Effect on Q Factor of Fixed Bit Pattern and Encoding Techniques in Intensity Modulated Optical Networks

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ABSTRACT

In this paper, Investigation of Q-Factor & Eye diagram in different transmitter and receiver module are shown. For this, 10Gbps optical communication system with fixed bit pattern of 16 bit sequence for iterations are used. For the analysis purpose return to zero (RZ) and non return to zero (NRZ) coding are taken. Here Q-Factor is improved by changing encoding techniques at two different wavelengths of 1310nm & 1550nm.

General Terms

Quality-factor, Eye diagram, Modulation Techniques, Encoding Techniques

Keywords

Quality factor, Eye diagram, NRZ, RZ, MZM, EAM, PIN, APD.

1. INTRODUCTION

Predicting the performance of the fiber optic communication systems through numerical simulations has become an increasingly important way to complement expensive system experiments and to explore large variations in system designs that are difficult to study experimentally. Numerical modelling of the systems allows isolating specific nonlinear interactions or effect of one specific device in a system [1]-[2]. Measuring the quality of optical signal is most important task in optical communication system. There are variety of metrics are available namely the general shape of the eye diagram, optical signal to noise power ratio, Q-factor and bit error rate (BER) [3]. Quality of optical system is depends upon several factors which is classified as linear and non linear or System design based and Temporal. In temporal parameters are jitter, spectral density fluctuations and polarization state fluctuations are taken while the system based are bit sequence, input power, encoding, channel length, modulator, wavelength, type of receiver and type of filter are considered. In reference [4] Stamatios V. Kartalopoulos presented a comprehensive view of parameters that affects the optical signal integrity. S. M. Jahangir Alam, M. Rabiul Alam shows the bit error rate optimizations [5]. Hayee & Wilner found that the NRZ is more adversely affected by the nonlinearity and dispersion than RZ [6]. Also research work in this direction is carried out by Link 3, an ISP of Bangladesh. In this paper the performance of the system is measured in terms of Q factor & eye diagram by varying the system components. The network layout is designed and simulated with help of Optisystem 7 software. This paper is divided in 4 sections: Section 2 shows the Q factor, Section 3 describes the system description including system parameters and also includes the result obtained and discussion and finally Section 4 conclude this paper.

2. Q-FACTOR

Q-factor is a parameter that directly shows the quality of the optical communication system. It indicates that how good the quality of the system, good here means low loss. The high the value of Q, better the quality of the system. System performance is estimated in terms of Bit Error Rate. Bit Error Rate is not counted directly but measured by the evaluation of statistical fluctuations. These fluctuations are characterized by Q-factor. Q factor is defined as

$$Q = \frac{|\mu_1 - \mu_0|}{\sigma_1 + \sigma_0}$$

where $|\mu_1 - \mu_0|$ denotes the separation between the intensity levels of “1” and “0”, and $\sigma_1+\sigma_0$ is the sum of the standard deviations of the intensities around the levels of “1” and “0”.

Based on the Gaussian approximation for the noise distribution in the received signal, one can derive the relation between BER and *Q*, i.e.

$$BER = \frac{1}{2} erfc\left(Q/\sqrt{2}\right) \approx \frac{1}{\sqrt{2\pi}} \frac{1}{Q}\, e^{-\frac{Q^2}{2}}$$

Figure 1 shows the relation between BER versus Q Factor. This graph shows that as the bit error rate increases the quality of signal decreases [7]-[8].

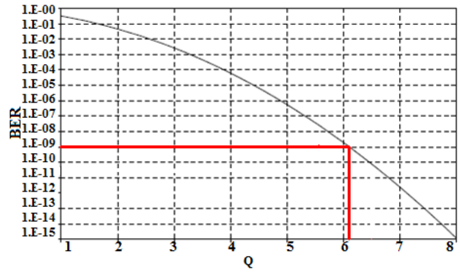


Fig 1: Relationship between BER versus Q Factor [8]

3. SYSTEM DESCRIPTION, RESULTS AND DISCUSSION

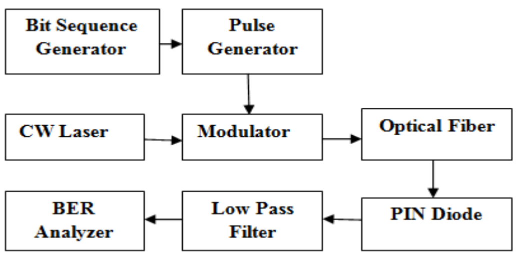


Fig 2: Simulation Setup

In present optical transmission system, communication traffic is conveyed by optical carriers whose intensity is modulated by the communication traffic i.e. the optical carrier is amplitude modulated. Generally the communication traffic is used to modulate the optical carrier. Optical carrier will have a NRZ or RZ format [9]. There are two technique for modulation i.e. direct and external modulation format. In direct modulation technique, input signal varies directly with the bias of LASER diode. External modulator is either integrated with mach-zehnder interferometer or electro absorption modulator. External modulator scheme is preferred because it avoids nonlinearities and excessive chirp [10], [11]. At the receiver section, two different types of photo diodes are used.

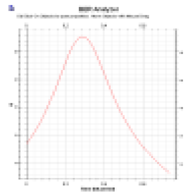
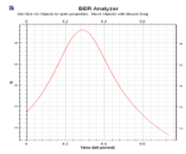
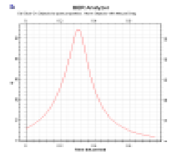
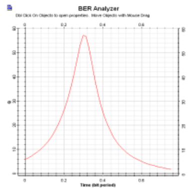
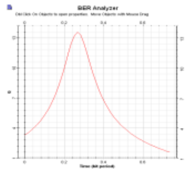
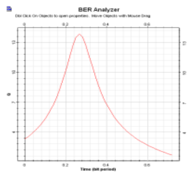
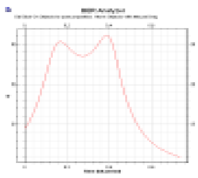
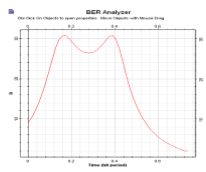
For analyzing the effect of Q-factor the schematic experimental setup is shown in figure 2. In this, data transmitter comprises of continuous wave laser operated at 193.1THz frequency and power of light is 10 dB. The pulse train is intensity modulated with user defined bit sequence generator which uses 16 bit pattern and bit rate of 10Gbps. This 10Gbps signal is encoded by pulse generator and then combine at modulator and modulated signal is then transmitted over 50km single mode fiber. The overall link is operated at two wavelengths i.e. 1310 & 1550nm. At the receiver, electrical signal is detected by photodiode whose responsitivity [A/W] is 1 and after that passed through low pass Bessel filter with cut off frequency 75*Bit rate. Finally the signal is applied to BER analyzer which is used as a visualiser to generate graphs for Q-factor and Eye Diagram [12].

In figure 2, Mach-Zehnder & Electro-Absorbtion Modulator at 1310nm & 1550 nm wavelengths with PIN & APD photodiodes are used for observing the effect of input bit combination 1010101010101010 at 10 dB input laser power on RZ & NRZ encoding techniques,. The results of simulations are shown in Table 1 and their corresponding Quality and Eye diagrams are shown in Table 2 & 3 .

Table 1. Numerical values of Quality factor

Signal Generator-Modulator-Wavelength(nm)-Receiver				Q-Factor
RZ	MZM	1310	PIN	6.54161
RZ	MZM	1310	APD	6.63914
RZ	MZM	1550	PIN	54.4153
RZ	MZM	1550	APD	57.1576
RZ	EAM	1310	PIN	13.5817
RZ	EAM	1310	APD	14.7381
RZ	EAM	1550	PIN	32.2934
RZ	EAM	1550	APD	33.6387
NRZ	MZM	1310	PIN	36.9569
NRZ	MZM	1310	APD	40.086
NRZ	MZM	1550	PIN	28.4404
NRZ	MZM	1550	APD	29.561
NRZ	EAM	1310	PIN	32.0048
NRZ	EAM	1310	APD	35.9882
NRZ	EAM	1550	PIN	29.4464
NRZ	EAM	1550	APD	30.6186

Table 2. Graphs of Quality factor

Signal Generator-Modulator- Wave-length (nm)- Receiver	Q Factor
MZM- RZ-1310- PIN	
RZ- MZM-1310- APD	
RZ-MZM-1550-PIN	
RZ-MZM-1550-APD	
RZ-EAM-1310-PIN	
RZ-EAM-1310-APD	
RZ-EAM-1550-PIN	
RZ-EAM-1550-APD	

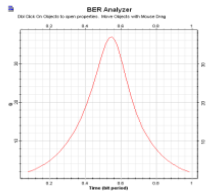
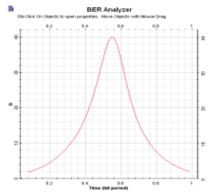
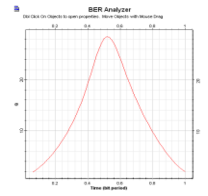
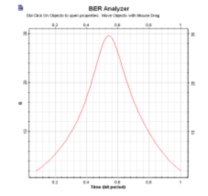
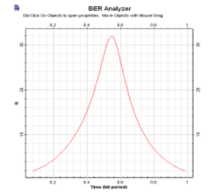
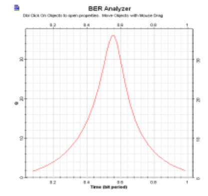
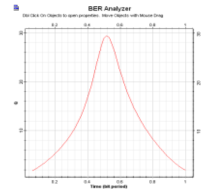
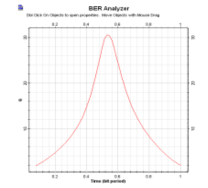
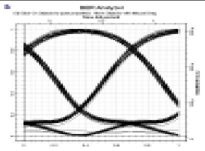
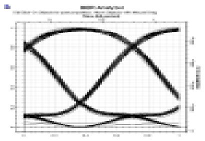
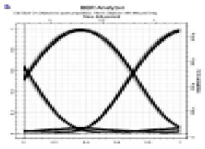
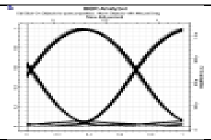
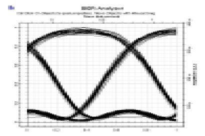
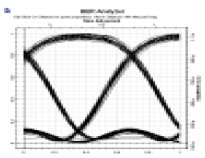
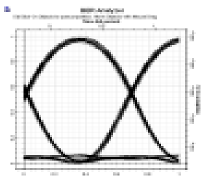
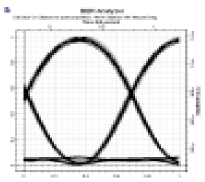
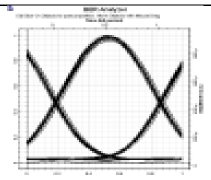
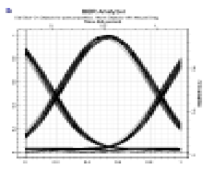
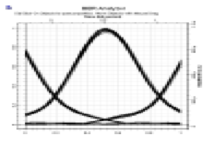
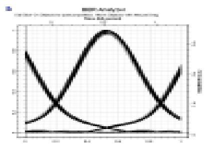
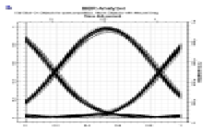
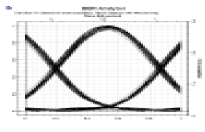
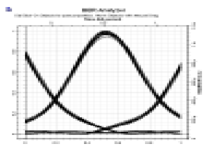
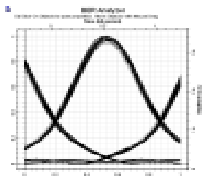
NRZ-MZM-1310-PIN	
NRZ-MZM-1310-APD	
NRZ-MZM-1550-PIN	
NRZ-MZM-1550-APD	
NRZ-EAM-1310-PIN	
NRZ-EAM-1310-APD	
NRZ-EAM-1550-PIN	
NRZ-EAM-1550-APD	

Table 3. Eye-Diagrams

Signal Generator-Modulator-Wavelength (nm)-Receiver	Eye Diagram
RZ-MZM-1310-PIN	
RZ-MZM-1310-APD	
RZ-MZM-1550-PIN	
RZ-MZM-1550-APD	
RZ-EAM-1310-PIN	
RZ-EAM-1310-APD	
RZ-EAM-1550-PIN	
RZ-EAM-1550-APD	
NRZ-MZM-1310-PIN	

NRZ-MZM-1310-APD	
NRZ-MZM-1550-PIN	
NRZ-MZM-1550-APD	
NRZ-EAM-1310-PIN	
NRZ-EAM-1310-APD	
NRZ-EAM-1550-PIN	
NRZ-EAM-1550-APD	

From the above tables it is observed that there are different values of Q-factor for different encoding and modulation schemes. It is found that at 1310 nm wavelength NRZ encoding technique and at 1550 nm wavelength RZ encoding technique provides better system performance. In both cases Mach-Zehnder Modulator amends the performance than Electro-Absorption Modulator because Mach-Zehnder have large electro-optic bandwidth, low insertion loss, zero chirp and less prone to dispersion. In all cases APD provide better system performance since APD have intrinsic ability to amplify the signal, have better sensitivity and higher gain. The overall improved system is designed by RZ encoding at 1550nm as RZ encoding is more robust to nonlinear effect and less susceptible to inter symbol interference.

4. CONCLUSION

Numerical simulation shows that at 1310nm wavelength NRZ encoding technique provide better system performance while at 1550 nm RZ encoding amends the system performance. In comparison to PIN photodiode, APD provide better system performance. In this paper the effect of encoding technique and wavelength on Q-factor with 16 bit sequence is tested. The maximum Q factor [57.1576] is obtained by RZ encoding with Mach-Zehnder modulator at 1550nm using APD photodiode. This work can be extended with 32 bit sequences and there are a lot of parameters which have effect on Q-factor can be taken. More Simulation can be conducted in future taking more parameters in consideration and this may provide more effective results.

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