International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2015): 6.391

Performance Analysis of Modulation Formats for WDM Spectrum Slicing

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Abstract: ***The spectrum slicing technique of wavelength division multiplexing system is attracting more market recently since it is power efficient and less costly than the traditional laser sources. In this paper Continuous Wave (CW) array lasers element are utilized instead of de-multiplexer to reduce more cost and simplify the WDM system design structure. An erbium-doped fiber amplifier (EDFA) module is also used for laser power level enhancement. Data from different sources were transmitted to evaluate new WDM like system. Furthermore, spectrum slicing, modulation formats is used to analyze the relevant performance parameters. Optisystem14 software was used to design, implement and simulate the passive optical system of WDM. It is found that The NRZ system has been found to be good for transmitting optical signal at the rate of 8Gb/s and 60 km length.***

Keywords: WDM, Spectrum Slicing, Non-Return Zero, Return Zero, Bit Error Rate, Q factor

1. Introduction

Telecommunication's future access network is increasing day by day with a need to meet greater bandwidth and reliable data transmission. Optical access network is the most demanding network for industry after the deployment of optical fiber in metro areas, where the use of optical fiber technology by reducing the Central Office (CO) equipments and maintenance cost of these systems with provision of higher data transmission operating over repeater less peer to peer (P2P) networks [3]. Incorporating Wavelength Division Multiplexing (WDM) in a Passive Optical Networks (PON) allows one to support higher bandwidth compared to the standard PON since each wavelength is dedicated to a single subscriber. The WDM-PON offers other advantages such as ease of management and upgradability, strong network security, high flexibility with data and protocol transparency, so that it has been considered by many as a future-proof access technology and an ultimate next-generation Fiber to the Home (FTTH) network [4].

The optical fiber is the most advanced transmission medium and the only one capable of supporting next generation services. The main advantages of having a last mile of optical fiber are many: higher bandwidth, longer distances from the central to the subscriber, the more resistance to electromagnetic interference, increased security, reduced signal degradation. Moreover, the fact of using PON technology assumes the elimination of repeaters and optical amplifiers and therefore reducing the initial investment, lower power consumption, less space, fewer points of failure [1]. So that dispersion significantly degrades the performance of this system more than it is observed in conventional laser-based systems. The influence of dispersion needs to be studied in order to understand the characteristics of a spectrum sliced WDM PON system employing standard Single Mode optical Fiber (SMF) [2,6]. Most of the currently existing WDM systems have multiple CW lasers operating at different wavelengths, which require the wavelength to be selected for each channel and operate at specific wavelength. This makes the system costly and increase the complexity of network architecture using many spectrum sliced channels. However, the spectrum sliced techniques currently used have dispersion issues due to dispersion compensation techniques used, modulation formats and other spectral related matters. How can make overall performance of the system better and the received signal clarity by choosing best Modulation format in the Wavelength Division Multiplexing Spectrum slicing technique.

The rest of this work is organized as follows: Section 2 shows the system block diagram of Spectrum slicing systems. Section 3, explains experimental simulation model of up to 8-channel SS-WDM PON system including spectrum slicing wavelength division multiplexing and the experiment schematic. Section 4, explains results and discussion. Section 5, provides Conclusion.

2. Background

2.1 Spectrum Slicing Technique

Spectrum slicing technique is one of basic techniques available in WDM PON systems in order to reduce the cost of components and simplify the passive network architecture. There incoherent broadband light source (BLS) is sliced and equally spaced multi-wavelength channels is generated. The aim of spectrum slicing is to employ a single BLS for transmission on a large number of wavelength channels as shown in Figure 1 [2].

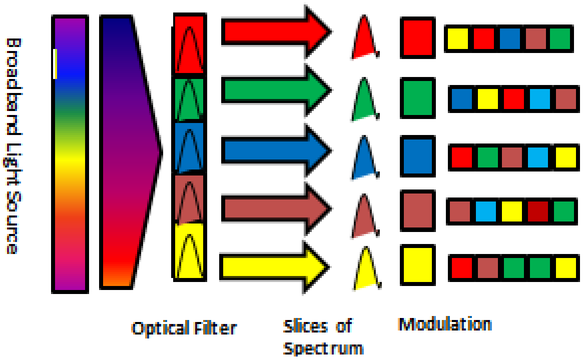


Figure 1: The Principle of Spectrum Slicing

The question arising here is the reason why spectrum slicing attracted many people, and become alternative solution to the pre-existing systems. The first implementations of the WDM systems used LED as a light source, which is quite low power compared to other sources. This caused loss in energy and efficiency [5]. WDM-PON has inherent advantages over TDMA-PON in terms of bandwidth, protocol transparency, security, and simplicity in electronics, etc. In addition, the splitting ratio is not limited by splitting loss at the remote node (RN). However, the bandwidth for the dedicated wavelength is not fully utilized [7].

2.2 Related Works

In [6], the authors proposes implementation of chromatic dispersion compensation for cost effective spectrum-sliced 16-channel DWDM PON system with data rate 2.5 Gbit/s per channel as well as realization of broadband ASE light source with output power +23 dBm, channel power variation 0.42 dBm and flat spectrum in wavelength range from 1545.32 nm to 1558.98 nm. In addition, the authors of [9] build a wavelength division multiplexing system and implement the technique of Spectrum Slicing instead of using different laser sources for each wavelength for four channels and Optisystem 7.0 software is used in the design. In [8], potentially inexpensive light source for multichannel WDM applications. In which, the high-power amplified spontaneous emission (ASE) from an erbium-doped fiber amplifier (EDFA) is used. In [7], the authors implement a WDM-PON system as a platform for TPS. The system employs an amplified spontaneous emission (ASE)-injected Fabry–Pérot laser diode scheme. It has 32 channels of 125 Mb/s and adopts Ethernet as Layer 2.

3. Experimental Simulation Model of up to 8-channel SS-WDM PON System

3.1 Spectrum Slicing Wavelength Division Multiplexing

In order to make the system more reliable and less cost, two changes are added to the system shown in Figure 2. Firstly, the de-multiplexer replaced direct connection between continues wave lasers and modulators. Array is added to get a matrix of laser sources to the system, therefore the signals have better performances and reliable to reduce the dispersion and noise than traditional system. CW Lasers Array has line width of 10MHz, frequency of 193.1 to 193.8 and has noise threshold of -100 dB. Secondly, Periodic optical amplifications are provided by inline erbium-doped fiber amplifier (EDFA) modules. Each EDFA module consists of a length of dispersion compensating fiber (DCF), which is sandwiched between two sections of erbium doped fibers and the noise figure of each EDFA is 6dB, Gains 10dB, 5dB respectively. Gain spectrum slicing of erbium is much flatter intrinsically in the L-band than in C-band. The EDFA provides much more powerful ASE light into single-mode fiber than semiconductor devices (e.g., LED's, SLD's, or amplifiers) [8].

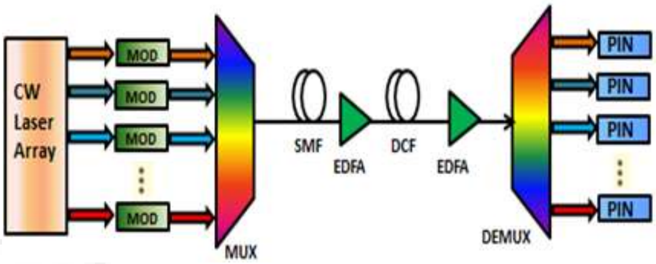


Figure 2: Spectrum slicing multiplexer demultiplexer system

3.2 The Experiment Schematic

The first part in the Experiment Schematic is the broadband light source which carries the data through the optical fibers. The second main component of the WDM spectrum slicing technique is the external modulations. The signal is divided in to eight different channels each having different frequency by eight of lasers sources. After that, a multiplexer is used to combine the few channels in order to transmit it through the single mode fiber. The area of the signal mode fiber differs and depends on demand, and length of dispersion compensating fiber (DCF). However, in this paper, the simulated distance of the single mode fiber and dispersion compensating fiber (DCF) selected to be 60 km. Meanwhile, it is less dispersion and noise effects for the system to use this distance since the objective is to compare the performance of the modulation techniques used in the experiment. Once the signal reaches the destination receiver, it is split back in to its eight channels for proper detection of each channel. PIN photo detectors are used in the receiver side to detect the incoming spectral sliced signals. These signals are then analyzed and their characteristics such as the BER, Q factor, and threshold and spectrum analyzer properties are calculated. A simulation scenario is carried out using the proposed approach (SS-WDM) [9]. The simulation parameters are shown in Table 1.

Table 1: Simulation parameters

Section	Components	Parameters	
		Type	Value
Transmitter	CW Laser Array	Line width	10 MHz
		Frequency	(193.1,193.2, …,193.8) THz
		Noise threshold	-100 dB
	PRBS	Bit rate	(5,10,15) *10^9 bit/s
	NRZ Pulse Generator	Rise time	0.15 bit
	Mach-Zehnder Modulator	Extinction ratio	30 dB

	WDM Mux	Bandwidth	10 GHz
		Number of input port	8
		Depth	100 dB
Optical fiber system	SMF	Reference wavelength	1550 nm
		Length	50 km
		Attenuation	0.2 dB/km
		Dispersion slope	0.075 ps/nm^2/k
		Differential group delay	0.2 ps/km
	EDFA	Gain	10 dB, 5 dB
		Noise figure	6 dB
	DCF	Reference wavelength	1550 nm
		Length	10 km
		Attenuation	0.5 dB/km
		Dispersion slope	-0.3 ps/nm^2/k
		Differential group delay	0.2 ps/km
Receiver	WDM Demux	Bandwidth	10 GHz
		Number of output port	8
		Depth	100 dB
	Photodetector or PIN	Responsivity	1 A/W
		Dark current	10 nA
	Low Pass Bessel Filter	Cutoff frequency	8*10^9 Hz

The following diagram shows the overall system design which contains all the components and links of WDM spectrum slicing system. Figure 3 shows the overall system structure and figure 4 and figure 5 shows the modulations and line amplification subsystem.

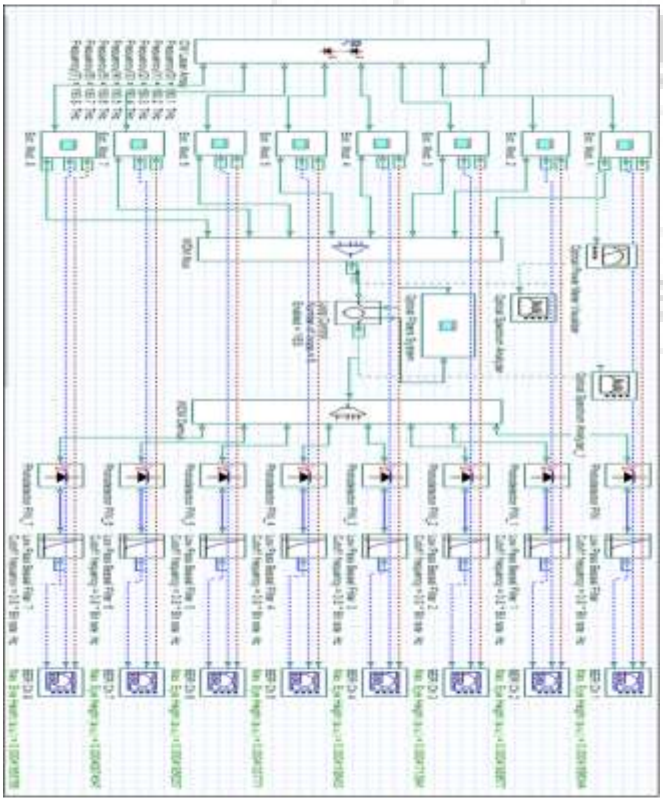


Figure 3: Overall system structure

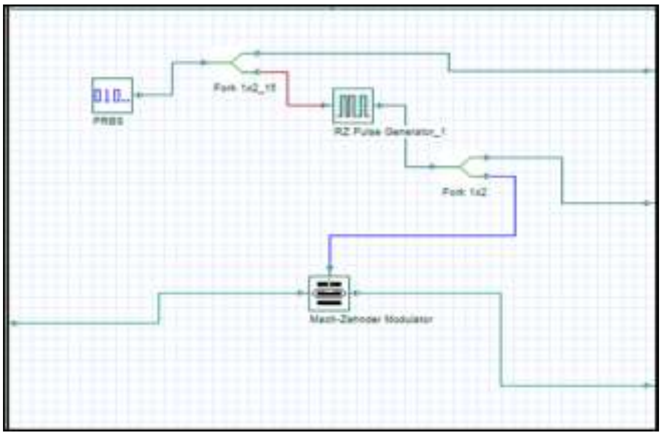


Figure 4: External modulation

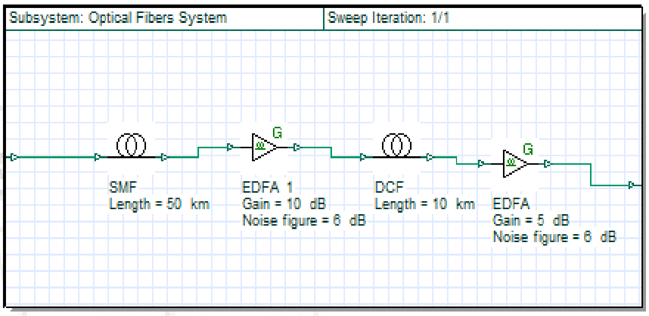


Figure 5: Optical Fibers System

3.3 Simulation Setup

Compactly, the simulation setup contains transmitter, fiber and receiver. The WDM transmitter encompasses a CW laser source, signal modulators and optical demultiplexer. The transmission channel is designed by using single mode fiber (SMF) and a fiber parameter of dispersion compensating fiber in order to compensate the dispersion by dispersion compensating fiber (DCF).The effective area of the SMF is assumed to be 70 μm^2. Before the signal is transmitted through the optical fiber, the process of transforming digital data stream in to sequence of light pulses is known as modulation is applied. The signal is generated by the big sequence generator. The signal coming from the bit sequence generator is then passed to either the NRZ generator or NRZ generator. Additionally, a chain of EDFAs causes reduction in the usable gain bandwidth due to self-filtering effect. In the receiver side, a de-multiplexer separates the wavelengths on the light with a bandwidth of twice the bit rate for both RZ and NRZ and passes to the PIN detector. The PIN detector is connected directly to the de-multiplexer channels in order to detect and shape the incoming signal waveform. The signal is passed through a Gaussian low pass filter in order to remove the unwanted noise levels below the desired frequency and to get the proper waveform for analyzing. Finally, spectrum analyzer is installed on each channel to detect the signal properties mainly the BER, the Q-factor and the other parameters of performance. This analyzer visualizes and generates graphs to let measurements taken on eye diagram, Q factor and eye opening (An eye diagram is a common indicator of the quality of signals in high-speed digital transmissions).

4. Results and Discussion

There are many of parameters which effect on the signal detected at the receiver and how the transmission is done. Firstly, the following diagram in Figure 6, a and b, shows optical spectrum analyzer output using eight channels received signal before going through the single mode fiber. It is clearly shown that noise ratio in NRZ is lower than in RZ.

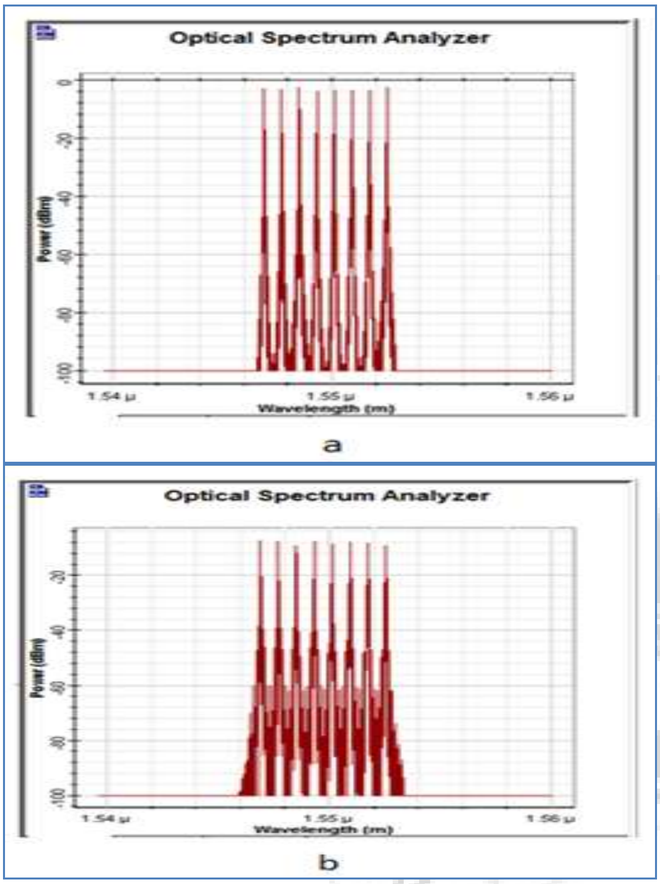
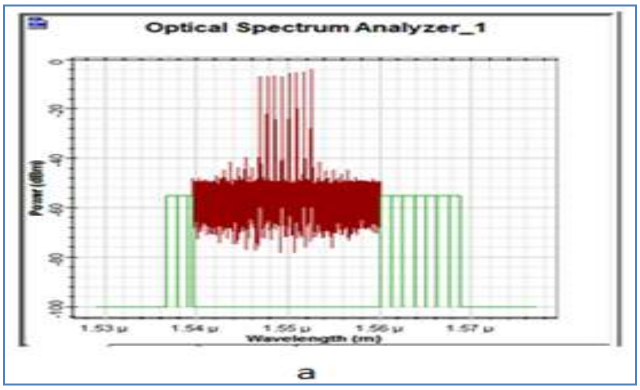


Figure 6: Optical spectrum analyzer of the channel before SMF, (a) NRZ, (b) RZ

The diagram shown in Figure 7, a and b, shows the optical spectrum analyzer illustrating the eight channels being received after goings through the single mode fiber. Here also can be noticed that noise ratio in NRZ is lower than in RZ.



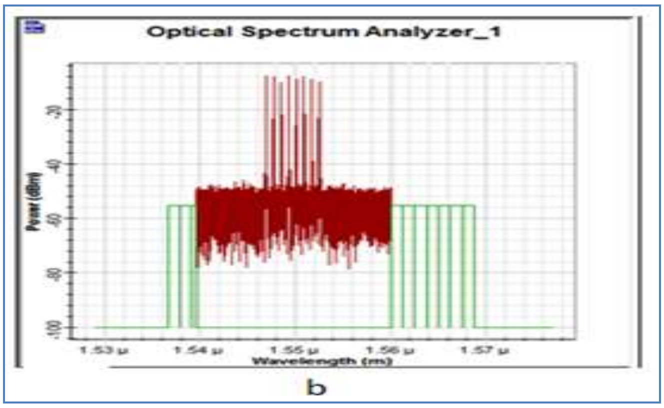


Figure 7: Optical spectrum analyzer of the channel after SMF, (a) NRZ, (b) RZ.

In this paper, the BER of the received signals are studied and the comparison is based on it. Accordingly, we measured BER and Max Q factor at different bit rates, such as 8 Gb/s, 10 and 15 Gb/s using both RZ and NRZ modulation format, which are as shown in Figures 8, and 9. It is also noticeable that the proposed system under NRZ modulation format requires a bit more power as compared to RZ modulation format. However, the received signal quality under NRZ modulation format is better than that of RZ modulation format, which is ascertained by eye diagrams and RF spectrum signal of both RZ and NRZ modulation format.

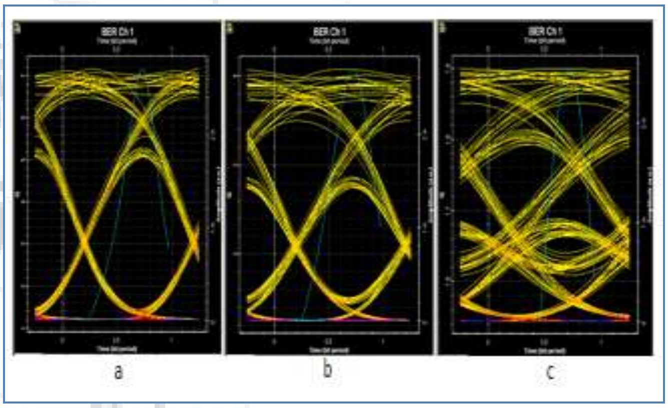


Figure 8: Eye diagrams for RZ at Data rate (a) 8 Gbps, (b) 10 Gbps, and (c) 15 Gbps at distance 60km, and power 4 dBm.

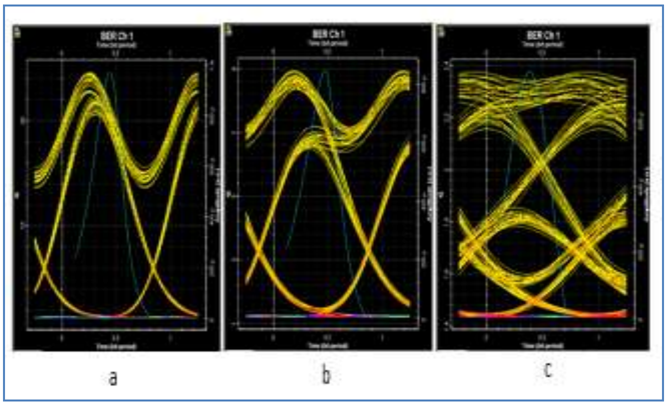


Figure 9: Eye diagrams for NRZ at Data rate (a) 8 Gbps, (b) 10 Gbps, and (c) 15 Gbps at distance 60km, and power 4 dBm.

Also we measured BER and Max: Q factor at different input power, such as -10 dB, 0 and 10 dB using both RZ and NRZ modulation format, which are as shown in Figures 10 and 11.

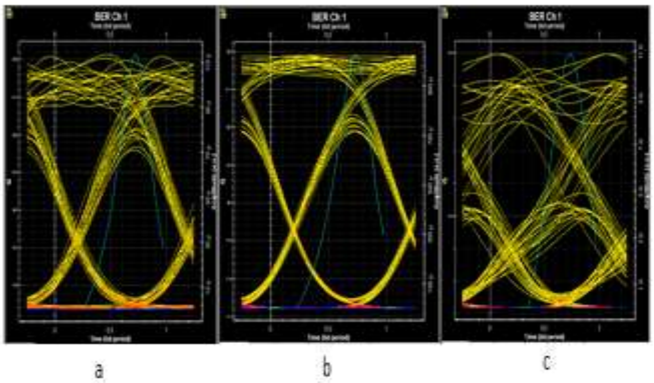


Figure 10: Eye diagrams for NRZ at input power (a) -10 dB, (b) 0 dB, and (c 10 dB at distance 60km, and Data rate 8Gbps

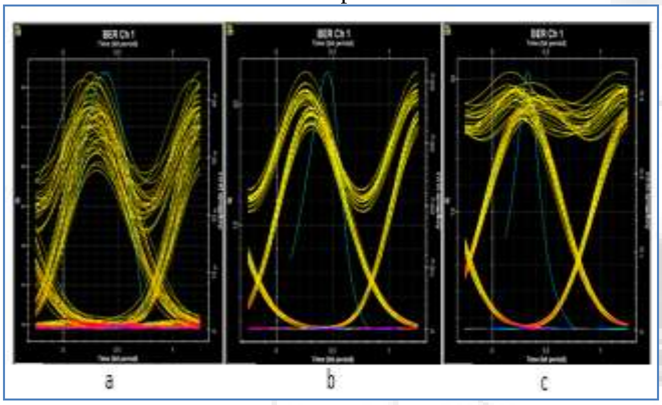


Figure 11: Eye diagrams for RZ at input power (a) -10 dB, (b) 0 dB, and (c 10 dB at distance 60km, and Data rate 8Gbps.

The simulation results are in the form of line graphs. The performance of SS-WDM, based on the varying the type of modulation format (NRZ and RZ), is done on parameters like BER, Q factor and throughput, this shown in appendix.

Figure 12 highlights the BER performance metric of SS-WDM on modulation format NRZ & RZ with different data rate 8Gbps, 10Gbps, 15Gbps.

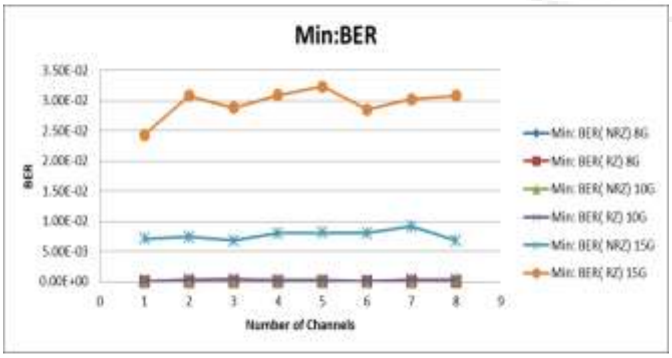


Figure 12: Non Return Zero versus Return Zero for Min: BER at different data rate 8Gbps, 10Gbps, 15Gbps.

From Figure 12; it is observed that RZ have Min: BER greater percentage of the error data (98%- 100%) than NRZ (70% - 98). Also it is observed that the BER of both modulation formats, NRZ and RZ, becomes greater with increasing the data rates.

Figure 13 highlights the Q factor performance metric of SS-WDM on modulation format NRZ & RZ with different data rate 8Gbps, 10Gbps, 15Gbps.

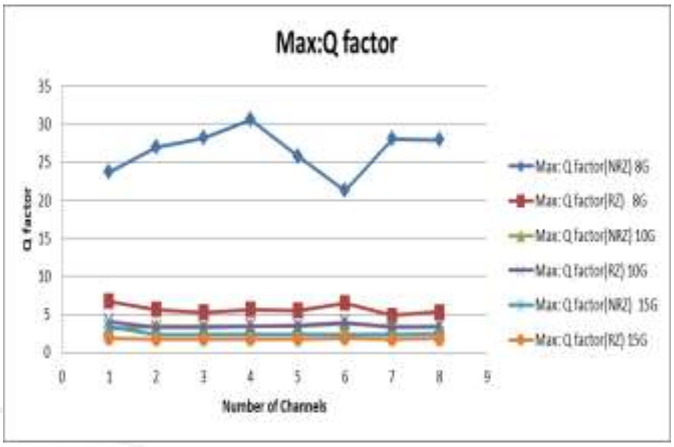


Figure 13: Non Return Zero versus Return Zero for Max: Q factor at different data rate 8Gbps, 10Gbps, 15Gbps

From figure 13, it is observed that RZ have Q factor lesser value (0.24 – 0.7) than NRZ (0.22 – 0.37). Also it is observed that the Q factor of both modulation formats, NRZ and RZ, becomes lesser with increasing the data rates.

Figure 14, highlights the Threshold performance metric of SS-WDM on modulation format NRZ & RZ with different of input power -10 dB, 0 dB, 10 dB.

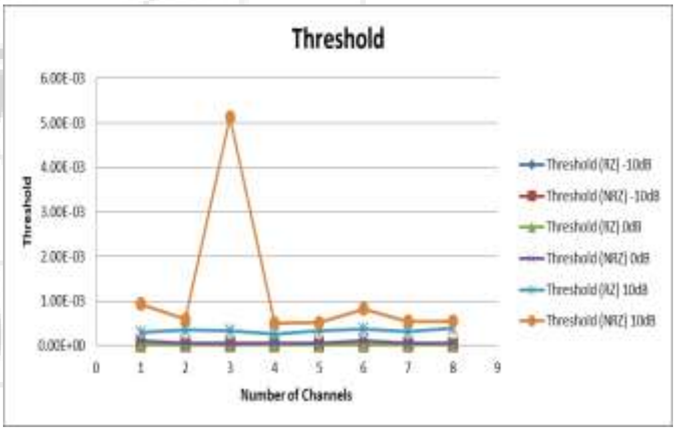


Figure 14: Non Return Zero versus Return Zero for BER at different of input power -10 dB, 0 dB, 10 dB.

From figure 14, it is observed that RZ have threshold greater value (0.24 – 0.7) than NRZ (0.22 – 0.37). Also it is observed that the threshold of both modulation formats, NRZ and RZ, becomes greater with increasing input power.

5. Conclusions

This paper discusses the impact of the spectrum slicing technique in WDM system and evaluates the performance of different formats of modulations in WDM used in the optical networks. SS-WDM method optimizes the performance and cost issues of the system. Optisystem14 software was used to design, implement and simulate the passive optical system of *WDM*. In the simulation, the WDM spectrum sliced technique which is running instantaneously eight different channels of 0.5 nm spectral widths is successfully built. The simulated results show that various parameters have been studied considering their effect in the overall system performance and the received signal clarity. The system performance analysis is carried out by using spectrum analyzer considering the BER as the main performance parameter, Q factor and threshold.

References

[1] Virach Wongpaibool,"Effect of Dispersion on Spectrum-Sliced WDM Systems", Faculty of the Virginia Polytechnic Institute and State University, Electrical Engineering, September 1998, Blacksburg, Virginia.
[2] Vjaceslavs Bobrovs, Sandis Spolitis, Ilja Trifonovs, Girts Ivanovs, "Spectrum Sliced WDM-PON System as Energy Efficient Solution for Optical Access Systems", Institute of Telecommunications, Riga Technical University, Riga, Latvia, 978-1-4799-1148-6/13/$31.00 ©2013 IEEE.
[3] Nimrat Kaur, Malti Sarangal," Effects of using RZ and NRZ modulation formats for TDM-PON system on Transmission Characteristics for Downstream Signals", Sai institute of Engg. & Tech, Amritsar, Punjab, India, International Journal of Computer Applications Technology and Research Volume 2– Issue 6, 645 - 649, 2013, ISSN: 2319–8656.
[4] Renu S1. Sujith Kumar V2, 1PG Scholar 2Asst. Professor, "Development of SS-WDM and High Speed SS-WDM", 1Opto Electronics and Communication Systems1, 2Dept. of Electronics and Communication Engg1, 2TKM Institute of Technology, Kollam, Kerala, India, IJSRD - International Journal for Scientific Research & Development Vol. 2, Issue 01, 2014 | ISSN (online): 2321-0613.
[5] Anoma D. McCoy, Peter Horak, Benn C. Thomsen, Morten Ibsen, M. R. Mokhtar, and D. J. Richardson, "Improving Signal Quality in a Spectrum-Sliced WDM System Using SOA-Based Noise Reduction", IEEE Photonics Technology Letters, vol. 17, no. 1, January 2005.
[6] Sandis Spolitis, Vjaceslavs Bobrovs, Girts Ivanovs," New Generation Energy Efficient WDM-PON System Using Spectrum Slicing Technology", Institute of Telecommunications , Riga Technical University, Riga, Latvia, 978-1-4673-2015-3/12/$31.00 ©2012 IEEE.
[7] Soo-Jin Park, Chang-Hee Lee, Ki-Tae Jeong, Hyung-Jin Park, Jeong-Gyun Ahn, and Kil-Ho Song, "Fiber-to-the-Home Services Based on Wavelength-Division-Multiplexing Passive Optical Network", Members,IEEE, Members, OSA, JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 22, NO. 11, NOVEMBER 2004, 0733-8724/04$20.00 © 2004 IEEE.
[8] J. S. Lee, Y. C. Chung, Member, IEEE, and D. J. DiGiovanni, "Spectrum-Sliced Fiber Amplifier Light Source for Multichannel WDM Applications", IEEE Photonics Technology Letters, vol. 5. no. 12, December1993.
[9] Ahmed Mohamed Awl, "Wavelength Division Multiplexing Spectrum Slicing Techniques Performance Comparison", Faculty of Electrical EngineeringUniversiti Teknologi Malaysia, JUNE 2014.

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