

Bit Error Rate Performance for Optical Fiber System

Wissam Mahjoob Osman^{1*}, Khalid Hamed Billal² and Amin Babiker Al Nabi¹

¹Department of Communication, Faculty of Engineering, AL Neelain University, Khartoum, Sudan

²University of Science and Technology, Khartoum, Sudan

Abstract

This paper explain how to determine the link budget design and receiver sensitivity design in term of bit error rate, BER and Q factor for different length and attenuation.

The parameters which were taken into consideration of the simulation are network, type of coding, optical fiber length, attenuation, wave length, data rate, power detection, type of noise, type of modulator. The objective is achieved by using (OPTI system) and MATLAB software program, the results were obtained in terms of tables and charts.

Keywords: Link budget design; Receiver sensitivity; BER; Q factor; OPTI system

Introduction

Communication implies transmit of information from one point to another, When it is necessary to transfer information, like image, speech, or data, over a distance. The concept is to use carrier wave communication [1]. Fiber optics have become a huge building blocks in the telecommunication field and it's the best system for transmitting information, since its invention in the early 1970s, the need and use of optical fiber have grown extremely [2,3]. Optical Fibers are made of ultra-pure glass or Plastic that can transfer light from one point to another without much loss or attenuation [4]. Because of evolution, studies shown that optical communication systems in the future will become stronger and better than current systems [5].

The objectives of this paper are to study optical communication software design (OPTI system), to calculate minimum amount of light power required by the receiver to operate correctly, to calculate the maximum fiber optic length attainable in various networks. A simulator and calculation will be used to determine link budget and to achieve performance evaluation of bit error for optical fiber communication system [6-9].

Descriptive Analysis

The system is divided into three parts, part one is transmitter in constricted form. The PSRBS refers to message signal and non-return to zero, which translate the message to unipolar signal format and laser source, which originates laser with (1550 nm, 0 dBm) and MECAH ZENDER modulator which modulate the electrical signal into optical signal [10].

Then signal goes to attenuator (which attenuates the optical power) after the signal arrive to receiver, which consist of PIN (APD) with cut off frequency (0.75 bit rate). Finally the signal is detected at BER analyzer to observe BER, Q factor, Eye diagram [11,12].

Mathematical Modeling Formulation

Bit error rate equation show schematic the fluctuating signal received by the decision circuit, these samples took at the decision instant to determine bit error through clock [13]. The sampled value I fluctuates from bit to bit around an average value I 1 or 0 depending on whether the bit corresponds to 1 or 0 in the bit stream.

The decision circuit compares the sampled value with a threshold value ID and calls it bit 1 if $I > ID$ or bit 0 if $I < ID$. Mistakes happen if

$I < ID$ for bit 1 because of receiver fuss. An error also Occurs if $I > ID$ for bit 0. Both sources of errors can be included by defining the error probability as

$$BER = P(1)P(0/1) + P(0) = 1/2 [P(0/1) + (1/0)] \quad (1)$$

$P(0/1)$ = condition probability of deciding 0 when 1 is sent, since

$$P(1) = P(0) = 1/2, \quad BER = 1/2 [P(0/1) + (1/0)] \quad (2)$$

Common to assume Gaussian static for the current

$P(0/1)$ = area below the decision level ID

$$P(1/1) = \frac{1}{\sqrt{2\pi}\sigma_0} \int_0^{-(I-1)/\sigma} e^{-\frac{(I-1)^2}{2\sigma^2}} dI = \frac{1}{2} \operatorname{erfc} \left(\frac{|I| - ID}{\sigma_1 \sqrt{2}} \right) \quad (3)$$

$P(0/1)$ = area below the decision ID

$$P(1/1) = \frac{1}{\sqrt{2\pi}\sigma_0} \int_0^{-(I-10)/\sigma} e^{-\frac{(I-10)^2}{2\sigma^2}} = \frac{1}{2} \operatorname{erfc} \left(\frac{ID - I0}{\sigma_1 \sqrt{2}} \right) \quad (4)$$

So

$$BER = \frac{1}{4} \left(\operatorname{erfc} \left(\frac{|I| - ID}{\sigma_1 \sqrt{2}} \right) + \operatorname{erfc} \left(\frac{ID - I0}{\sigma_0 \sqrt{2}} \right) \right) \quad (5)$$

Then

$$Q = \frac{|I| - I0}{\sigma_1 - \sigma_0} \quad (6)$$

Where Q is Quality factor

And the equations that describe the behavior of it are:

$$E_{out}(t) = E_{in}(t) \cdot \cos(\Delta \theta(t)) \cdot \exp(j \cdot \Delta \phi(t)) \quad (7)$$

Where $\Delta \theta$ is a phase difference between two branches and refer to:

$$\Delta \theta(t) = \frac{\pi}{2} \left[0.5 - \operatorname{ER}(\operatorname{Modulation}(t) \cdot 0.5) \right] \quad (8)$$

With

***Corresponding author:** Wissam Mahjoob Osman, Department of Communication, Faculty of Engineering, AL Neelain University, Khartoum, Sudan, Tel: 0915044840; E-mail: wisam.132@gmail.com

Received June 06, 2017; **Accepted** January 02, 2018; **Published** January 09, 2018

Citation: Osman WM, Billal KH, Al Nabi AB (2018) Optical Fiber Review. J Electr Electron Syst 7: 249. doi: [10.4172/2332-0796.1000249](https://doi.org/10.4172/2332-0796.1000249)

Copyright: © 2018 Osman WM, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

$$ER = 1 - \frac{4}{\pi} \cdot \text{Arc tan} \left(\frac{1}{\sqrt{\text{extrat}}} \right) \quad (9)$$

And $\Delta\phi$ is the signal phase change defined as

$$\Delta\phi(t) = SC \cdot \Delta\theta(t) \cdot (1+SF)/(1-SF) \quad (10)$$

Where, the parameter SC is -1 if negative signal chirp is true or 1 if negative signal chirp is false. Extract is the extinction ratio, SF is the symmetry factor, and modulation (t) is the electrical input signal. The incoming signal is confined between 0 and 1. For parameterized and noise bins signals, the average power is calculated according to the above [6].

Computer Modeling

Computer modeled for receiver sensitivity (Figure 1)

Computer module for power budget (Figure 2)

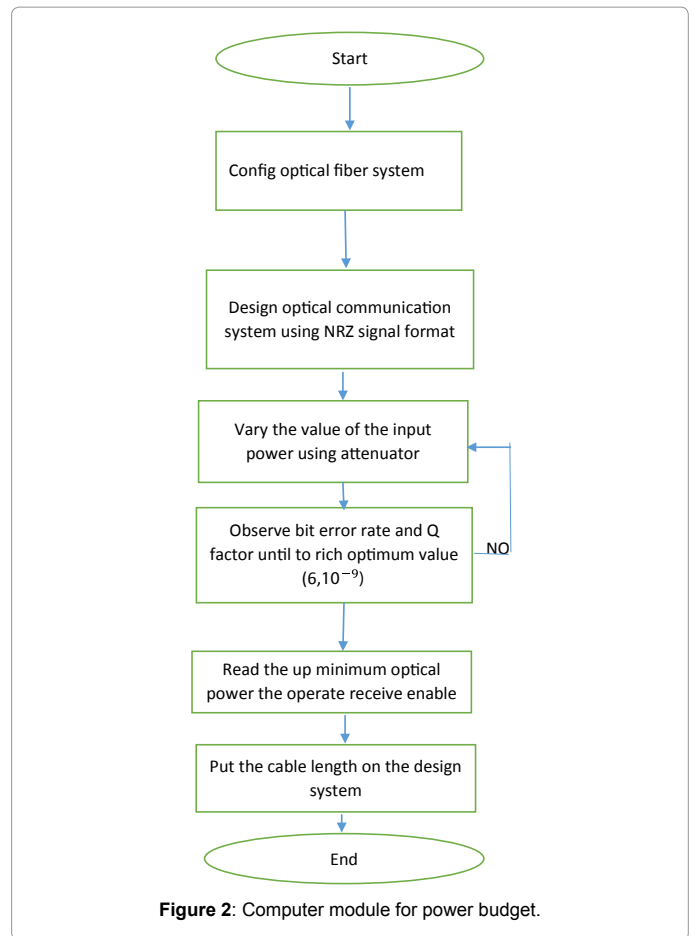
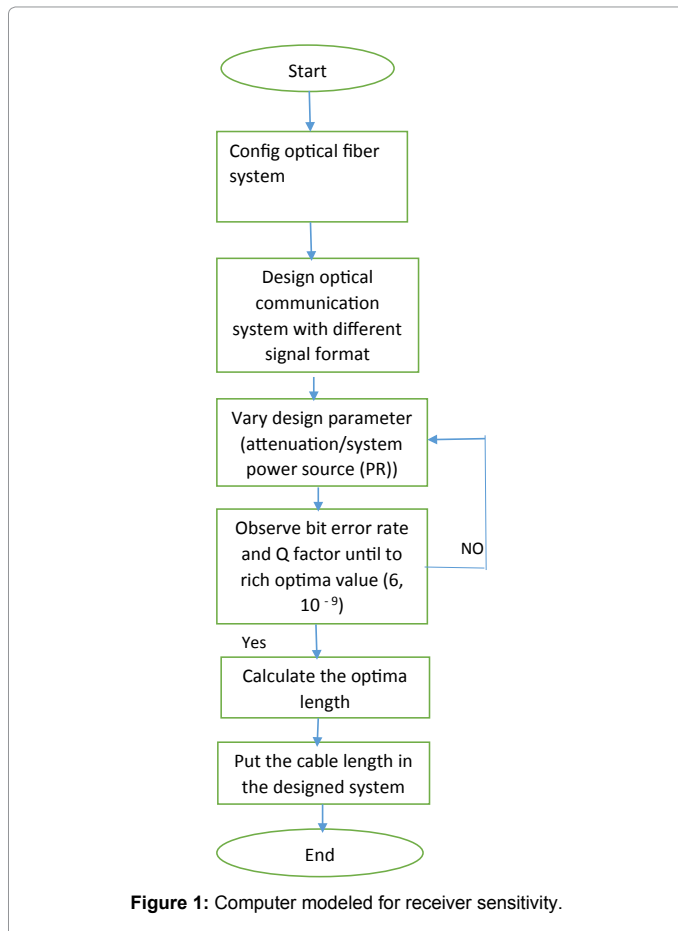
Simulation Parameter

Simulation parameters are shown in Table 1.

Simulation

OPTI system

OPTI system is an innovative optical communication system simulation package for design, testing, and optimization of virtually any type of optical link in the physical layer of a board spectrum of optical networks [14-17].



Parameter	Value
Network	Optical Fiber
Coding	Bipolar, Unipolar
Length	129
Attenuation	38.2
Wave Length	1550, 1310
Data Rate	2.5 g bit/s
Power	0 dBm
Detection	PIN, APD
Type of Noise	Additive Noise Gaussian
Type of Modulator	Laser

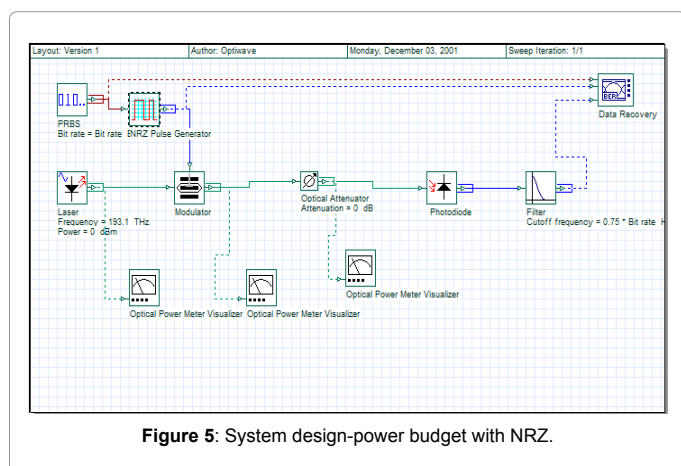
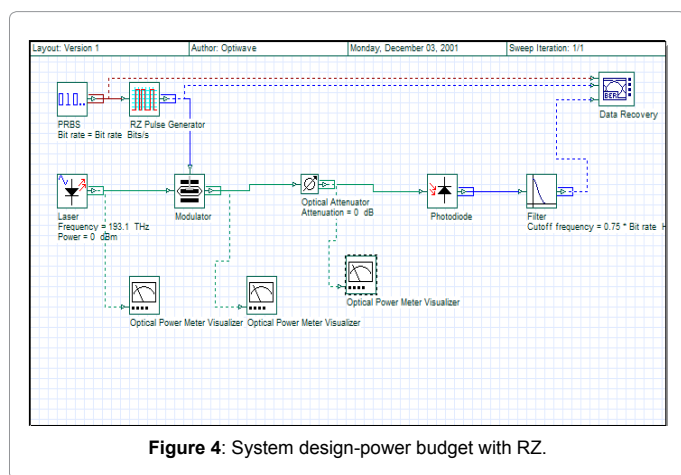
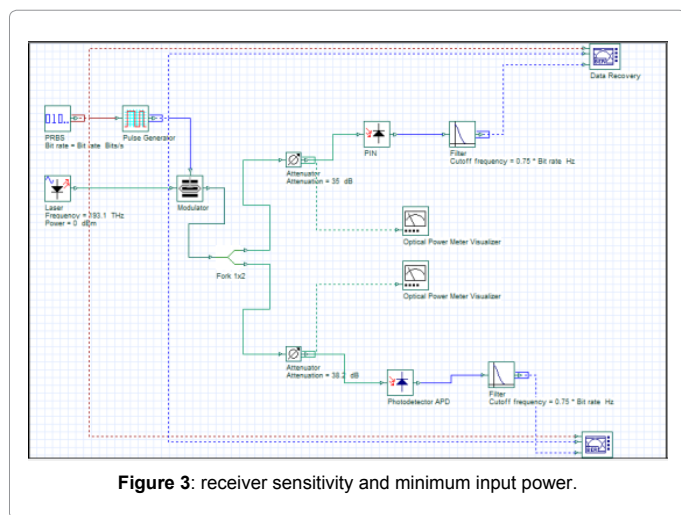
Table 1: Simulation parameters.

OPTI system is a standalone product that does not rely on other simulation frameworks, it is physical layer simulator based on the realistic modeling of fiber-optic communication systems, it possesses a new powerful simulation environment and a truly hierarchical definition of components and systems, Its capabilities can be extended easily by addition of user components, also can be seamlessly interfaced to a wide range of tools [18,19].

The extensive library of active and passive components includes realistic wavelength dependent parameters. Parameter sweeps and its optimizations allow you to investigate the effect of particular device specifications on system performance, created to address the needs of system integrators, optical telecom engineers, research scientists, and academia. OPTI System satisfies the demand of the booming photonics

market and facilitates the use of optical system tools. We can simulate implemented scenario by using OPTI system program as shown in Figures 3-5.

In this step of project we adjusted value of attenuator until to reach optimum values of BER (10^{-9}), Q factor 6 after adjustable it was found that, the minimum optical power that the receiver need to operate reliable (PIN).



In this step of the project, it's important to find the values of optimum power for both source and detectors to find the perfect length by using unipolar, bipolar signal format and the most uses wave lengths (1550 nm, 1310 nm).

This can be done by setting the value of BER to (10^{-9}) and Q factor to 6.

Then if value of optical attenuator is gradually tuned, the values of both BER and Q factor will vary respectively until finding the considered values of the performance parameter.

Result and Discussions

After execution of simulation for adjustable value of attenuation and length we get the following results in term of table and graph and are plotted by using MATLAB program.

Receiver sensitivity result

Variation of power vs. Q factor and BER for PIN is shown in Table 2.

Variation of power vs. Q factor and BER for APD is shown in Table 3.

It's clear that modulation technique is being used to modulate signal and using PIN detection to convert light signal to electrical signal that to evaluate the performance of optical through bit error rate, BER in dB (Figure 6). There are many factors effect on BER such as Q factor, if Q factor increase the BER will decrease (Figure 7).

BER against attenuation, when the probability of error increases, the attenuation will increase by using PIN detection (Figure 8).

Power against attenuation is the inverse relationship, when the

Attenuation	Bower	Bit error rate	Q factor
30	-33.21 dBm	1.88×10^{-68}	17.44
31	-34.21 dBm	3.33×10^{-46}	14.22
32	-35.21 dBm	3.73×10^{-31}	11.54
33	-36.21 dBm	4.41×10^{-21}	9.34
34	-37.21 dBm	2.16×10^{-14}	7.54
35	-38.21 dBm	5.6×10^{-10}	6
36	-39.21 dBm	4.66×10^{-7}	4.90
37	-40.21 dBm	3.89×10^{-5}	3.94
38	-41.21 dBm	0.0007	3.18
39	-42.21 dBm	0.0005	2.56
40	-43.21 dBm	1	0

Table 2: Variation of power Vs. Q factor and BER for PIN.

Attenuation	Bower	BER	Q factor
34	-37.41 dBm	3.83×10^{-31}	11.53
35	-38.41 dBm	4.22×10^{-23}	9.82
36	-39.41 dBm	4.23×10^{-17}	8.31
37	-40.4 dBm	1.16×10^{-12}	7.006
38	-41.41 dBm	2.07×10^{-9}	5.87
39	-42.41 dBm	4.76×10^{-7}	4.89
40	-43.41 dBm	2.40×10^{-5}	4.05
41	-44.41 dBm	0.0039	3.34
42	-45.41 dBm	0.0029	2.74
43	-46.41 dBm	0.0013	2.203
44	-47.41 dBm	1	0

Table 3: Variation of power Vs. Q factor and BER for APD.

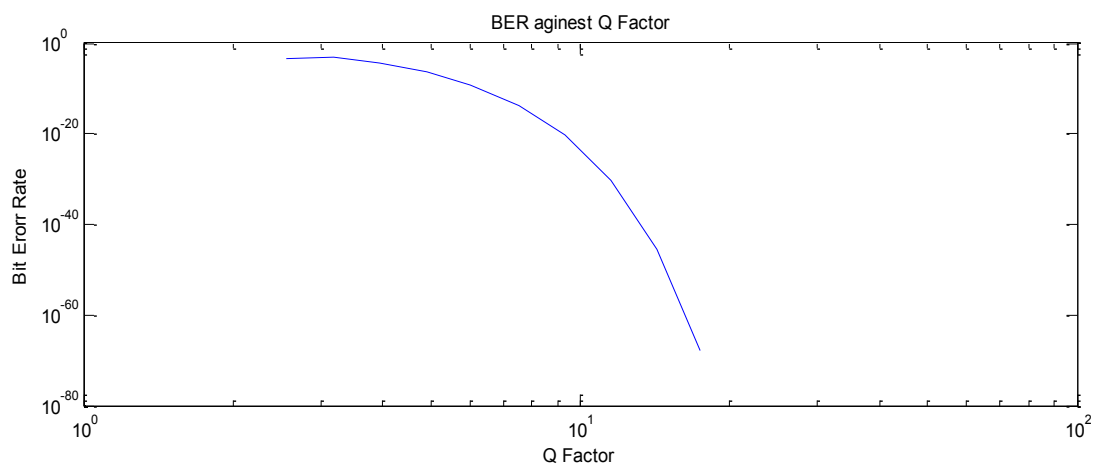


Figure 6: BER vs. SNR for NRZ with PIN.

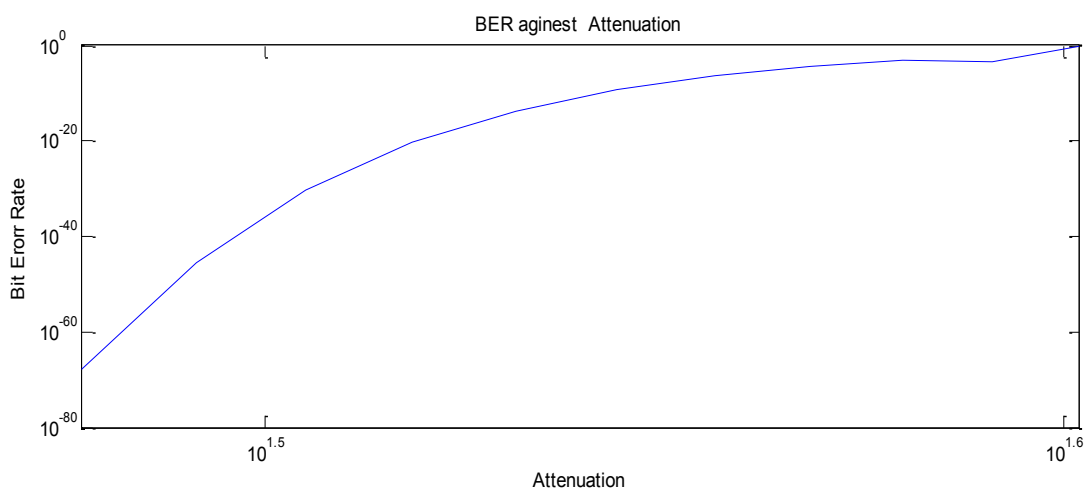


Figure 7: BER vs. Attenuation for NRZ with PIN.

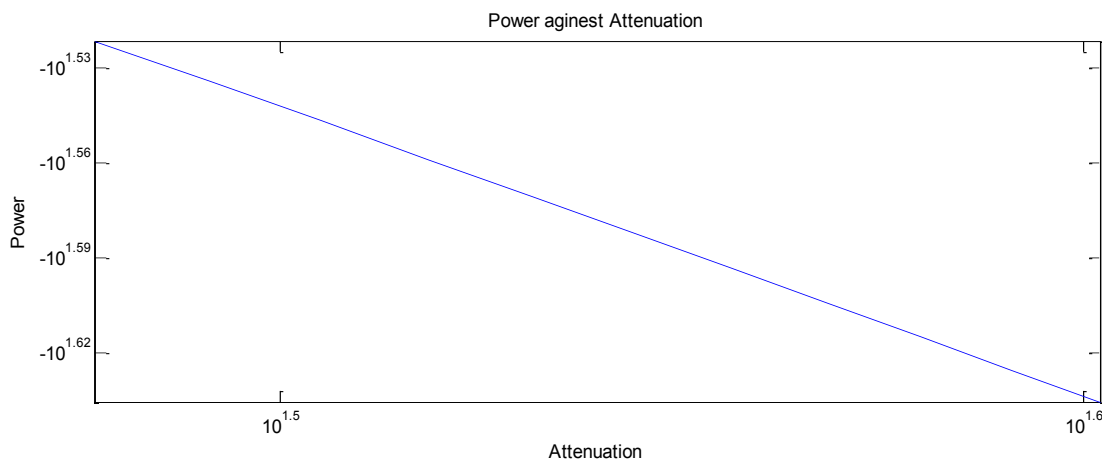


Figure 8: Power vs. Attenuation for NRZ.

power decrease the attenuation will increase by using PIN detection (Figure 9).

Q Factor against attenuation, when the Q factor increases the attenuation will decrease by using PIN detection (Figure 10).

We notice that, modulation technique is being used to modulate

signal by using APD detection to evaluate the performance of optical through bit error rate BER in dB; there are many factors effect on BER such as Q factor, also its inverse relationship (Figure 11).

Q Factor against attenuation, when the Q factor decreases the attenuation will increase by using APD detection (Figure 12).

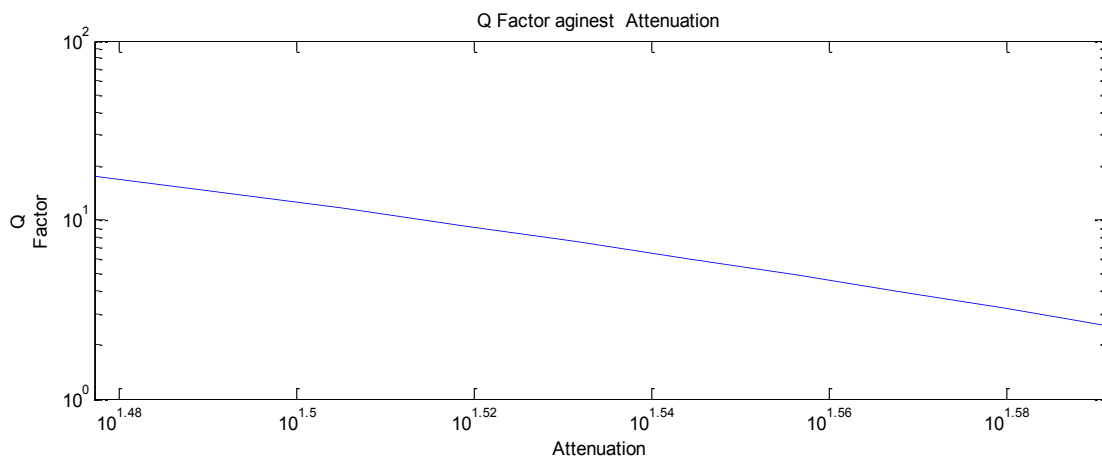


Figure 9: Q Factor vs. Attenuation for NRZ with PIN.

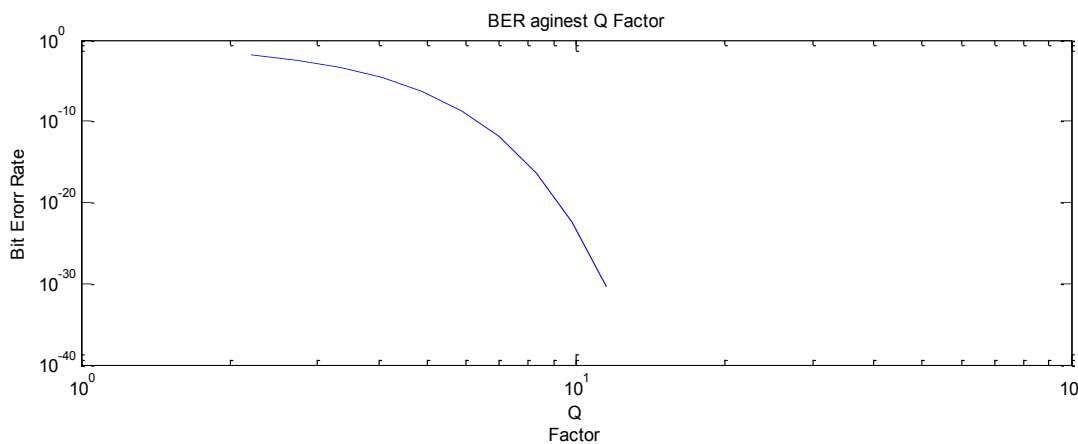


Figure 10: BER vs. Q Factor for NRZ with APD.

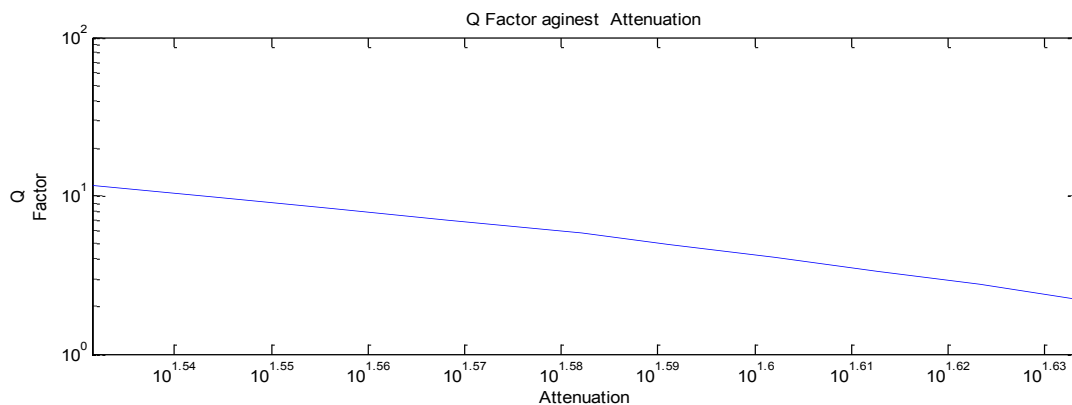


Figure 11: Q Factor vs. Attenuation for NRZ with APD.

Power against attenuation is the inverse relationship, when the power increase the attenuation will decrease by using APD detection (Figure 13).

BER against attenuation, when the probability of error increases, the attenuation will increase by using APD detection.

Power budget result

Variation of power Vs. Q factor and BER for RZ at 1550 nm is shown in Table 4.

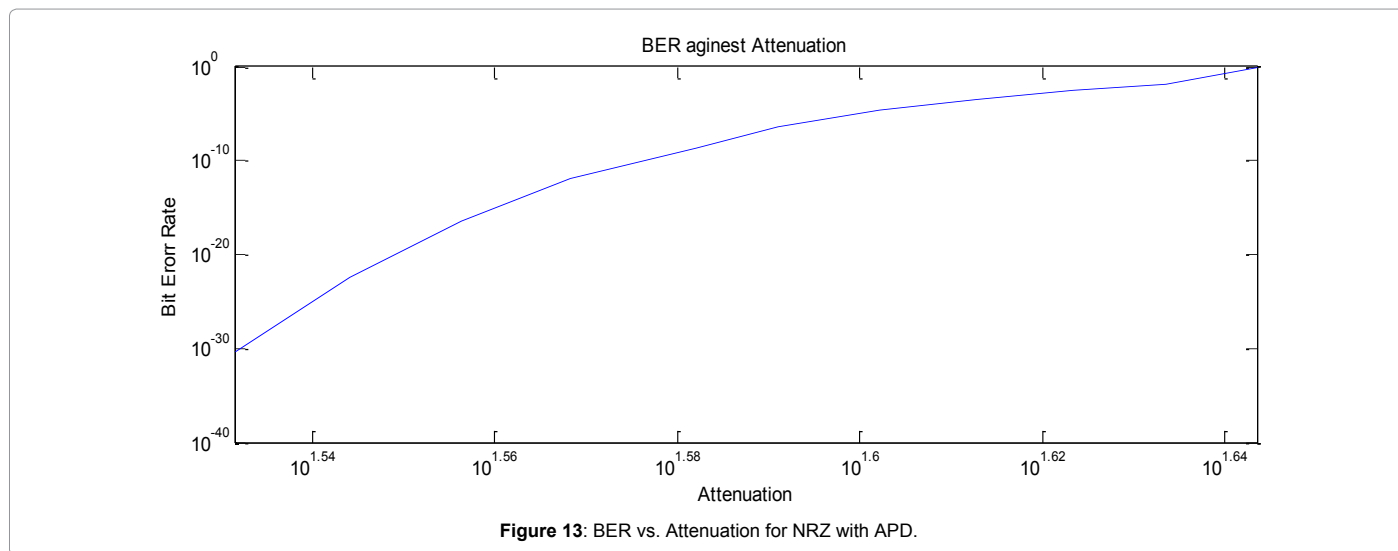
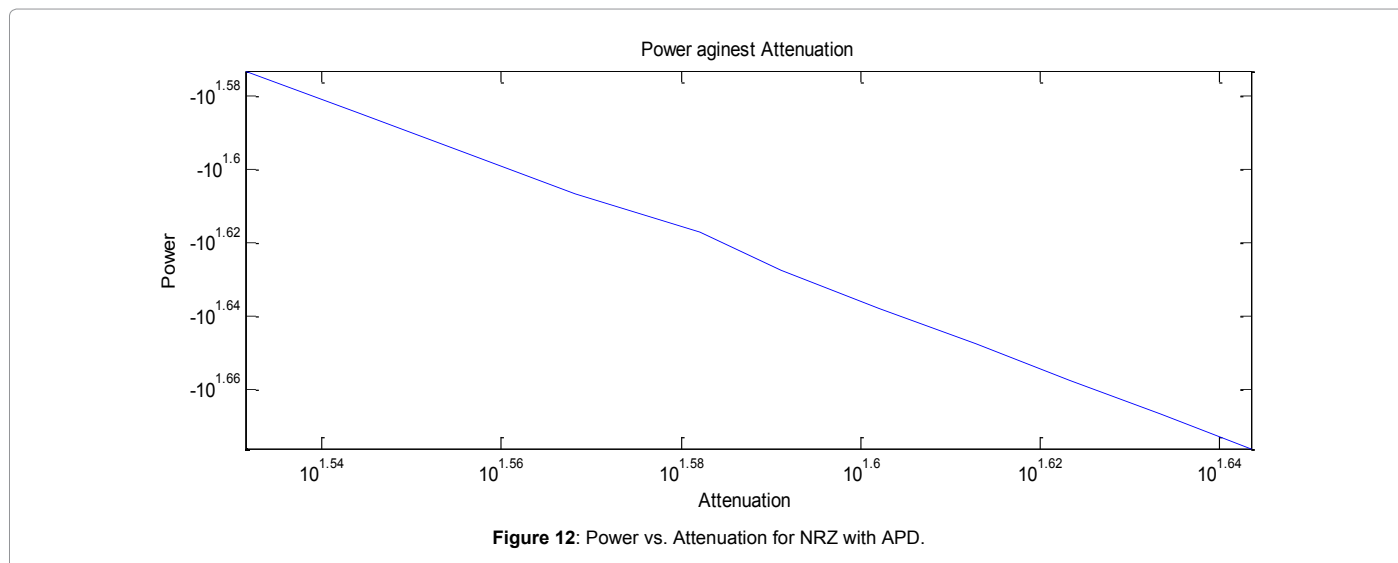
Variation of power Vs. Q factor and BER for NRZ at 1550 nm is shown in Table 5.

Variation of power Vs. Q factor and BER for RZ at 1310 nm is shown in Table 6.

Variation of power Vs. Q factor and BER for NRZ at 1310 nm is shown in Table 7.

Eye diagram for 1550 nm with attenuation and (RZ) format is shown in Figures 14-19.

Eye diagram for 1310 nm with attenuation and (NRZ) format is shown in Figures 20-25.



Attenuation	Power source	Power receiver	Q factor	BER	Length
20	-6.011 dBm	-26.012 dBm	21.906	1.133 × 10 ⁻¹⁰⁶	100.005
21	-6.011 dBm	-27.012 dBm	17.530	4.190 × 10 ⁻⁶⁹	105.005
22	-6.011 dBm	-28.012 dBm	14.005	7.241 × 10 ⁻⁴⁵	110.005
23	-6.011 dBm	-29.012 dBm	11.175	2.676 × 10 ⁻²⁹	115.005
24	-6.011 dBm	-30.012 dBm	8.911	2.513 × 10 ⁻¹⁹	120.005
25	-6.011 dBm	-31.012 dBm	7.103	6.089 × 10 ⁻¹³	125.005

Table 4: Variation of power Vs. Q factor and BER for RZ at 1550 nm.

Attenuation	Power Source	Power Receiver	Q factor	BER	Length
22	-3.010 dBm	-25.010 dBm	18.67	3.603×10^{-178}	111
23	-3.010 dBm	-26.010 dBm	14.899	1.647×10^{-50}	115
24	-3.010 dBm	-27.010 dBm	11.857	9.783×10^{-33}	120
25	-3.010 dBm	-28.010 dBm	9.420	2.236×10^{-21}	125
26	-3.010 dBm	-29.010 dBm	7.473	3.907×10^{-14}	130

Table 5: Variation of power Vs. Q factor and BER for NRZ at 1550 nm.

Attenuation	Power Source	Power Receiver	Q factor	BER	Length
20	-6.011 dBm	-26.012 dBm	21.906	1.133×10^{-106}	57.14571
21	-6.011 dBm	-27.012 dBm	17.530	4.190×10^{-69}	60.00286
22	-6.011 dBm	-28.012 dBm	14.005	7.241×10^{-45}	62.86
23	-6.011 dBm	-29.012 dBm	11.175	2.676×10^{-29}	65.71714
24	-6.011 dBm	-30.012 dBm	8.911	2.513×10^{-19}	68.57429
25	-6.011 dBm	-31.012 dBm	7.103	6.089×10^{-13}	71.43143

Table 6: Variation of power Vs. Q factor and BER for RZ at 1310 nm.

Attenuation	Power Source	Power Receiver	Q factor	BER	Length
22	-3.010 dB	-25.010 dBm	18.67	3.603×10^{-178}	62.85714
23	-3.010 dB	-26.010 dBm	14.899	1.647×10^{-50}	65.71429
24	-3.010 dB	-27.010 dBm	11.857	9.783×10^{-33}	68.57143
25	-3.010 dB	-28.010 dBm	9.420	2.236×10^{-21}	71.42857

Table 7: Variation of power Vs. Q factor and BER for NRZ at 1310 nm.

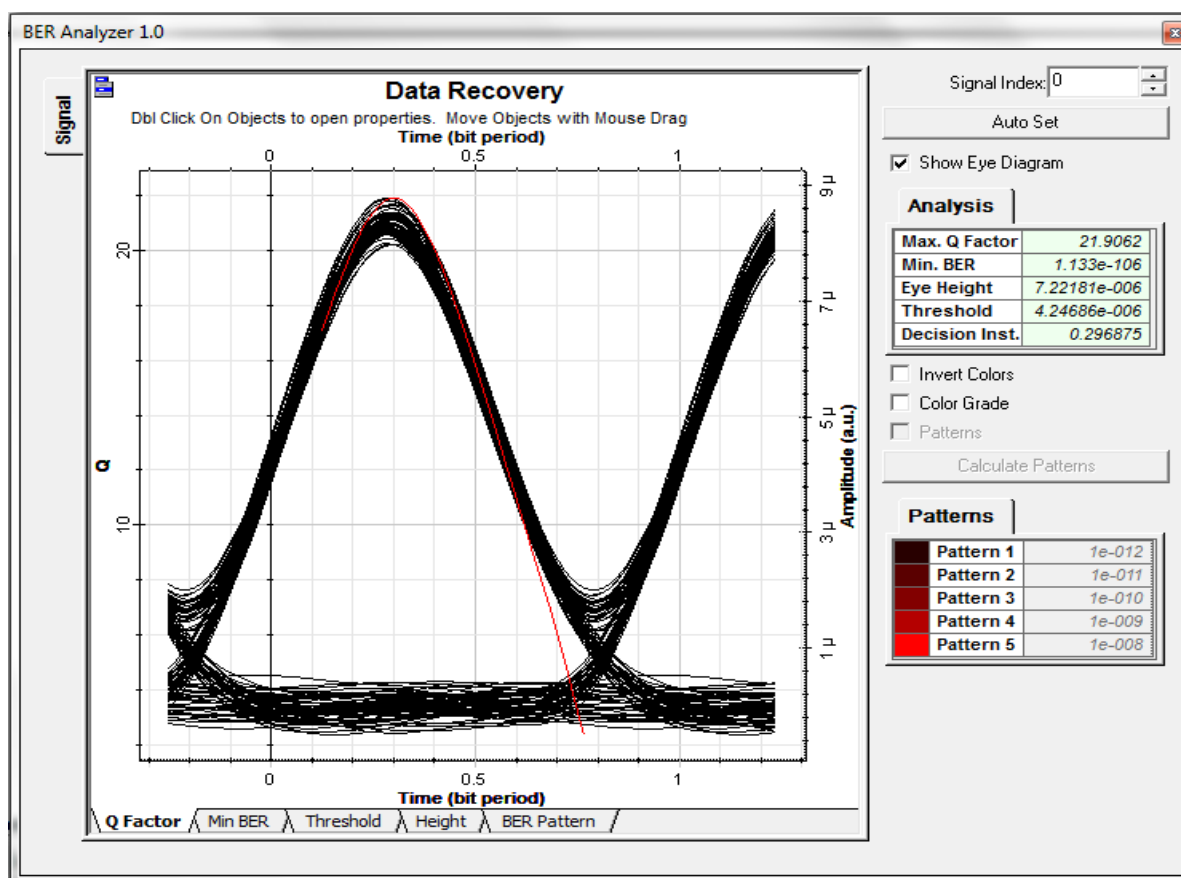


Figure 14: Diagram for 1550 nm with attenuation and (RZ) format.

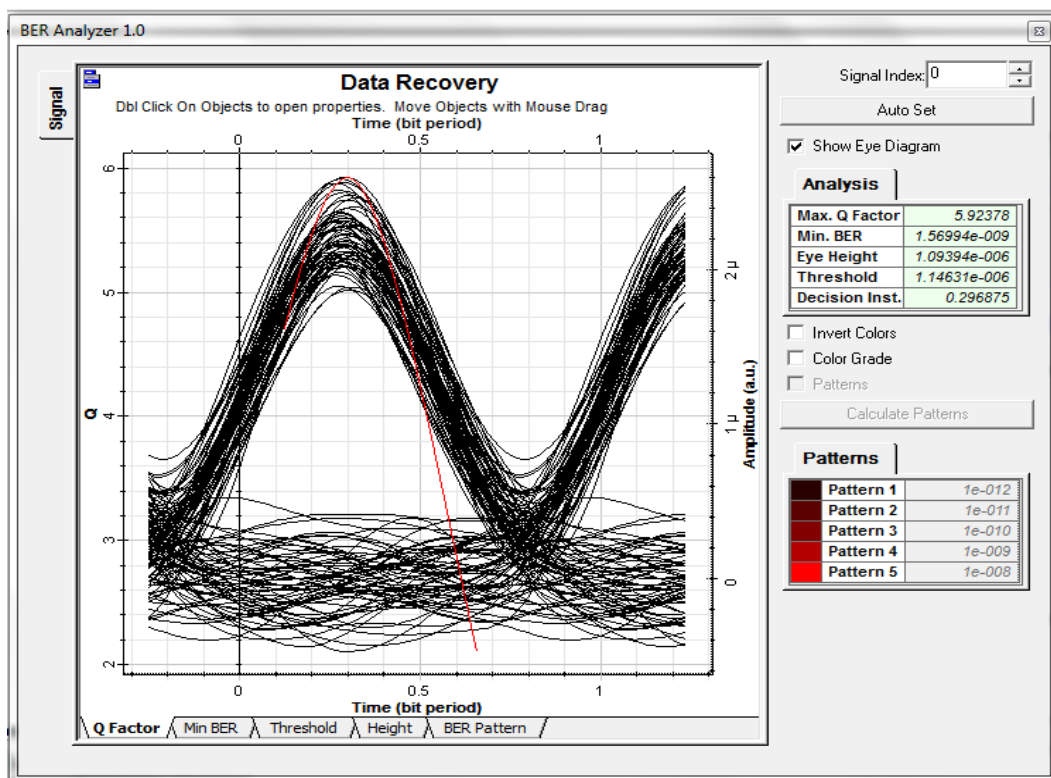


Figure 15: Eye diagram for 1550 nm with attenuation and (RZ) format.

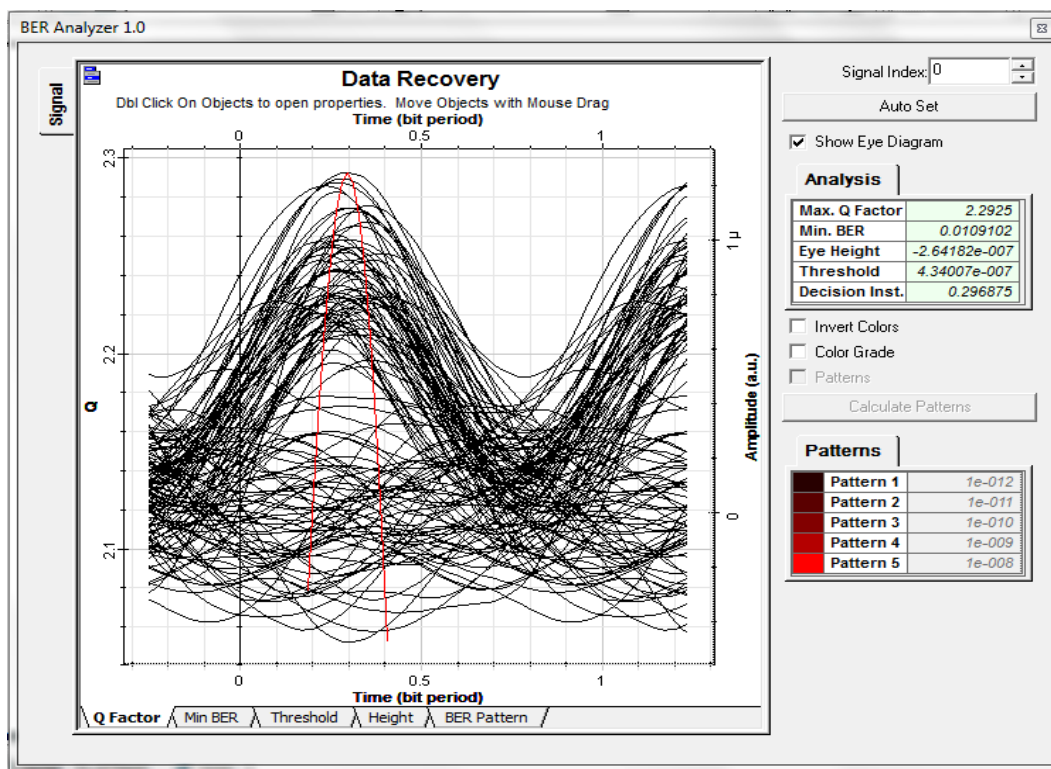


Figure 16: Eye diagram for 1550 nm with attenuation and (RZ) format.

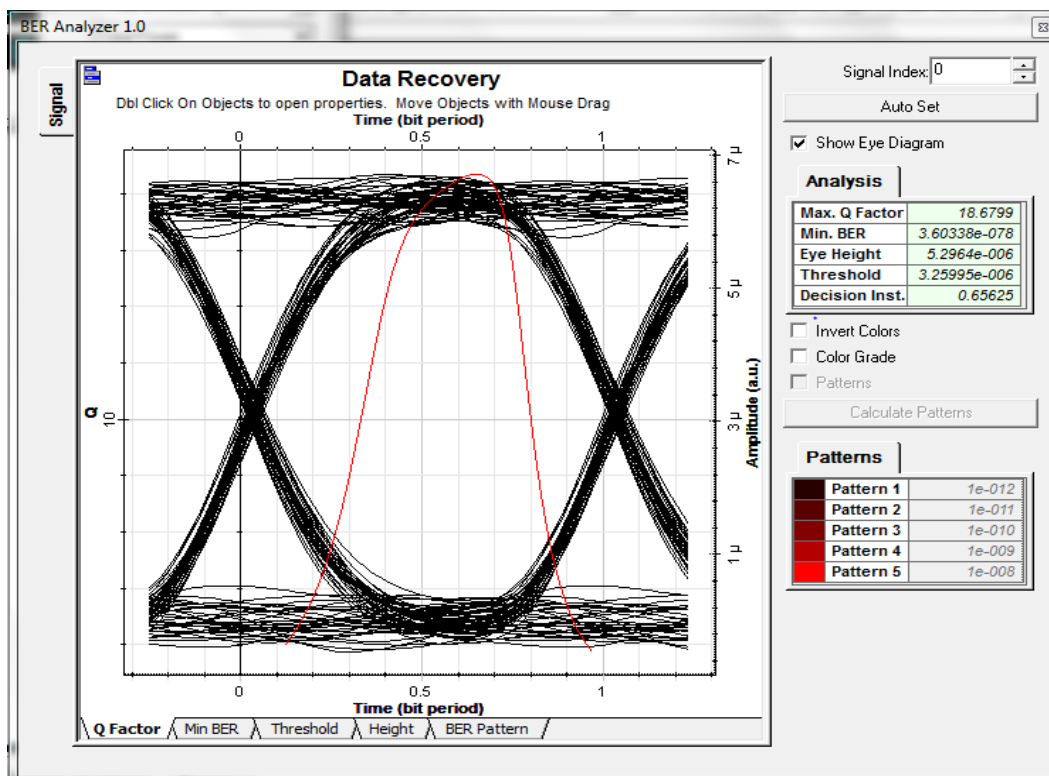


Figure 17: Eye diagram for 1550 nm with attenuation and (NRZ) format.

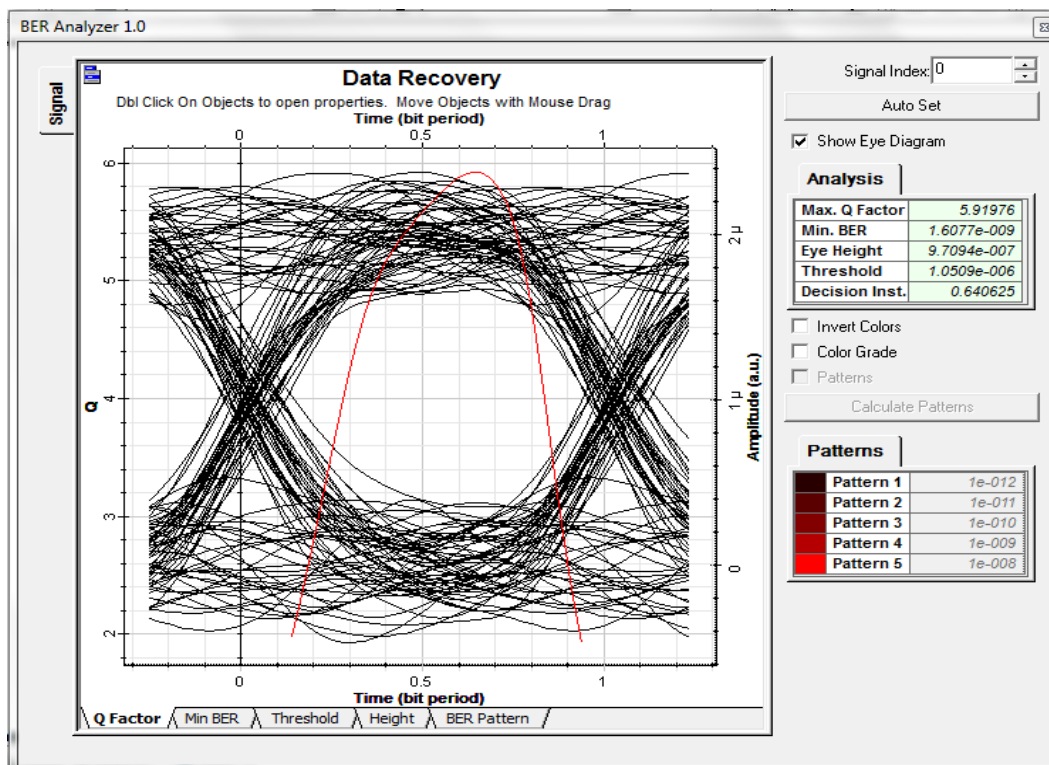


Figure 18: Eye diagram for 1550 nm with attenuation and (NRZ) format.

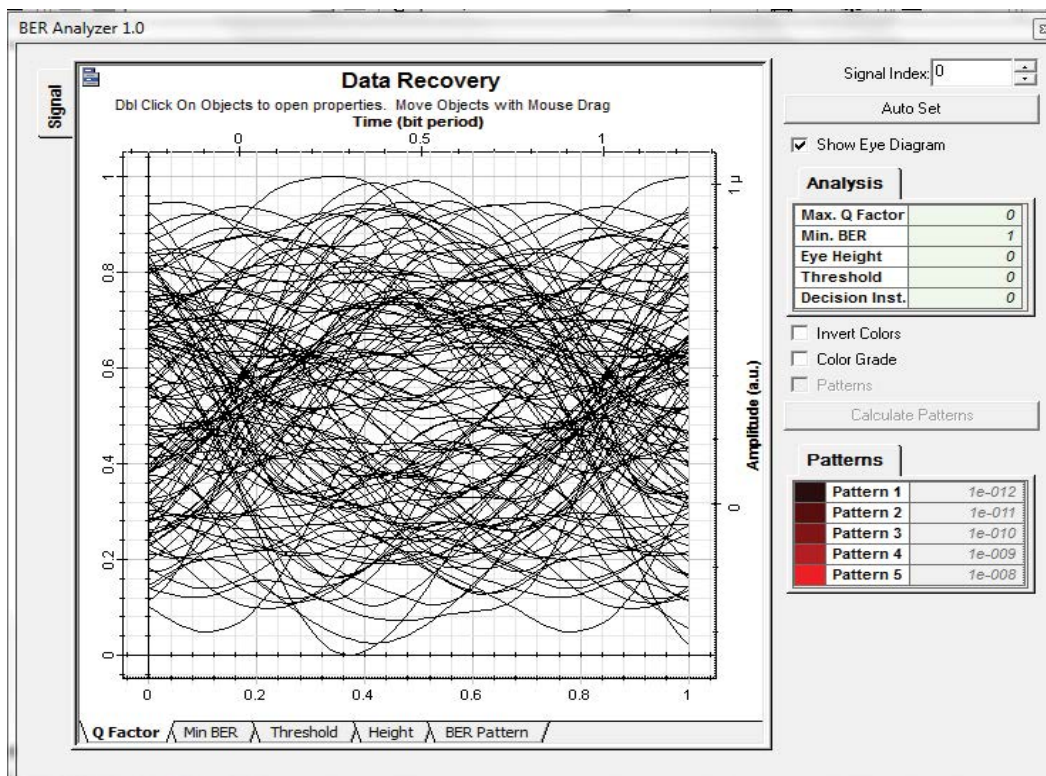


Figure 19: Eye diagram for 1550 nm with attenuator and (NRZ) format.

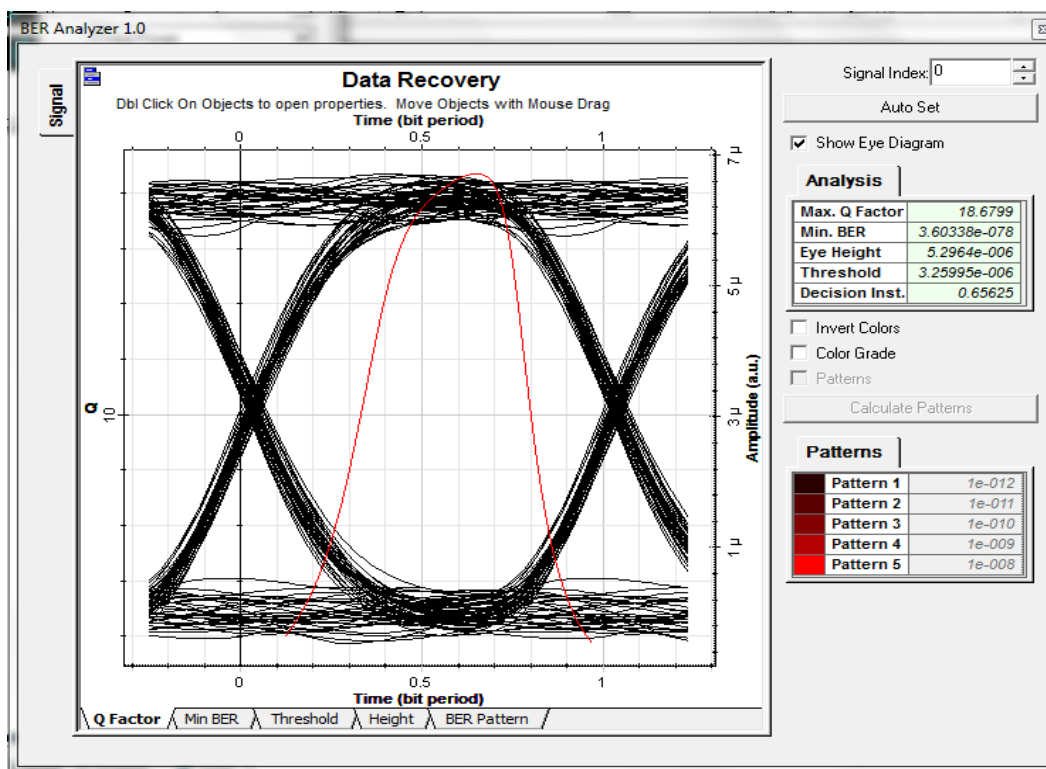


Figure 20: Eye diagram for 1310 nm with attenuation and (NRZ) format.

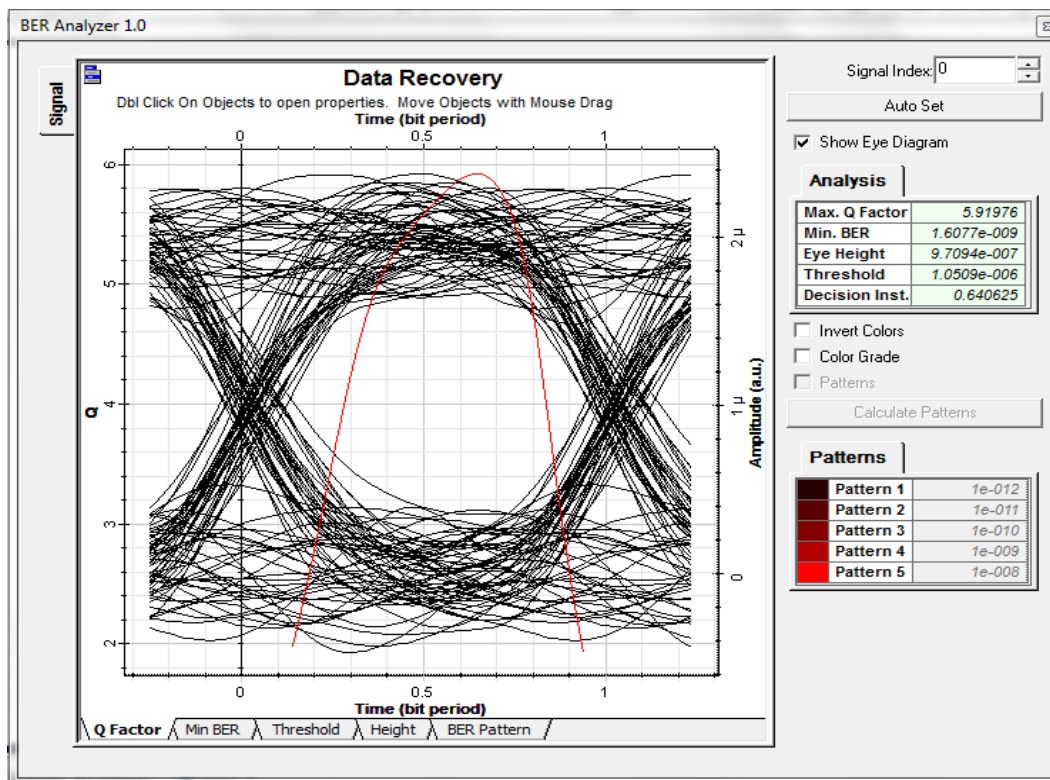


Figure 21: Eye diagram for 1310 nm with attenuation and (NRZ) format.

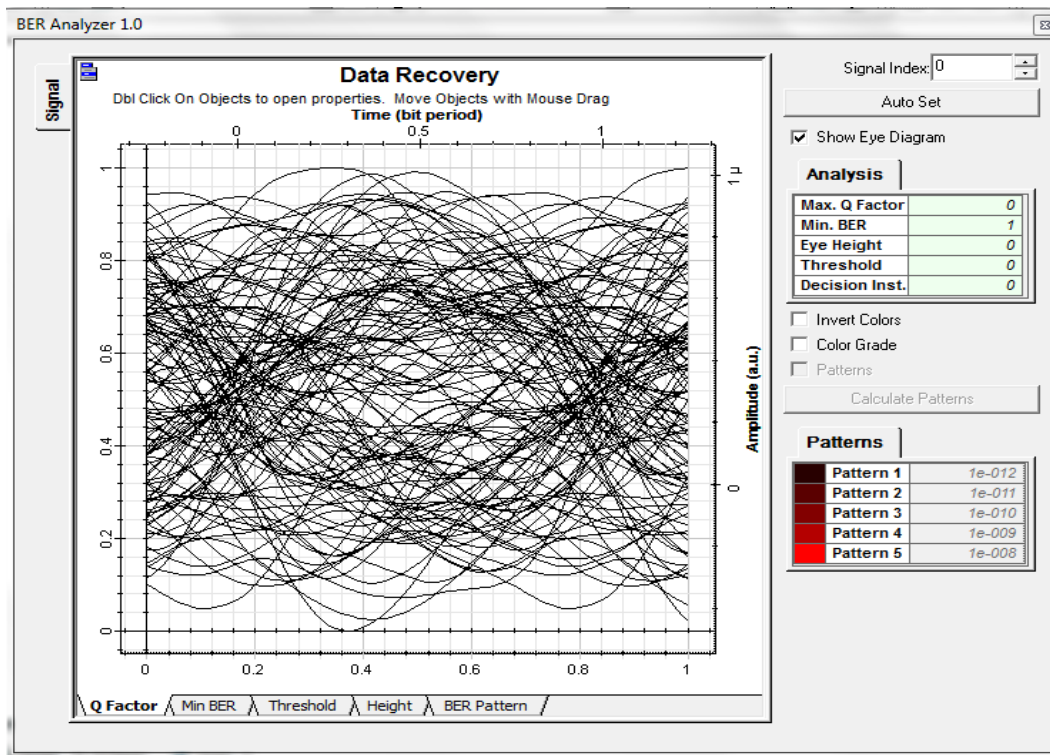


Figure 22: Eye diagram for 1310 nm with attenuation and (NRZ) format.

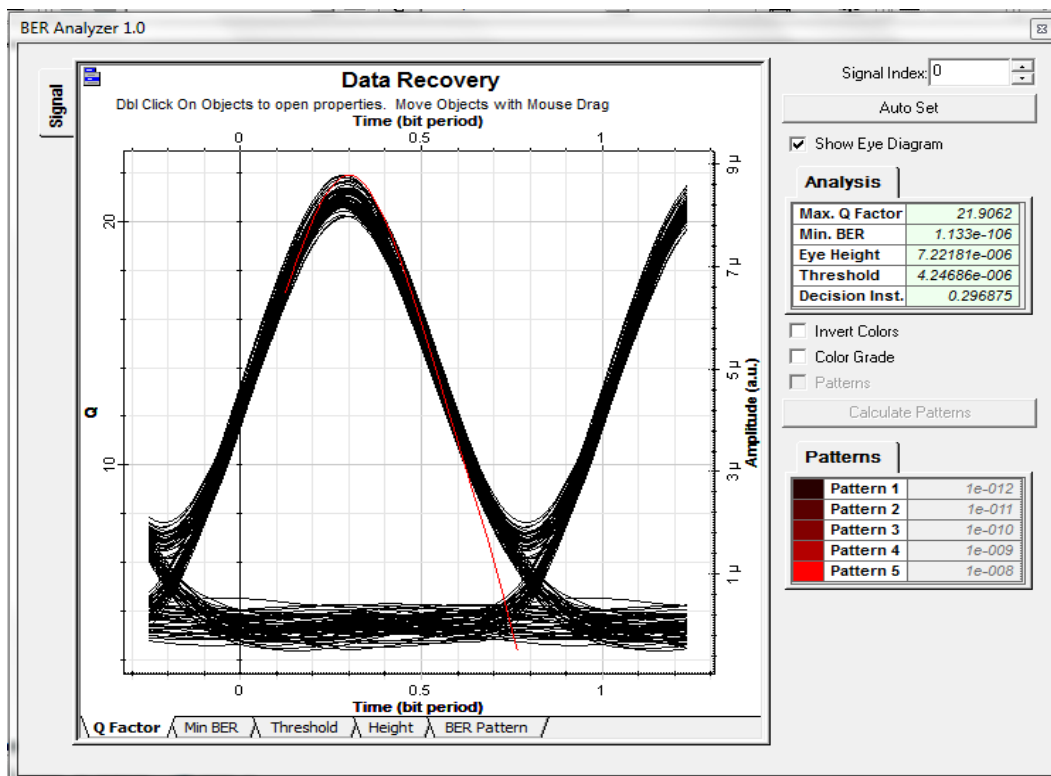


Figure 23: Eye diagram for 1310 nm with attenuation and (RZ) format.

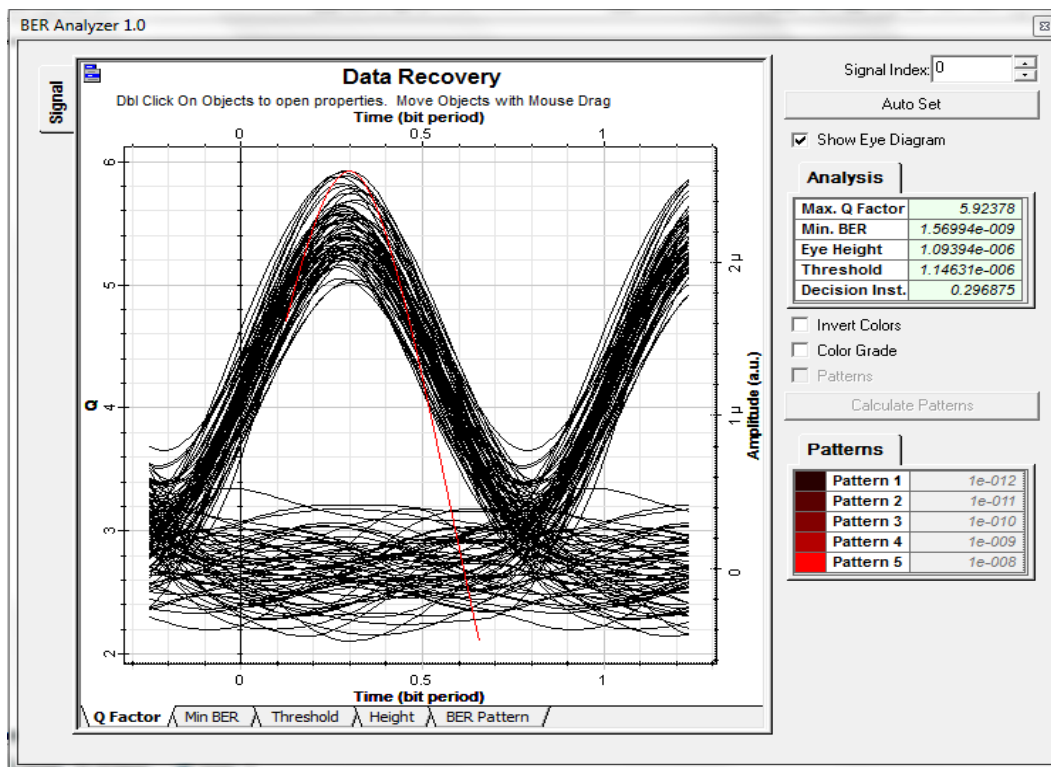


Figure 24: Eye diagram for 1310 nm with attenuation and (RZ) format.

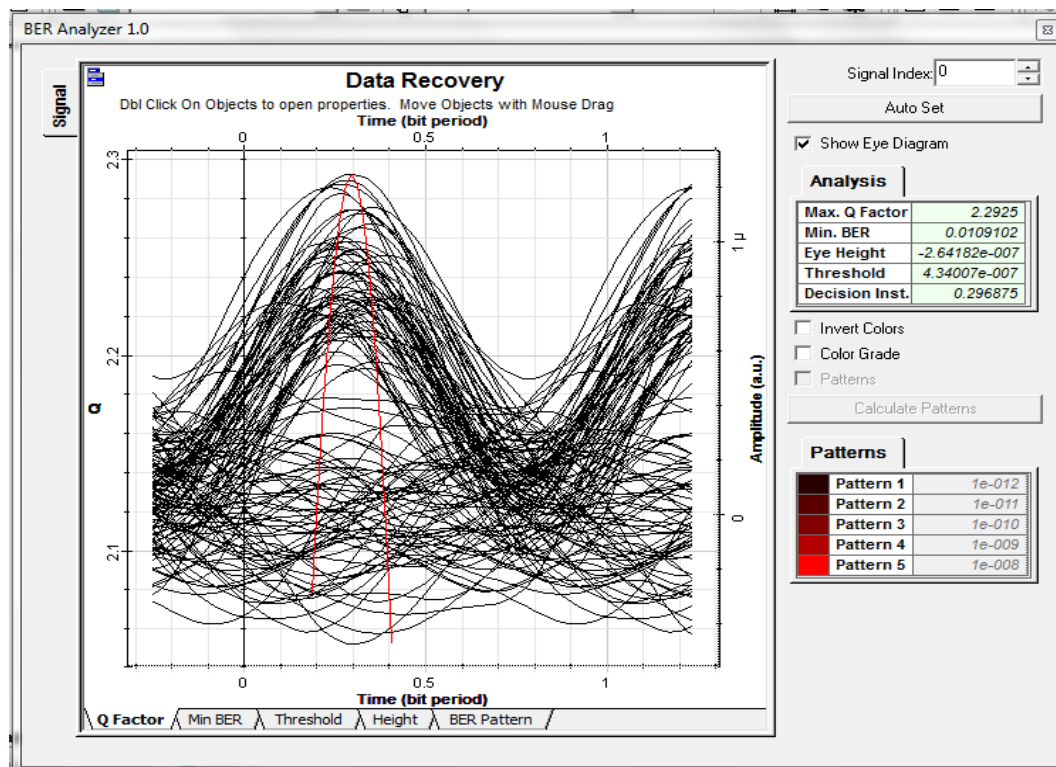


Figure 25: Eye diagram for 1310 nm with attenuation and (RZ) format.

Conclusion

Study, analysis, plane and design to simulate bit error rate for optical fiber communication have been done, the objective is achieved by using (OPTI system) and MATLAB software program. Results were obtained in terms of tables and charts.

The parameters which were taken into consideration of the simulation are network, type of coding, optical fiber length, attenuation, wave length, data rate, power detection, type of noise and type of modulator.

From the analysis it was observed that, the power that can operate PIN receiver optimum is 35 and for APD 38.2. Also from the results it's found that APD, receiver is more sensitive than PIN detector which deals with theoretical concepts.

Depending on the previous points, 1550 nm wave length better because it have less attenuation than 1310 nm and the NRZ signaling format it gives the great distance than using RZ signaling format.

References

- Ghatak A, Thyagarajan K (2000) Optical waveguides and fibers. Fundamentals of Photonics, pp: 249-292.
- Jadhav RA, Shitole DS (2013) Fiber optics communication and applications. International Journal of Innovative Research in Engineering and Science.
- Massa N (2000) Fiber optic telecommunication. Fundamentals of Photonics, pp: 293-347.
- Patel MG, Khant SB (2014) Soliton transmission in fiber optics for long distance communication. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering 3: 7100-7107.
- Idachaba F, Ike DU, Hope O (2014) Future trends in fiber optics communication. Proceedings of the World Congress on Engineering.
- <https://optiwave.com/>
- Rose Mary (2010) Wireless communication and types. Engineers Garage.
- Saleh BEA, Teich MC (1991) Fiber optic. Fundamentals of Photonics.
- Hull D, Souders J (2008) Principles of fiber optic communication. Waco, Texas: CORD Communications.
- Agarwal T (2010) What are the basic elements of a fiber optic communication system? The Budding Electronic Engineer's Knowledge Space.
- Abbas TZ (2011-2012) Fiber optics.
- Vivek Alwayn (2004) Fiber-optic technologies. CISCO.
- http://www.services.eng.uts.edu.au/~akadi/ite/major_assignments/barber/advdisad.htm.
- https://www.juniper.net/documentation/en_US/release-independent/junos/topics/concept/fiber-optic-cable-signal-loss-attenuation-dispersion-understanding.html.
- <http://www.m2optics.com/blog/bid/61431/Chromatic-Dispersion-in-Optical-Fibers>.
- Yu Y, Zhang B, Yu C (2014) Optical signal to noise ratio monitoring using single channel sampling technique. OSA 22: 6874-6880.
- Basics of non-linear fiber optics.
- <https://www.slideshare.net/Rimmi07/application-of-fibre-optics-in-communication>.
- Architectures of fiber-optic communication systems. Communication through optical fibres.