiver is connected to the BER analyzer. Figure 3 depicts the block diagram of the receiver.

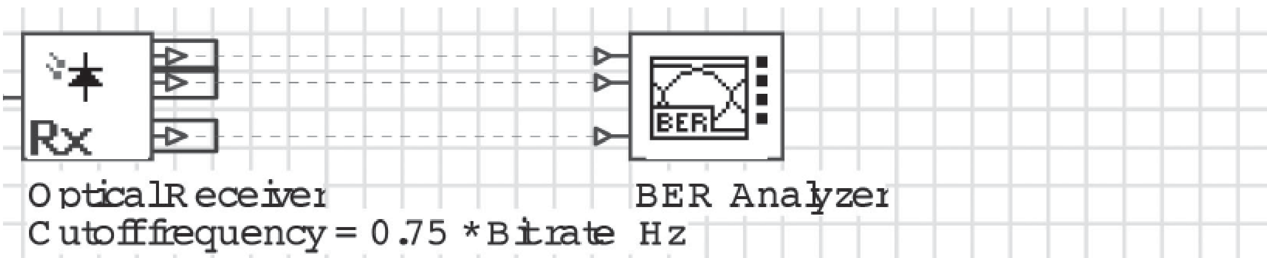

Figure 3. Receiver Block Diagram

Figure 4 depicts the subsystem block diagram of a DWDM system. The transmitter is made into a subsystem that is expanded as shown in figure 1. The bitrate for the simulation setup has been fixed at 2.5 Gbps, sequence length of 128 bits and sample per bit 64. The input power is varied in the transmitter block for input powers 0 dBm and -10dBm. The optical gain has been taken as 10dB and 5dB for the first instance and 15 dB and 6 dB for the second instance with a noise figure of 6 dB in both the cases. The simulation has been carried on for a 3 channel and an 8-channel DWDM system. A channel spacing of 100 GHz and 110 GHz has been for the above simulation setup depicted in figure 4.

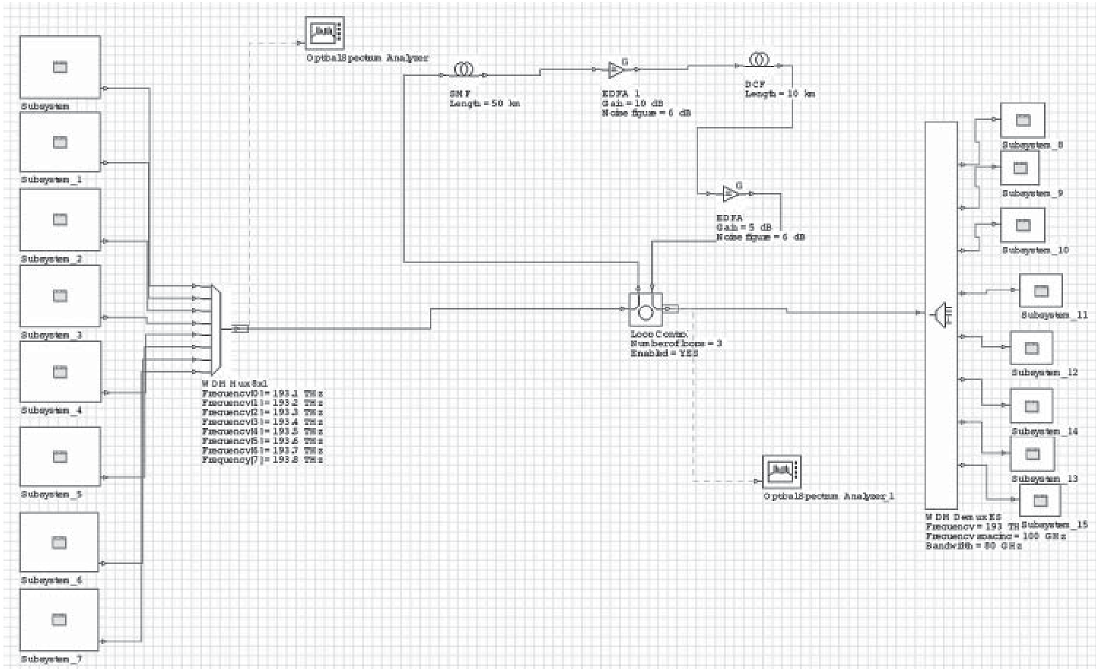

Figure 4. Subsystem layout

2.2 Simulation of Fiber To The Home (FTTH System)

The FTTH system consists of the transmitter, the optical span and the receiver. Figure 1 represents the transmitter and figure 2 represents the optical span.

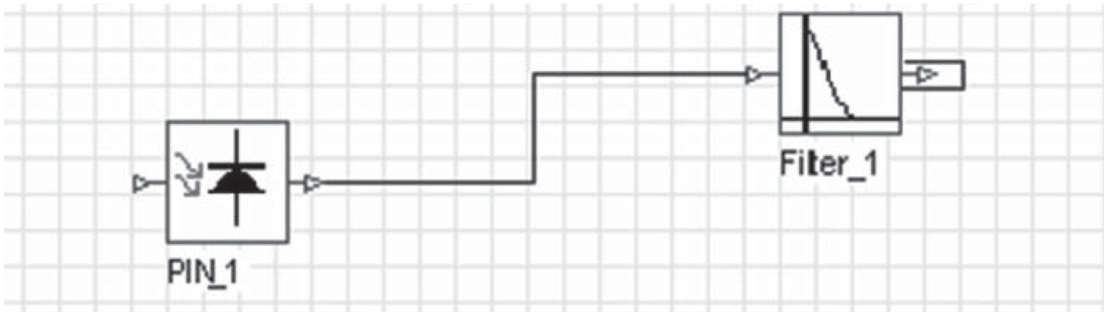

Figure 5. FTTH Receiver layout

Figure 5 represents the receiver block diagram for the FTTH system. The receiver consists of a PIN photodiode along with a low pass filter with cut off frequency that of 0.75*Bitrate. This setup ensures that the end user gets the signal in the optical domain.

III. EXPERIMENTAL RESULTS AND ANALYSIS

The eye diagram and optical spectrum has been obtained to validate the results obtained through simulation. Figures 6 and 7 depicts the eye diagram and optical spectrum respectively of an 8 channel DWDM system with 0 dBm input power, EDFA amplifier gain of 10 dB and 5 dB respectively with a noise figure of 6 dB and channel spacing of 100 Ghz. Figures 8 and 9 depict the eye diagram and optical spectrum respectively of an 8-channel DWDM system obtained by varying the input power to -10 dBm. On comparing the results obtained by varying the input power from 0 dBm to -10 dBm in the transmitter layout, it is clearly observed that the Q factor has reduced from 10.5316 to 5.328 as shown in figures 6 and 8.

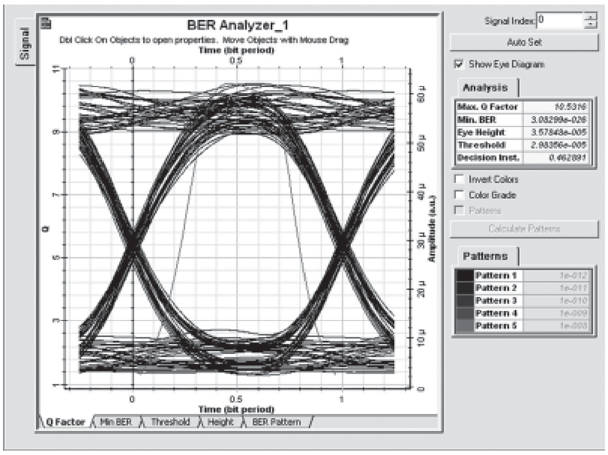

Figure 6. Eye Diagram for 0 dBm input power (8 channel)

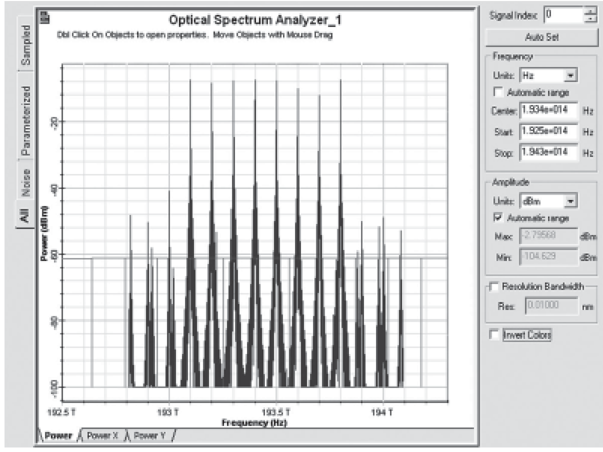

Figure 7. Optical Spectrum Analyzer for 0 dBm input power (8 channel)

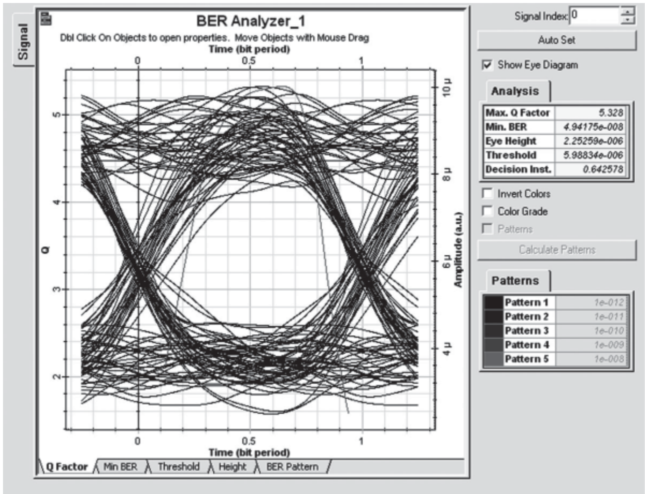

Figure 8. Eye Diagram for -10 dBm input power (8 channel)

The FWM, which was initially observed in -48 dBm in the optical spectrum analyzer in figure 7, has now come down towards -68 dBm to -70 dBm ranges.

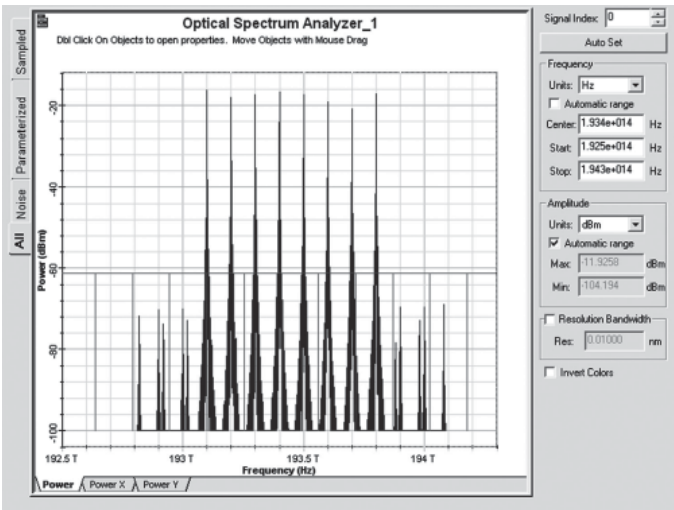

Figure 9. Optical Spectrum Analyzer for -10 dBm input power (8 channel)

Figures 10 and 11 depicts the eye diagram and optical spectrum respectively for the varying the EDFA amplifier gain to 15 dB and 6 dB with a noise figure of 6 dB. On comparing the eye diagrams in figure 6 and 10, on varying the optical gain from 10 dB to 15 dB for EDFA 1 and 5 dB to 6 dB for EDFA 2 there occurs a slight increase in the Q factor from 10.5316 to 12.9877.

An Efficient DWDM system is designed by keeping the input power -10db with 100GHz channel spacing and the optical gain 12dB and 6dB respectively with a noise figure of 6dB each. The above designed system is also implemented in an FTTH system.

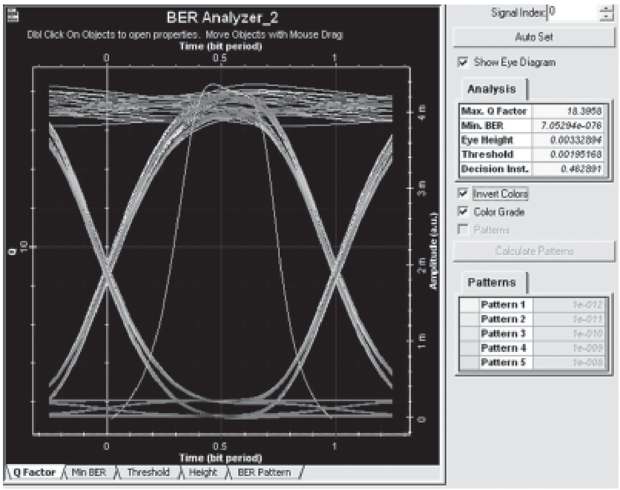

Figure 10. Eye Diagram for Efficient FTTH system

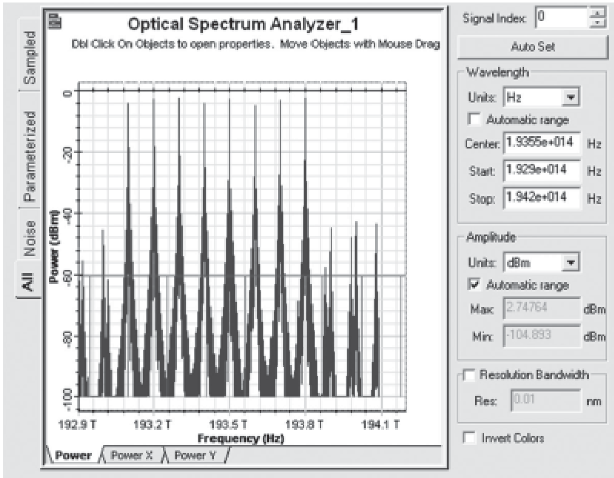

Figure 11. Optical Spectrum Analyzer for Efficient FTTH system

It is also observed from experimental results, FWM occurs below -68dBm in the FTTH system whereas it occurs at -40dBm in the DWDM system. The implemented FTTH system has been optimized with lower rates of FWM.

6. CONCLUSION

The phenomenon where an undesirable nonlinear effect gives significantly degraded system performance, and becomes the major drawback for optical communication systems is known as Four wave mixing. In order to achieve affordable BER and Q-factor, a comparison of a DWDM system with equal and unequal channel spacing is performed. The result of the channel spacing can be verified using opt-sim 7.0. A channel allocation method, based on the optimal Golomb ruler, that allows the reduction of FWM effect while maintaining bandwidth efficiency, is presented. The two algorithms i.e. Exhaust algorithm and Search algorithm to construct the Golomb ruler sequences are presented here. The result of these two algorithms is compared using Matlab9. Two different modulation techniques are also implemented, i.e, low level FWM reduction and high level FWM reduction. The performance of these two factors is calculated by noting BER, Q-Factor and power of the generated FWM products. The eye diagrams of these processes are also plotted using Optisystem 7.0. The calculation of BER, Q-factor and power of generated FWM products are calculated for different lengths of fibers(50 km, 75 km and 100km). Later a comparative analysis is done between both low level reduction technique and high level reduction technique.

In the Dense Wavelength Division Multiplexing system (DWDM) the nonlinear effects plays an important role. DWDM system carries different channels, hence power level carried by fiber increases, which generates nonlinear effect such as SPM, XPM, SRS, SBS and FWM. Four Wave Mixing (FWM) is one of the most troubling issues. The FWM gives crosstalk in DWDM system whose channel spacing is narrow. By using the fiber with proper amount of dispersion and by unequal spacing between channels it is possible to suppress FWM crosstalk. In this research I design DWDM system and simulate the parameters, which lead to generation and enhancement of FWM using OptiSystem software. The above designed DWDM system with optimum FWM parameters is implemented for FTTH applications.

The simulation for analysis of FWM by varying input power, optical gain, number of channels and channel spacing is analyzed using Optisystem. On varying the input power, it is concluded that on reducing the input power the Q factor is lowered drastically but the FWM component has reduced slightly. Increasing the EDFA gains in the optical span for the 6 loops results in slight increase in the Q factor but the FWM component has increased with the increase in the optical gain.

On analyzing for different number of channels in the transmitter side, it is found that the Q factor increases and the FWM components also decreased. On varying the channel spacing the Q factor reduces by a slight amount as well as the FWM components are also reduced. The efficient DWDM system has been designed and implemented in FTTH system with reduced FWM.

References

1. Jameel Ahmeda, Ashiq Hussainb, M.Y. Siyalc, Habibullah Manzoora and Abdullah Masooda, Parametric analysis of four wave mixing in DWDM systems (IJLEO Optik – 2013)
2. G.P.Agrawal, Nonlinear Fiber Optics, Academic press (2001). Mohammad. Amin. Dallaali, “Malin Premaratne Power and dispersion constrained optimization of optical links with unequally spaced repeater modules”, Optical Fiber Technology, Vol 13, No 4, pp.309-317, October. 2007.
3. A.Hodzik, B. Konrad and K. Petemann, Journ. Lightwave. Technol. 20, 598, (2002).
4. K.Marinov, I. Uzunov, M. Freitas and J. Klein, Optical amplifiers and their applications (OSA Topical meeting), 76 - 78, Otaru, Japan, July 6 - 9 (2003).
5. V.Pechenkin, I.J. Fair, On four-wave mixing suppression in dispersion man-aged fiber-optic OFDM systems with an optical phase conjugation module, J.Lightwave Technol. 29 (April (11)) (2011) 1678–1691.
6. Ahmed Jameel, et al., Optical signal processing using four wave mixingin highly nonlinear silicon nano-wire, Optik 124 (September (18)) (2013)3439–3442.
7. V.Vujicic, N. B. Pavlovic, and A. Teixeira, “SBS Induced Four-Wave Mixing in Ultra Dense WDM Systems,” IEEE 2011.
8. A.L.Zhang, H.Liu, M.S. Demokan, and H. Y. Tam, “Stable and broad bandwidth multiwavelength fiber ring laser incorporating a highly nonlinear photonic crystal fiber,” IEEE Photon. Technol. Lett., vol. 17, no.12, pp. 2535–2537, Dec. 2005.