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Development of BER Tool

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Abstract: This rsearch work presents an educational software interface tool for analyzing and estimating the bit error rate (BER) of an optical communication system. Currently BER estimation tool required expensive measurement equipment such as serial data analyzer (SDA) and BER Tester. In addition to cost all this equipment is also limited to BER estimation based on standard format and is not suitable for custom analysis because of time constraint to use equipment even during offline estimation. This educational software interface tool is developed using OPTISYSTEM software and built-in MATLAB command. MATLAB GUI is used as the software tool because it's friendly user. OPTISYSTEM is used to design the PAM two levels, four levels, and eight levels system. MATLAB is used as an interface to build the BER estimation tool for measuring the PAM multilevel modulation technique. The MATLAB GUI system for measuring BER is design using Gaussian probability errors approximation method. The designed BER estimation tool simulation, is able to plot the eye diagram, BER diagram, Q-factor value, threshold value, and the most important function is to analysis the BER value for two levels, four levels and eight levels of a PAM optical communication systems.

Keywords: BER; Optical Communication; MATLAB

1. Introduction

Optical communication plays an important role in providing high capacity communication network to all society worldwide. Generally, optical communication is used for long haul data transmission with high bit rate because of losses in fiber optic is very small. Optical signal is also immune to electromagnetic interference compared to electrical signal [1]. Conventional optical communication employed simple modulation is called as On-Off Keying based on non-return-to-zero (NRZ). For high bit rate, OOK based on return-to-zero (RZ) is used in order to extend fiber span [2]. Due to the rapid growth of internet users, the capacity of optical system also needs to upgrade as well. For next generation high capacity optical communication network, advance modulation with high spectral efficiency (SE) is the best option [3-5]. Multilevel signal modulation is one the candidate because it will be able to increase the SE. The development of high-capacity optical communication had rapidly increased day by day [6]. Since then there are various type of modulation format have been proposed. The conventional modulation format based on On-Off Keying (OOK) using non-return-to-zero (NRZ) is no longer suitable due to inefficient bandwidth usage [7-9]. The performance of any type of modulation format will be determined by BER. Currently, BER estimation tool, normally, comes with expensive measurement equipment such as serial data analyzer (SDA) and BER Tester [10]. In addition to cost all this equipment is also limited to BER estimation based on standard format and is not suitable for custom analysis because of time constraint to use equipment even for offline estimation [11-12]. Therefore, this rsearch work will focus on the development of BER estimation tool using MATLAB software for various type of modulation format such as RZ, NRZ and PAM in order to solve the above described problem [13].

2. Background and Literature Review

The primary objective of optical fiber communication system is to transfer the signal containing information from the source to the destination [14]. The general block diagram of optical fiber communication system. The source provides information in the form of electrical signal to the transmitter. The electrical stage of the transmitter drives an

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optical source to produce modulated light wave carrier. Semiconductor LASERs or LEDs are usually used as optical source here [15]. The information carrying light wave then passes through the transmission medium example optical fiber cables in this system. When the signal reaches the receiver stage where the optical detector demodulates the optical carrier and gives an electrical output signal to the electrical stage. The common types of optical detectors used are photodiodes [16]. Finally the electrical stage gets the real information back and distribute to the concerned destination. It is notable that the optical carrier may be modulated by either analog or digital information signal. In digital optical fiber communication system the information is suitably encoded prior to the drive circuit stage of optical source [17]. The purpose of modulation is to take a message bearing signal and superimpose it upon a carrier signal for transmission. A signal at baseband is often used to modulate a higher frequency carrier wave in order that it may be transmitted via radio. Modulation results in shifting the signal up to much higher frequencies (radio frequencies, or RF) than it originally spanned. Return-to-zero (RZ) describes a line code used in telecommunications signals in which the signal drops (returns) to zero between each pulse. This takes place even if a number of consecutive 0's or 1's occur in the signal [18-19]. The signal is self-clocking. This means that a separate clock does not need to be sent alongside the signal, but suffers from using twice the bandwidth to achieve the same data-rate as compared to non-return-to-zero format. NRZ-Level itself is not a synchronous system but rather an encoding that can be used in either a synchronous or asynchronous transmission environment, that is, with or without an explicit clock signal involved. Because of this, it is not strictly necessary to discuss how the NRZ-Level encoding acts "on a clock edge" or "during a clock cycle" since all transitions happen in the given amount of time representing the actual or implied integral clock cycle [19]. The real question is that of sampling--the high or low state will be received correctly provided the transmission line has stabilized for that bit when the physical line level is sampled at the receiving end [16].Pulse-amplitude modulation, acronym PAM, is a form of signal modulation where the message information is encoded in the amplitude of a series of signal pulses [3]. Bit error rate (BER) in digital transmission, the bit error rate or bit error ratio (BER) is the number of received binary bits that have been altered due to noise and interference, divided by the total number of transferred bits during a studied time interval [4].

2.1 Previous Rsearch work Work

In the past following related work is carried for BER tool descripted in Table 1

Table 1 – Work in the Past related BER tool

Year	Title	Description
2003	Soft Output Bit Error Rate Estimation for WCDMA	This paper introduces a method that computes an estimation of the bit error rate (BER) based on the RAKE receiver soft output only. Simulations show that the mean error of the estimation is below 2%, with only a small variance [9].
2003	Probability Of Error For Trained Unitary Space-Time modulation	The pair wise probability of error for trained unitary space-time modulation over channels with a constant specula component and time-varying diffuse fading is derived in this paper [12].
2004	Performance Of Nonuniform PAM Constellations For Gaussian Channel	They analyzed Pulse Amplitude Modulation (PAM) signal constellation obtained by means of different quantization methods for Gaussian channel [11].
2006	Accurate BER Estimation Of Optical DPSK System Using Sum Of Gaussian	Gaussian algorithm(GA).assisted bit error rate (BER) estimated using sum of Gaussian approximation(SGA) DPSK system effected by non linear phase noise is present[10]
2008	BER approximations using Poisson and negative binomial sampling Distributions	Estimation of bit error rates (BERs) in digital communications. This results in simple probabilistic representations for BERs, and consequently Monte Carlo estimators are constructed [13].
2009	BER Estimation For Turbo Decoding	Cross-over area of the Gaussian tails to estimate BER at each decoder iteration [8].
2009	BER Direct-Detected OFDM Signals with Optically Preamplifier Receivers	A numerical BER estimation approach for direct-detected OFDM in the presence of optical preamplifier receivers. The calculated BER is verified by the conventional error-counting approach with high precision and is still accurate with higher QAM formats, even under the influences of the optical filtering and polarization mode dispersion (PMD) effects [14].

3. Research Methodology

The system is designed using OPTISYSTEM. This rsearch work begin with identifying the bit error rate (BER), pulse amplitude modulation (PAM) technique and all the parameter related to bit error rate in optical communication system. OPTISYSTEM is the software usually used to design an optical communication system, because of that RZ and

NRZ optical communication system for this rsearch work is design using OPTISYSTEM where the output and input system is then saved, and to be used to develop the BER estimation tool. In this rsearch work MATLAB is used to design and program the source code for developing the BER estimation tool. Therefore MATLAB GUI is used as the interface in this rsearch work to simulate the BER. In the case of developing the BER estimation tools, MATLAB R2009a is highly recommended. After the BER estimation tool using MATLAB GUI is successfully develop, the save input and output from RZ and NRZ in OPTISYSTEM is used as an input for the BER estimation tool to simulate the BER system design. When the two level systems RZ and NRZ is successfully design based on the theoretical specification operation condition, the design is expand to the multilevel modulation which is the four levels and eight levels PAM optical communication system.

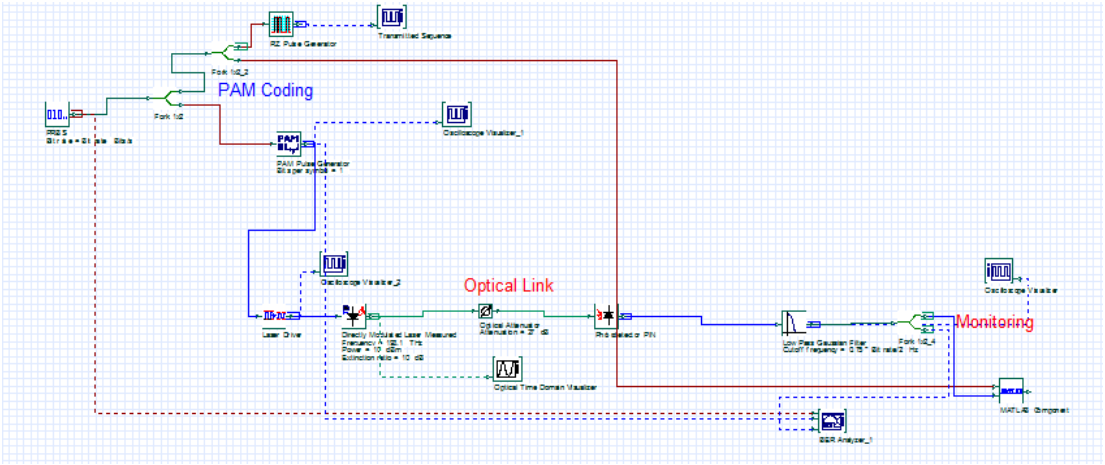

Fig. 1 - PAM system with external MATLAB in OPTISYSTEM

The OPTISYSTEM is used to generate the input and output waveform from the fiber optic system. Example of a PAM system design using OPTISYSTEM is shown in Fig. 1, where the output and input of this design will be simulated and save. The saved data from OPTISYSTEM is used as an input into the MATLAB GUI source code and the written MATLAB source code will be analysis and calculate the BER of the system. PAM optical system which has been designed using OPTISYSTEM, is connected external to MATLAB shown in Fig. 1 and the matlab component properties is required to be set up at the OPTISYSTEM shown in Fig. 2.

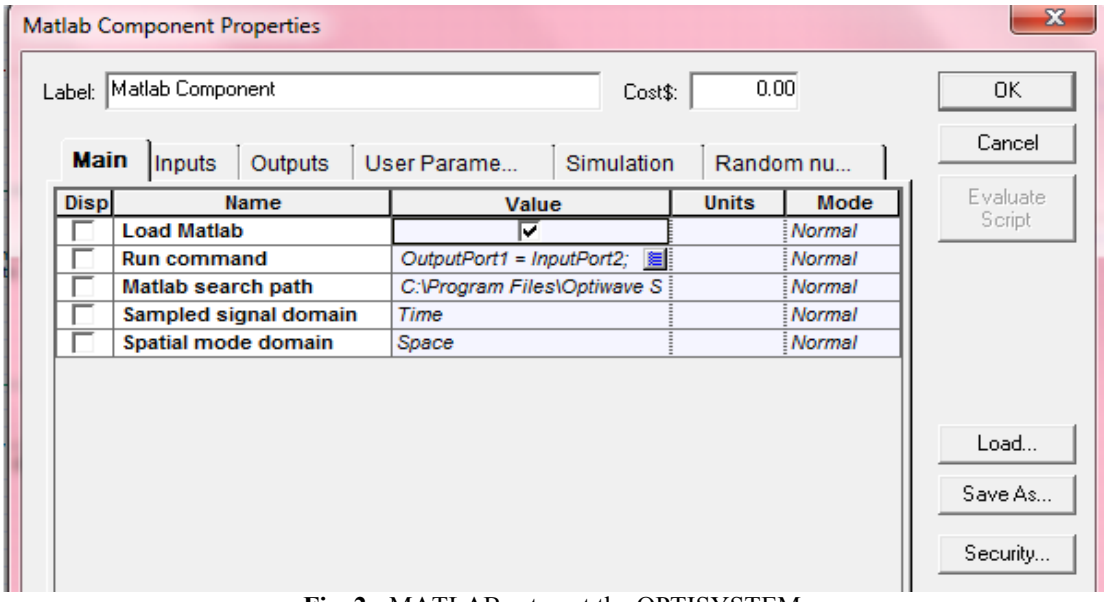

Fig. 2 - MATLAB setup at the OPTISYSTEM

Referring to Fig. 2, the link for saving the input and output result from the OPTISYSTEM is written at the Run Command. The Run Command function is to call back the inputs and outputs result that have been saved at the link folder as shown in Fig. 3.

```
OutputPort1 = InputPort1;

save C:\Users\cq627tu\Desktop\opty_mat\4level.mat;
```

Fig. 3 - Source code for link save folder at OPTISYSTEM

3.1 MATLAB

During the process using MATLAB in the design GUI MATLAB is used and the source code is written in a m-file as shown in Fig. 4.

```
for i = 1:length(binary)
    if (binary(i) == 0)
        Level0 = Level0 + 1;
        for j = 1:samples
            Level0Array(Level0, j) = electrical(elecIndex+j);
        end;
    else
        Level1 = Level1 + 1;
        for j = 1:samples
            Level1Array(Level1, j) = electrical(elecIndex+j);
        end;
    end;
    elecIndex = elecIndex + samples;
end;
```

Fig. 4 - Example of Coding for Amplitude Isolation

The seconds step is to calculate the mean and the variance for different levels of the system. The following step is to measure the Q-factor from the calculated value of the means and variance. The source code for measuring the Q-factor. From this source code, average value is calculated for level zero and level one. The average value is call mean of the system and the variance value is also calculated. After the mean and variance for both levels is calculated the Q-factor formula. The value for threshold (S1) can directly be calculated using variance of the PAM system. From when the value of variance is zero the probability error for the system is zero but when the value of variance is otherwise the probability error will be calculated for the system. After that, the BER value is calculated with the equation. Fig. 5 shows the MATLAB GUI for the BER estimation tool that will help the designer and researcher to design and measure their design with very low price tools.

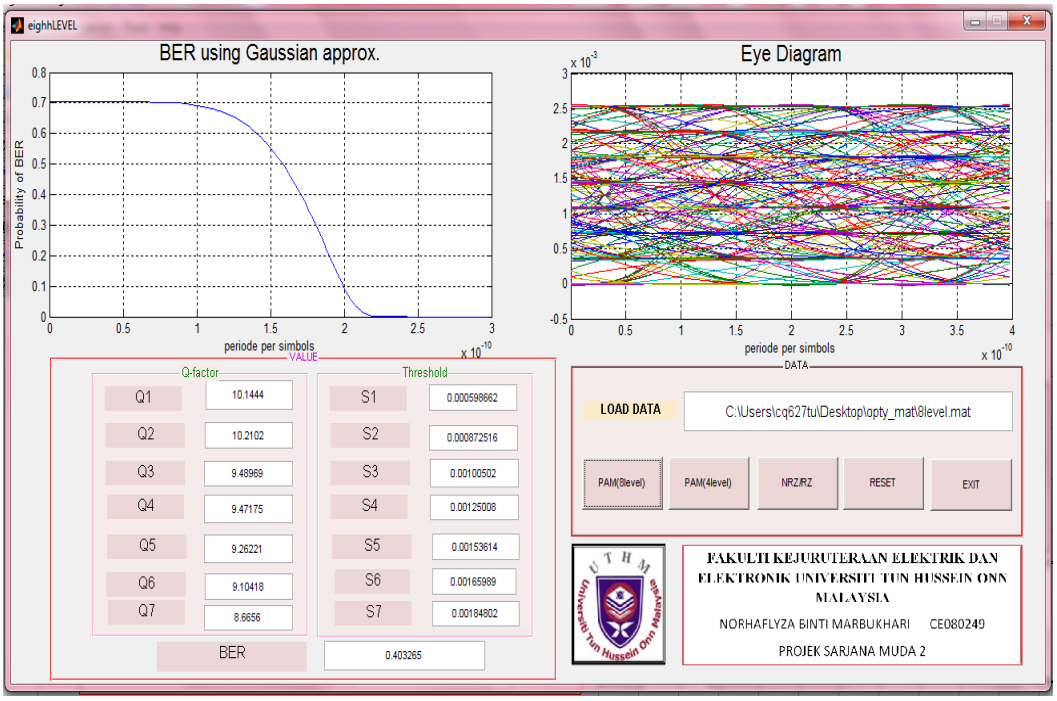

Fig. 5 - BER Estimation Tool

The save link data have to be set at the Run Command. Before the developed BER estimation tool can function, user need to write the link folder that have been set before in the Run Command at the load data command box. After the link has been setup, by pushing any of the buttons, will display the value and the graph of the systems. The BER Gaussian Graph, Eye diagram and all the calculated required value is shown in Fig. 5.

4. Experimental Result and Analysis

The result from BER estimation tool simulation for two levels, four levels and eight levels BER for PAM optical communication system is simulated from the MATLAB GUI. An eye diagram for two levels is shown in Fig. 6. The eye diagram has amplitude of 7.5 x10-6 height.

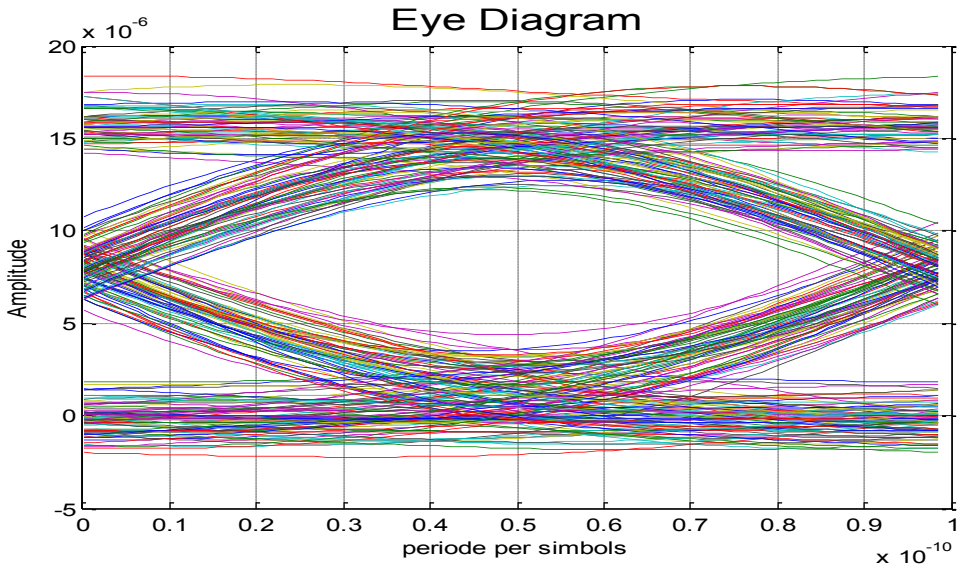

Fig. 6 - Eye Diagram for two levels

This BER estimation tool can also show the graph of BER Gaussian approximation. Fig. 7 shows the two levels of BER Gaussian approximation graph that was plotted using this tool, where the maximum ,minimum and mean value of probability BER is can estimated.

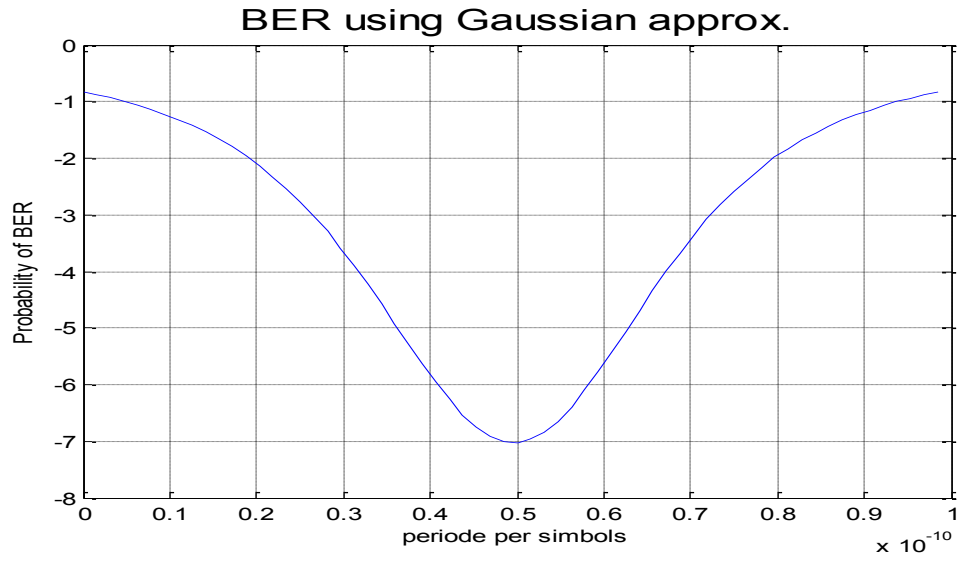

Fig. 7 - BER Using Gaussian for two levels

The BER estimation tool also can display directly the value of BER at the command box value as shown in Fig. 8. This will ease user in reading the result easily.

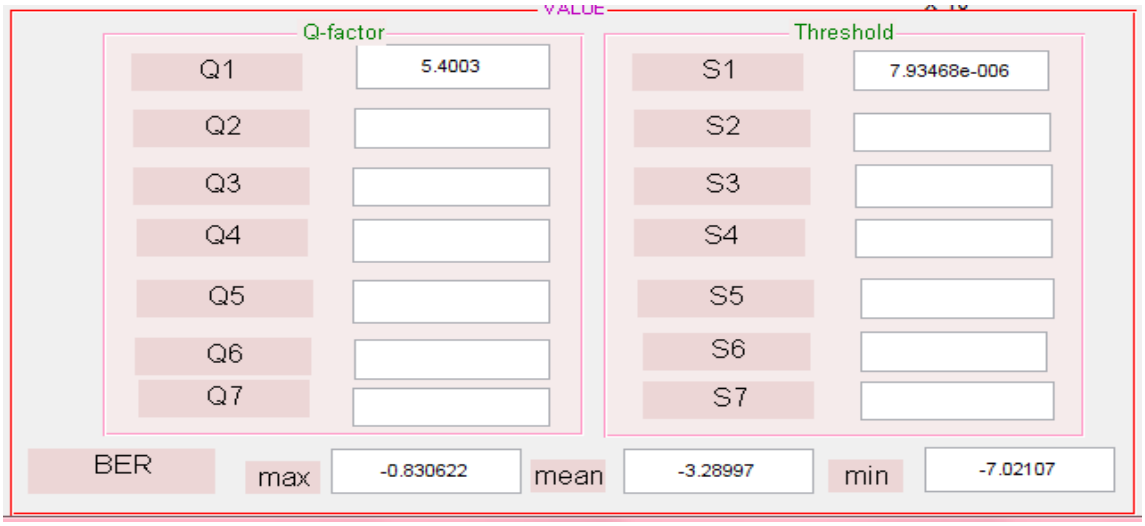

Fig. 8 - Simulation Value using MATLAB for two levels

Fig. 8 also show the value that has been measured from BER estimation tool for Q-factor is 5.4003, threshold value is 7.93468x10-6 and BER value for maximum is -0.830622, minimum is -7.02107 and mean is -3.28997 for PAM two levels systems. This simulated value of BER can be consider since the mean value is more than -3.when the mean value is less than -3 the BER of the system can consider zero.

Fig. 9 shows that the Eye diagrams for PAM four levels system. From this four levels eye diagram, the levels value for this system is 0, 5 x10-5, 11 x10-5 and 16x10-5 therefore its represent the amplitude of this system. This eye diagram contains three eye diagrams in one diagram, it's not like in two levels, where only consist one eye diagram.

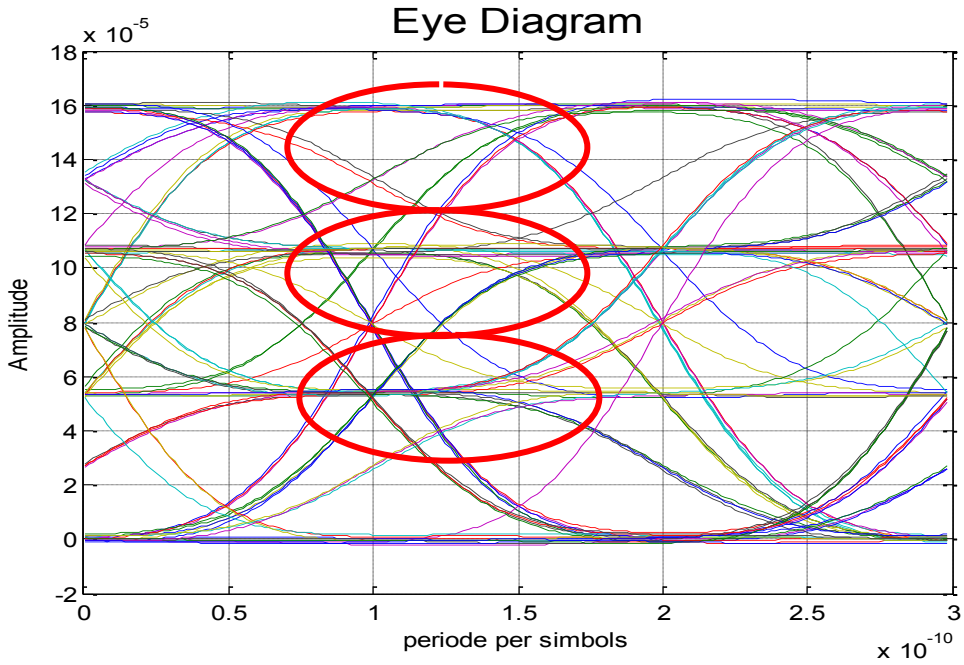

Fig. 9 - Eye Diagram for four levels

Fig. 10 is the Gaussian approximation for four level systems. From Fig. 10 shows the maximum, minimum and mean of the BER can be estimated.

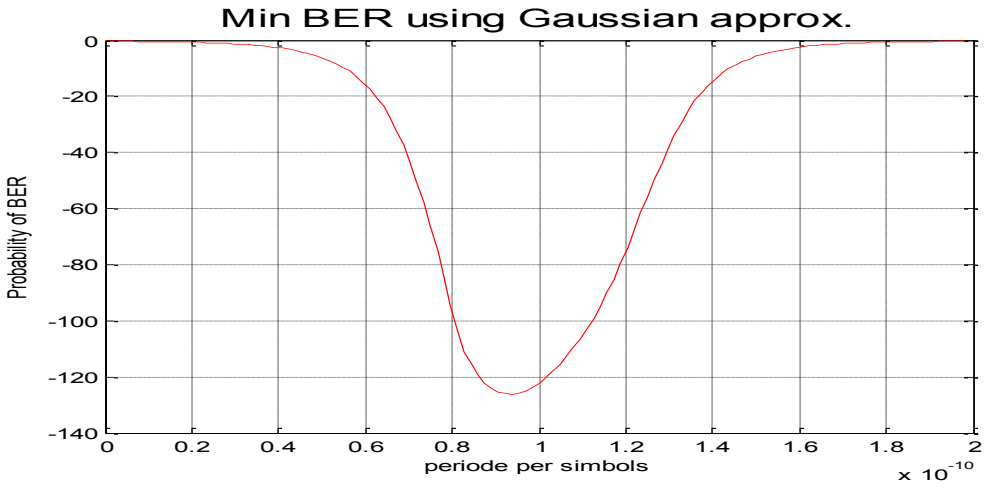

Fig. 10 - BER Using Gaussian for Four levels

BER estimation tool not only can display the Gaussian approximation graph but the value for BER also can be obtaining for four levels PAM system. From Fig. 11 all the value required for four levels system is show. The threshold value is 3.44092x10-5, 7.99748x10-5, and 0.000124677. Then the Q-factor is 10.1371, 9.46407, and 8.93679 not like two levels system. The BER minimum value is -128.084, then maximum value is -0.323741 and the mean value of BER are -32.8084.

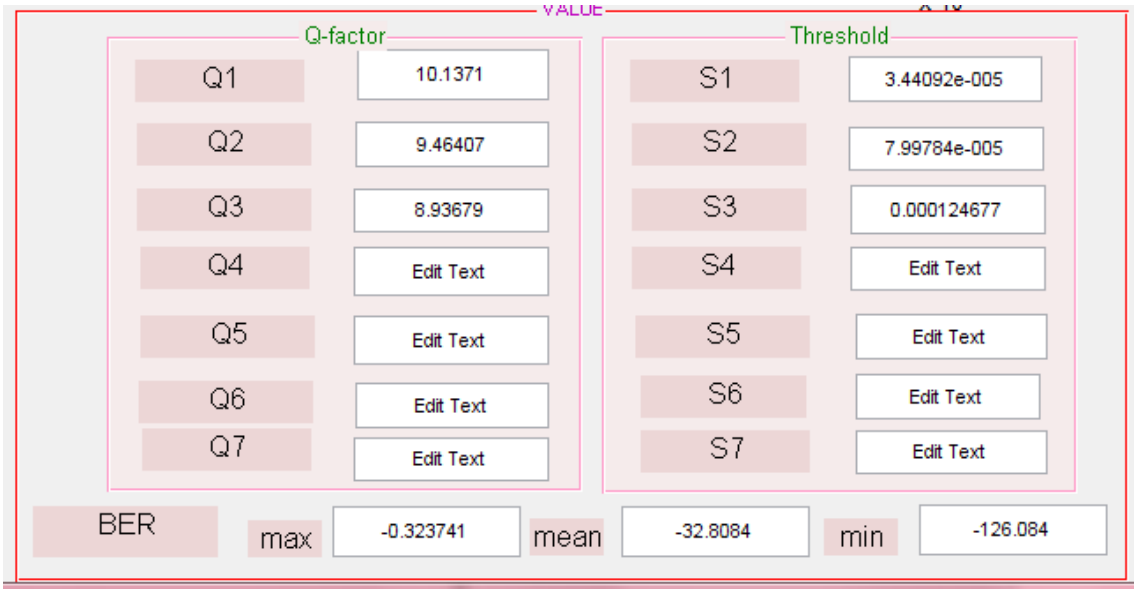

Fig. 11 - Simulation Value using MATLAB for Four levels

5. Conclusion

For the next generation of conventional modulation format based on On-Off Keying (OOK), using non-return-to-zero (NRZ) is no longer suitable due to inefficient bandwidth usage. The performance of any type of modulation format can be determined by BER. Currently, BER estimation tool, normally, comes with expensive measurement equipment such as serial data analyzer (SDA) and BER Tester. This rsearch work is to help in measuring the performances of BER for optical modulation system that were designed. Therefore this development hopefully generated more progress and can be improve time by time.

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