Comparative Analysis of OFDM Technique with RZ, NRZ and Duobinary Modulation Formats in 10 Gb/s Single Channel WDM System

[*]Monika Nehra
[*]Ph.D Scholar
[*]Department of Electronics and Communication Engineering,
[*]Guru Jambheshwar University of Science & Technology, Hisar-125001 (Haryana), India

***Abstract* - The focus of this paper is to evaluate the performance of different modulation formats like OFDM, RZ, NRZ and duobinary in 10 Gb/s single channel WDM system. A comparative performance analysis in terms of BER and Q factor is carried out for all these modulation formats. Further, the optical spectra corresponding to all these modulation formats is also analyzed.**

***Index Terms* - Not Return to Zero (NRZ), Orthogonal Frequency Division Multiplexing (OFDM), Passive Optical Networks (PONs), Return to Zero (RZ), Wavelength Division Multiplexing (WDM).**

I. INTRODUCTION

The recent advancements in both wired and wireless technologies needs low cost, flexible and promising solution to satisfy exponentially increasing high data rates. The various computing applications like HDTV, cloud computing, peer-to-peer file sharing, broadband mobile networks and video on demand etc. need good quality of services and also demand a significant increase in bandwidth [1]. The wavelength division multiplexing-passive optical networks (WDM-PONs) are getting more attention at high data rates due to mature optical technologies. WDM-PONs also ensure network security and have significant flexibility [2]. However, there are several issues that may hinder the system performance like fiber nonlinearity, chromatic dispersion etc. To improve the system performance, several modulation formats have been developed such as Return to Zero (RZ), Not Return to Zero (NRZ), Duobinary and optical OFDM etc. to support the use of lower bandwidth optical and electrical components at higher data rates also [3].

NRZ and RZ modulation formats are the most common formats for optical transmission systems and also known as on-off-keying (OOK) intensity modulation formats. The NRZ modulation format offers narrow optical spectrum in comparison to RZ format and has been used extensively in many data communication applications mainly because of its relative ease of generation whereas duobinary format performs better than both RZ and NRZ modulation formats [4]. It operates at full NRZ data rate and also introduces controllable intersymbol interference (ISI) to reduce the signal bandwidth [5]. Recently, orthogonal frequency division multiplexing (OFDM) has been introduced in optical communication [6]. OFDM offers an effective solution to ISI, resulting from a dispersive channel. The concept of OFDM is quite simple that involves the transmission of data in parallel over several orthogonal subcarriers. A guard interval is also inserted at the end of symbol to ensure that all interference occurs during this period and OFDM symbol remains unaffected.

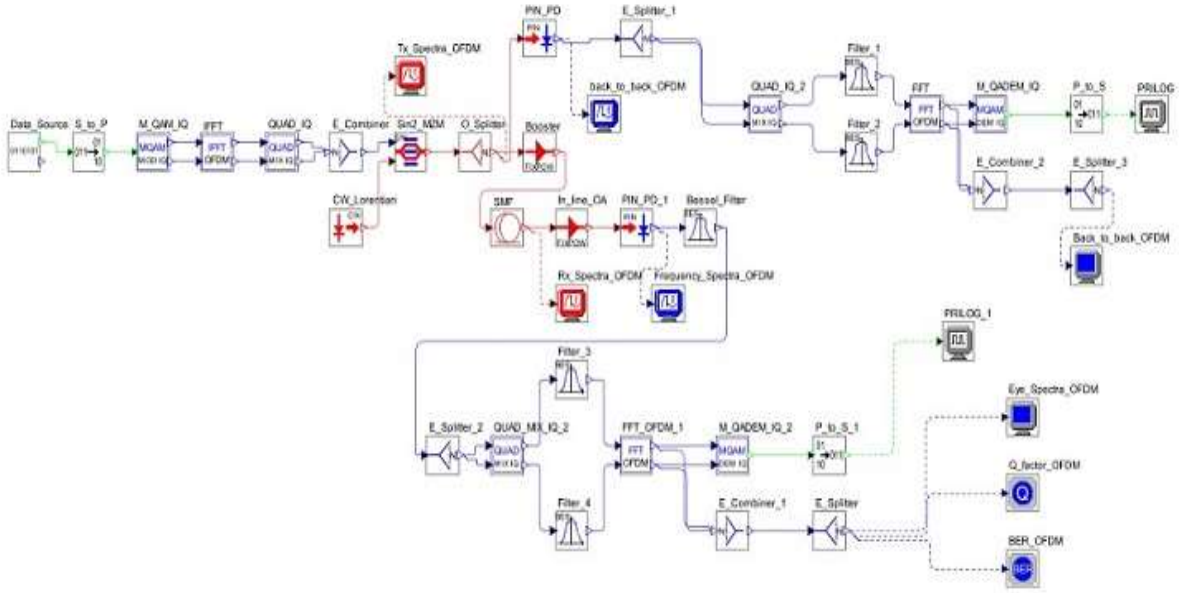
Recent research in WDM-PONs focus on advanced modulation formats to support the use of lower bandwidth optical and electrical components at higher data rates. Wei et. al. [7] reviewed the possible architectures for 400 Gb/s Ethernet links based on advanced modulation formats like duobinary, PAM, hybrid CAP/QAM and optical OFDM etc. and a comparative analysis of their optical link power budget, power dissipation etc. is also carried out via simulations. Winzer [8] reviewed the spectrally efficient optical modulation formats for use in digital coherent systems and also highlighted the important trade-offs pertaining to the design and performance of coherent higher-order QAM transponders. In this paper, performance of different modulation formats in 10 Gb/s single channel WDM system is carried out via OptSim simulation.

II. WDM SYSTEM USING DIFFERENT MODULATION FORMATS

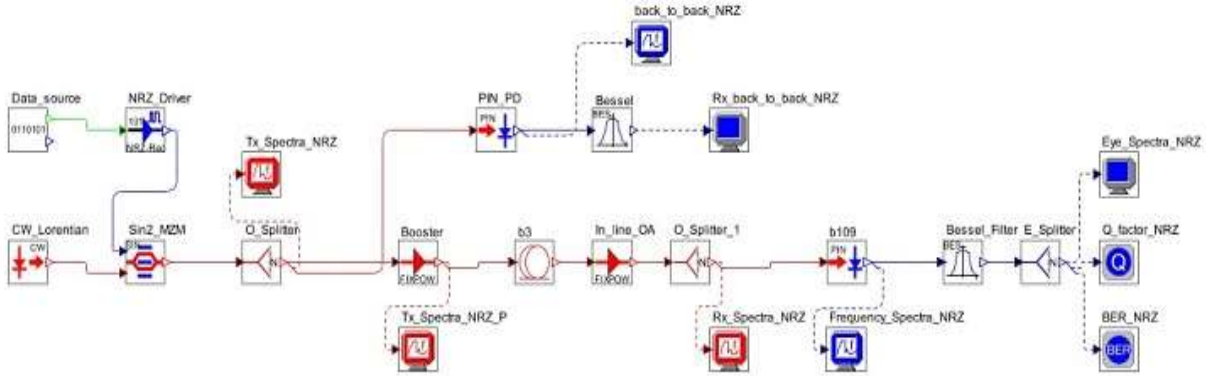
Figure 1(a), 1(b), 1(c) and 1(d) show the simulation set up of single channel WDM system using OFDM, NRZ, RZ and duobinary modulation formats, respectively. A modulation format is needed to impress data on an optical carrier signal for transmission over fiber. The data bits are formatted by different modulation formats.

In case of OFDM technique, the OFDM signal is generated by mapping of data bits using QAM constellations, inverse fast fourier transform (IFFT), cyclic prefix (CP) insertion, serialization and then digital-to-analog (DAC) conversion. In case of duobinary modulation format, a dual-drive mach-zehnder modulator (MZM) is derived by data and inverted data at full NRZ data rate. NRZ and RZ drivers directly format the input data and drive MZM. The optically modulated signal is then transmitted over single mode fiber.

At receiver, the direct-detection technique is employed to recover the original data. In case of OFDM signal, the output of photodetector drives OFDM receiver, involving removal of CP, fast fouier transform (FFT), QAM demodulation and serialization of data bits.



(a)



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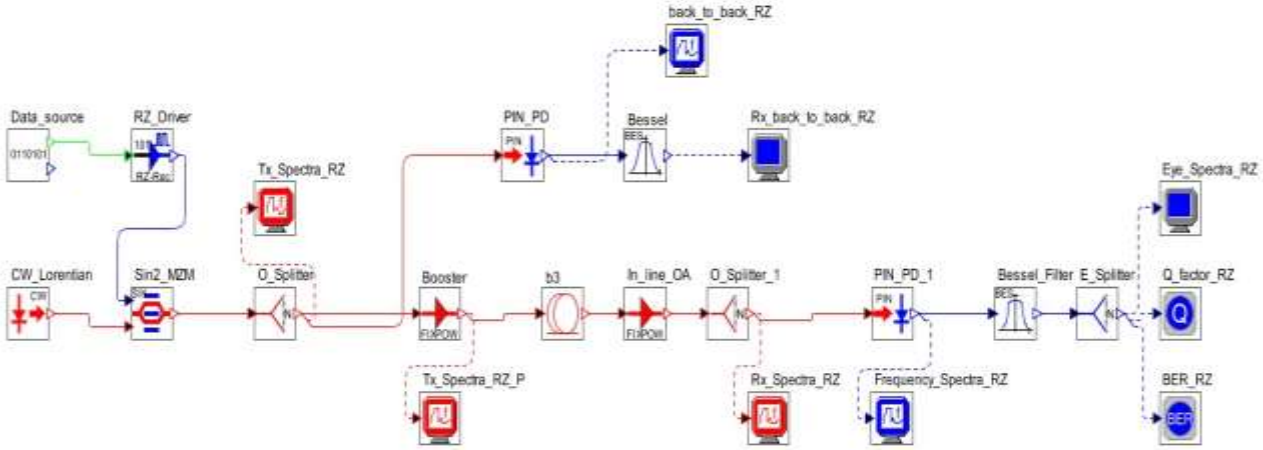
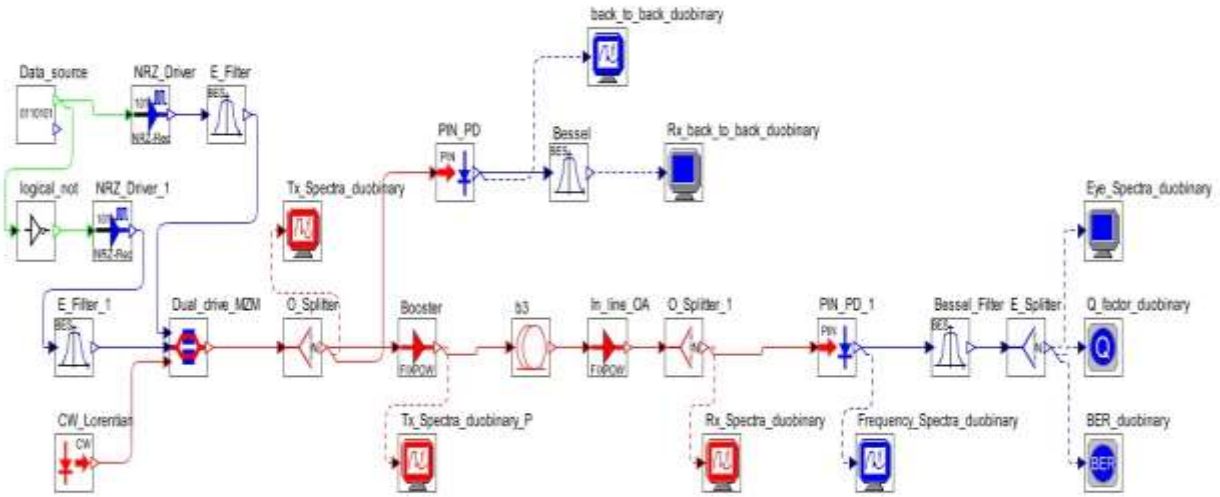


(c)



(d)

Figure 1: Single Channel WDM System using (a) OFDM, (b) NRZ, (c) RZ and (d) Duobinary Modulation Format.

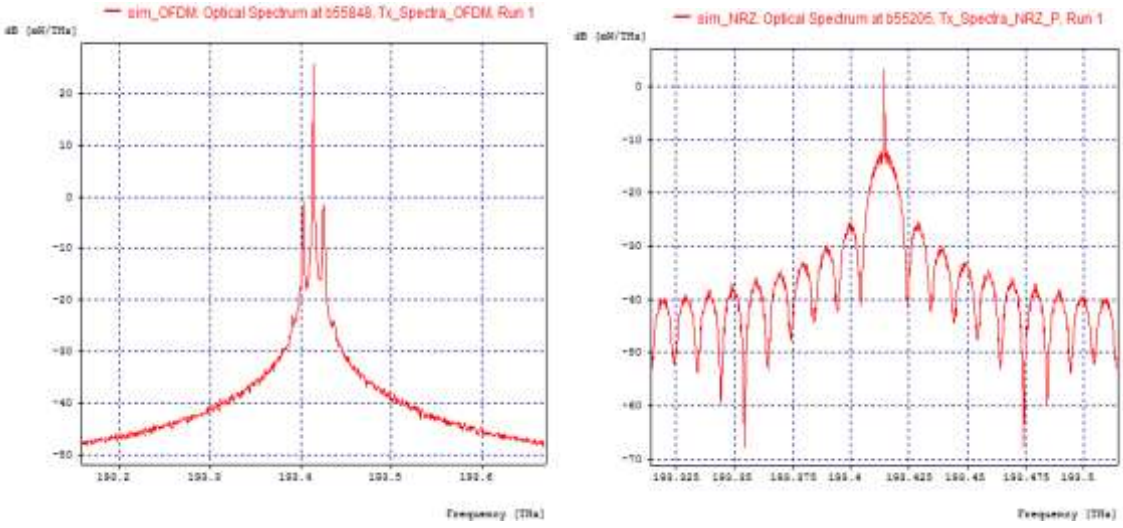
III. Simulative Analysis

The simulation of 10 Gb/s single WDM system as shown in figure 1, was carried out over 50 km SMF and the detailed performance analysis is presented in subsequent figures. The different parameters of the system are listed in table 1. Figure 2 shows the transmitted optical spectra over 50 km SMF for different modulation formats.

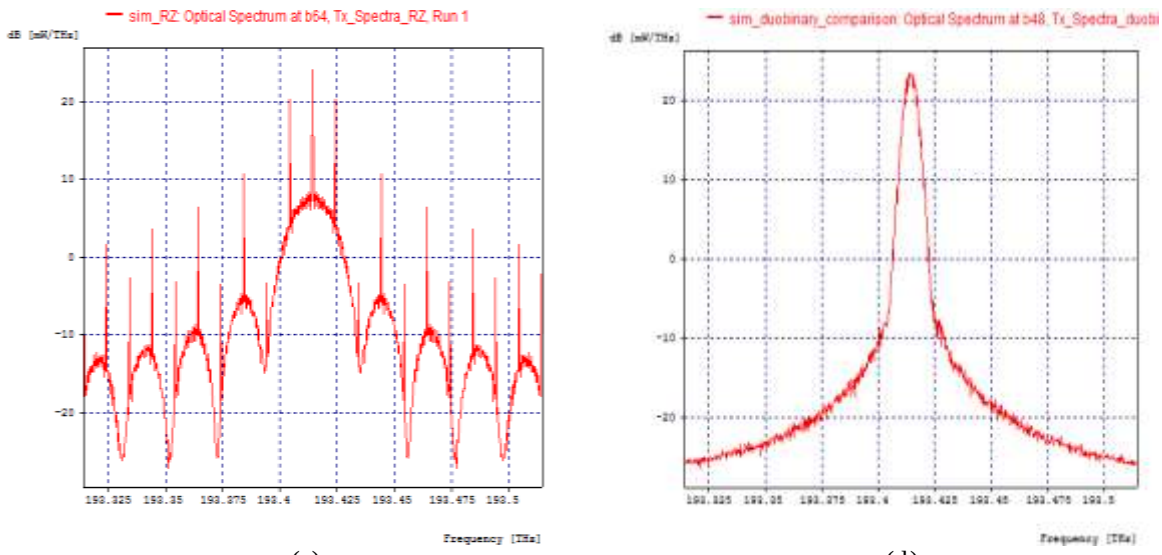
Table 1 Different Parameters of WDM System

Parameter	**Value**
Data Rate	10 Gb/s
Fiber Length	50 km
OFDM subcarriers	64
CP	0.25
Laser Linewidth	10 MHz
CW Laser Power	0 dBm
Operating Wavelength	1550 nm
Dispersion at Reference Frequency	-20 ps^2/Km
Attenuation	0.2 dB/km
Reference Frequency for Losses	193.41449 THz

As it is clear from Fig. 2 that OFDM modulation format results to more confined optical spectra than other modulation formats. Also, an eye spectra in case of all these modulation formats is shown in Fig. 3 for back-to-back transmission.

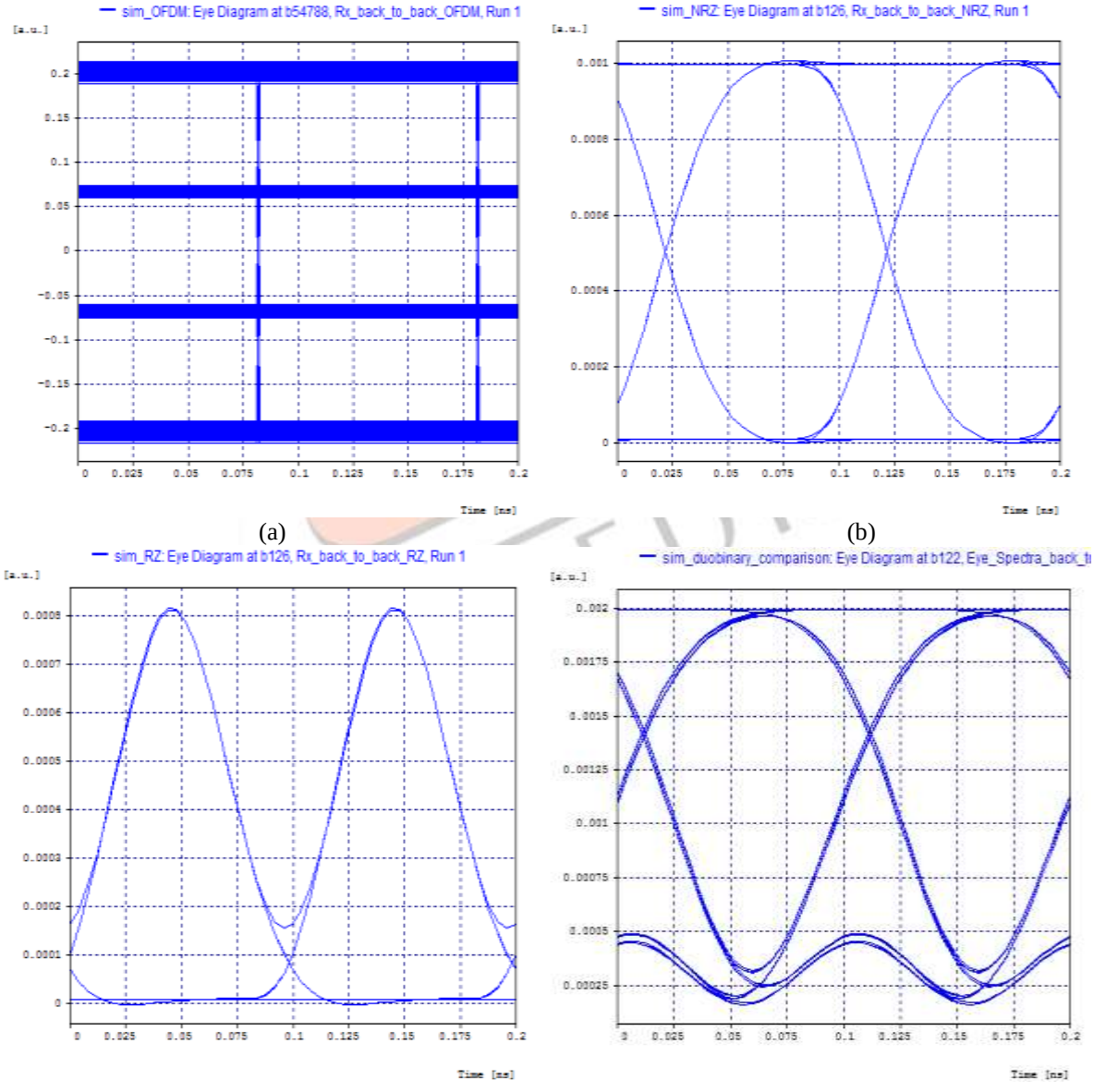


(a) (b)



(c) (d)

Figure 2: Launch Spectra into Fiber in case of (a) OFDM (b) NRZ (c) RZ and (d) Duobinary Modulation Format.

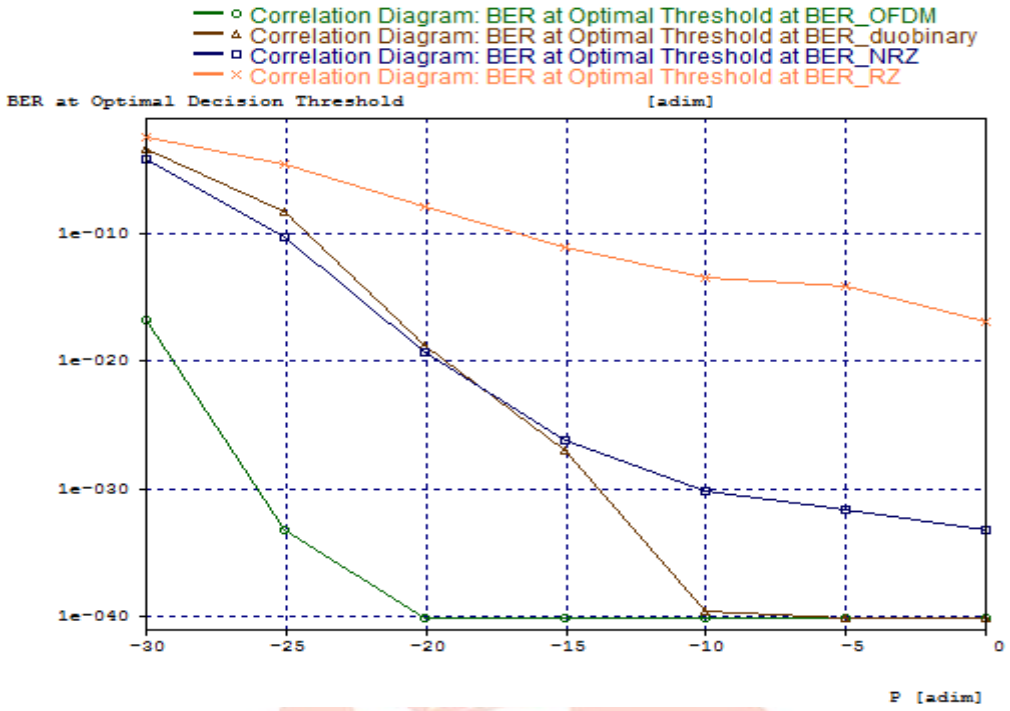


(a) (b)

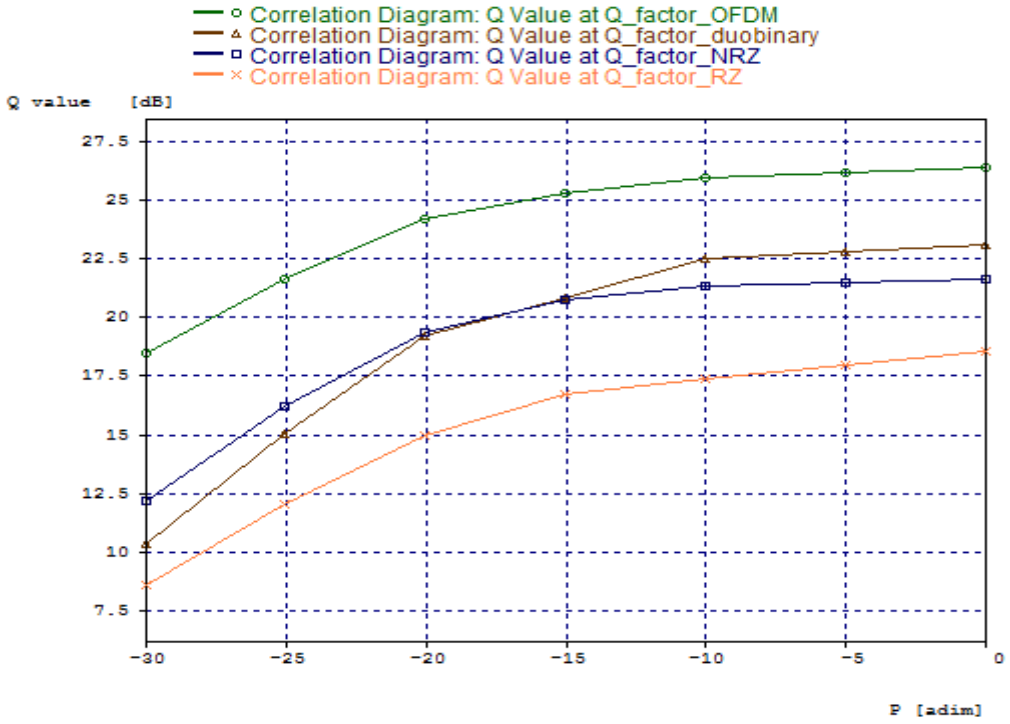
(c) (d)

Figure 3: Eye Spectra in case of (a) OFDM (b) NRZ (c) RZ and (d) Duobinary Modulation Format.

Further, a comparative performance analysis in terms of bit error rate (BER) and Q factor is also carried out for all these modulation formats, as shown in Fig. 4. As launched power (dBm) into fiber is increased from -30 dBm to 0 dBm, BER is decreased from 1.83×10^{-17} to 1×10^{-40} in case of OFDM modulation format. In case of NRZ modulation format, it is decreased from 7.78×10^{-5} to 7.47×10^{-34}. In case of RZ modulation format, it is decreased from 3.51×10^{-17} and it is decreased from 5.46×10^{-4} to 1×10^{-40} in case of duobinary modulation format. Thus, from Fig. 4(a), it is clear that OFDM format offers better performance in terms of BER than other modulation formats.



(a)



(b)

Figure 4: Performance Analysis of 10 Gb/s Single Channel WDM System (a) BER wrt Launch Power (dBm) and (b) Q factor wrt Launch Power (dBm).

Similarly, for same launched power, Q factor is increased from 18.49 dB to 26.48 dB in case of OFDM modulation format. In case of NRZ modulation format, it is increased from 12.22 dB to 21.67 dB. In case of RZ modulation format, it is increased from 8.64 dB to 18.59 dB and from 10.36 dB to 23.16 dB in case of duobinary modulation format.

Thus, it is clear that OFDM modulation format supports better performance in WDM system among all other modulation formats.

IV. CONCLUSION

In this paper, the performance of 10 Gb/s single channel WDM system is analysed for different modulation formats including OFDM, NRZ, RZ and duobinary. Among all these modulation formats, OFDM technique offers high spectral efficiency and also support better performance in terms of BER and Q factor. Thus, OFDM technique holds a great potential for next-generation high speed optical access networks.

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