TECHNOLOGY HORIZONS JOURNAL

Vol. 2 (2), 10 Feb 2018, pp. 48-52

Bit Error Rate Performance for Optical Fiber System

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Received: 00 December 00
Accepted: 00 February 00

ABSTRACT

This paper explains 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 of the network, type of coding, optical fiber length, attenuation, wavelength, data rate, power detection, type of noise, type of modulator. The objective is achieved by using (OPTI SYS) and MATLAB the results were obtained in terms of tables and charts.

Keywords—: Link Budget Design, Receiver Sensitivity, BER, Q factor, OPTI SYS

I. Introduction

Communication implies transmit 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 block in the telecommunication field [2]. 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 [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 sys), to calculate the 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 an optical fiber communication system.

II. Descriptive Analysis

The system is divided into three parts, part one is a transmitter in constricted form. The PSRBS which it reefer to massage signal and non-return to zero, which translate the message to unipolar signal format and the laser source, which originates laser with (1550 nm,0 dB m).MECAH ZENDER modulator which (modulate the electrical signal into the optical signal). Then the signal goes to the attenuator (which attenuates the optical power) after the signal arrives at the receiver, which consists of the 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.

III. 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 the clock. The sampled value *I* fluctuate 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 fusses. 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)]   (3.1)

P (0/1) = condition probability of deciding 0 When 1 is sent

Since P (1) = P (0) = 1/2, BER = ½ [P (0/1) + (1/0)] (3.2)

Common to assume Gaussian statistic for the current. P (0/1) = area below the decision level ID

$$P(1/1) = 1/(\sqrt{2\pi\sigma 0} \int e^{-(\frac{(I-I1)^2}{2\sigma^2})dI} dI = 1/2\ \mathrm{erfc}\left(\frac{I1-ID}{\sigma 1\sqrt{2}}\right) \quad (3.3)$$

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

$$P(1/1) = 1/(\sqrt{2\pi\,\sigma 0)}\int e^{-(\frac{(I-I0)^2}{2\sigma^2})} dI = 1/2 \text{erfc}\left(\frac{ID-I0}{\sigma 1\sqrt{2}}\right) \quad (3.4)$$

$$BER = 1/4\left(\text{erfc}\left(\frac{I1-ID}{\sigma 1\sqrt{2}}\right) + \text{erfc}\left(\frac{ID-10}{\sigma 0\sqrt{2}}\right)\right) \quad (3.5)$$

$$\text{Then } Q = \frac{I1-10}{\sigma 1-\sigma 0} \quad (3.6)$$

Where Q is called Quality factor. The modulator used in fig (3.3) called Mach Zehender Modulator**,** **a**nd the equations that describe the behaviour are:

$$E_{out}(t) = E_{in}(t).\,\text{Cos}(\Delta\theta(t)).\exp(j.\Delta\text{Ø}(t)) \quad (3.7)$$

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

$$\Delta\theta\ (t) = \frac{\pi}{2}(0.5 - ER.\ (\text{Modulation } (t)\ 0.5)) \quad (3.8)$$

$$ER = 1 - \frac{4}{\pi}.\ \text{Arc tan}\left(\frac{1}{\sqrt{extrat}}\right) \quad (3.9)$$

ΔØ is the signal changed defined as

$$\Delta\text{Ø}(t) = SC.\ \Delta\theta(t).\ (1+SF)/\ (1-SF) \quad (3.10)$$

Where the parameter SC is -1 if negative signal chirp is true or 1 if negative signal chirp is false. The 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].

SIMULATION PARAMETERS

Table 1 simulation parameters

parameter	Value
network	Optical fiber
coding	Bipolar, unipolar
length	129
attenuation	38.2
Wavelength	1550,1310
Data rate	2.5 g bit/s
power	0 dB m
detection	PIN,APD
Type of noise	Additive Noise Gaussian
Type of modulator	Laser

IV. Simulation

OPTI SYS 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. OPTISYS 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.
The extensive library of active and passive components includes realistic wavelength dependent parameters. Parameter sweeps and 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. OPTISYS satisfies the demand of the booming photonics market and facilitates the use of optical system tools. simulate implemented the scenario. By using Opti sys program as shown in Figure (1-3).

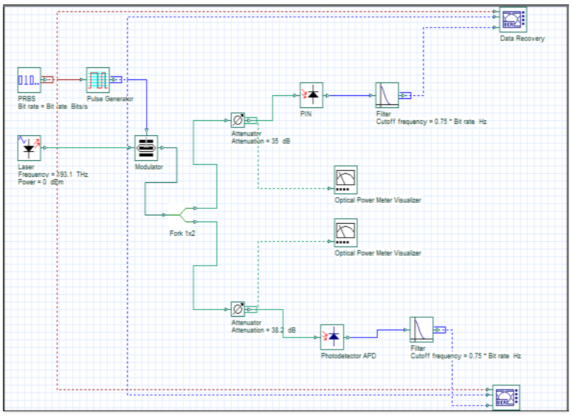

Figure 1 Receiver Sensitivity Minimum Input Power

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

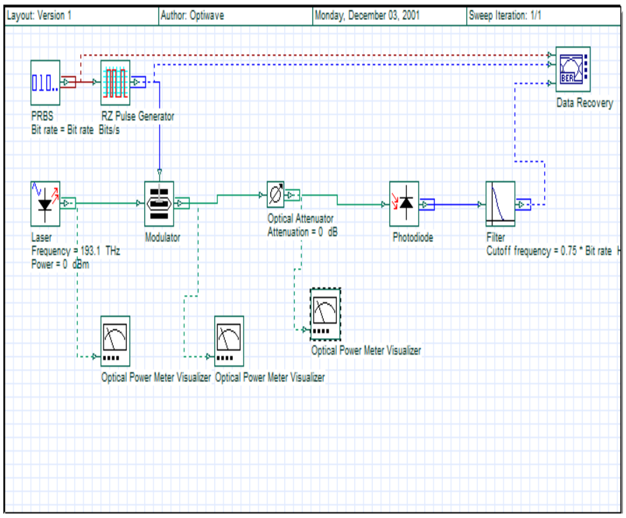

Figure 2. System Design-Power Budget with RZ.

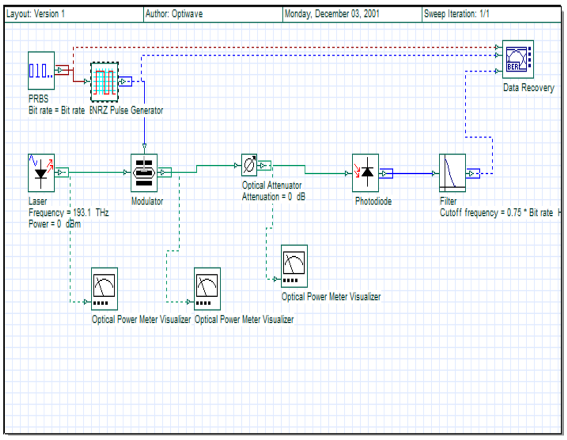

Figure 3 System Design-Power Budgets with NRZ.

In this step of the paper, 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 use wavelengths (1550nm, 1310nm). This can be done by setting the value of BER to (10^{-9}) and Q factor to (6). Then if the 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.

V. RESULT AND DISCUSSIONS

After execution of simulation for the adjustable value of attenuation and length, results are obtained in term of table and graph and are plotted by using MATLAB. Receiver sensitivity result

Table 2 Power Vs Q Factor and BER for the PIN

Attenuation	Power dB m	Bit Error Rate	Q Factor
30	-33.21	1.88×10^{-68}	17.44
31	-34.21	3.33×10^{-46}	14.22
32	-35.21	3.73×10^{-31}	11.54
33	-36.21	4.41×10^{-21}	9.34
34	-37.21	2.16×10^{-14}	7.54

Table 3 Power Vs Q factor and BER for APD.

Attenuation	power dB m	BER	Q factor
34	-37.41	3.83×10^{-31}	11.53
35	-38.41	4.22×10^{-23}	9.82
36	-39.41	4.23×10^{-17}	8.31
37	-40.4	1.16×10^{-12}	7.006
38	-41.41	2.07×10^{-9}	5.87

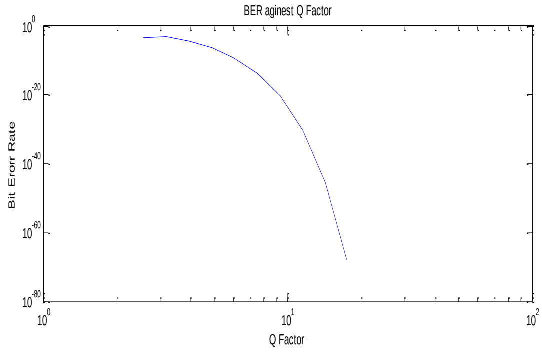

Figure 4 BER Vs SNR for NRZ with PIN.

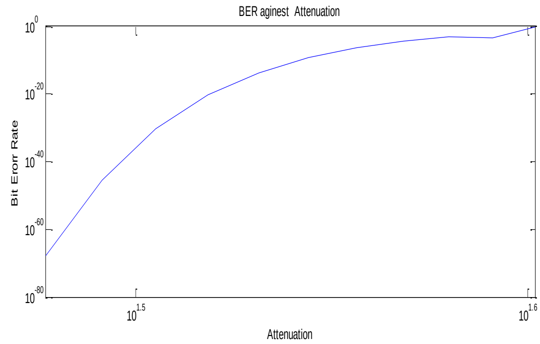

Figure 5 BER Vs Attenuation for NRZ with PIN

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

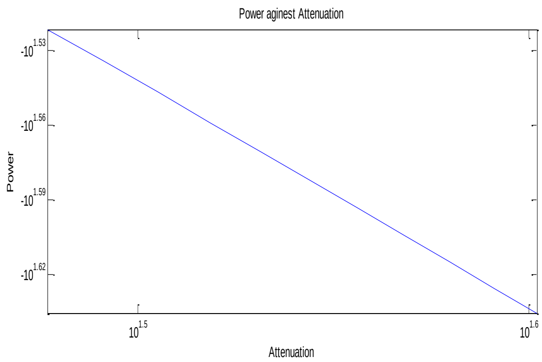

Figure 6 Power Vs Attenuation for NRZ

Power against attenuation is the inverse relationship when the power decrease the attenuation will increase by using PIN detection.

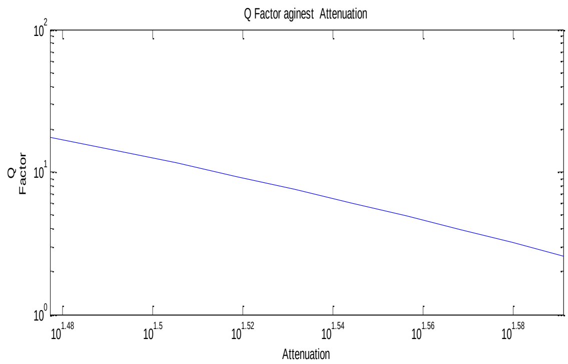

Figure 7 Q Factor Vs Attenuation for NRZ with PIN

Q Factor against attenuation, when the Q factor increases the attenuation will decrease by using PIN detection. It was observed 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.

POWER BUDGET RESULT

Table 4 Power Vs Q Factor and BER for RZ 1550nm

Att	Power source	Power receiver	Q factor	BER	length
20	-6.011 dB m	-26.012 dB m	21.906	1.133 $\times 10^{-106}$	100.005
21	-6.011 dB m	-27.012 dB m	17.530	4.190 $\times 10^{-69}$	105.005
22	-6.011 dB m	-28.012 dB m	14.005	7.241 $\times 10^{-45}$	110.005
23	-6.011 dB m	-29.012 dB m	11.175	2.676 $\times 10^{-29}$	115.005

Table 6 Power Vs Q Factor and BER for NRZ 1550nm

Att	PS	PR	Q factor	BER	L
22	-3.010 dB m	-25.010 dB m	18.67	3. 603 $\times 10^{-178}$	111
23	-3.010 dB m	-26.010 dB m	14.899	1.647 $\times 10^{-50}$	115
24	-3.010 dB m	-27.010 dB m	11.857	9.783 $\times 10^{-33}$	120
25	-3.010 dB m	-28.010 dB m	9.420	2.236 $\times 10^{-21}$	125
26	-3.010 dB m	-29.010 dB m	7.473	3.907 $\times 10^{-14}$	130

Att=attenuation PS=power source
PR=power receiver L= length

Table7 Power Vs Q factor and BER for RZ at 1310nm

att	PS	PR	Q Factor	BER	L
20	-6.011 dB m	-26.012 dB m	21.906	1.133 $\times 10^{-106}$	57.14571
21	-6.011 dB m	-27.012 dB m	17.530	4.190 $\times 10^{-69}$	60.00286
22	-6.011 dB m	-28.012 dB m	14.005	7.241 $\times 10^{-45}$	62.86
23	-6.011 dB m	-29.012 dB m	11.175	2.676 $\times 10^{-29}$	65.71714

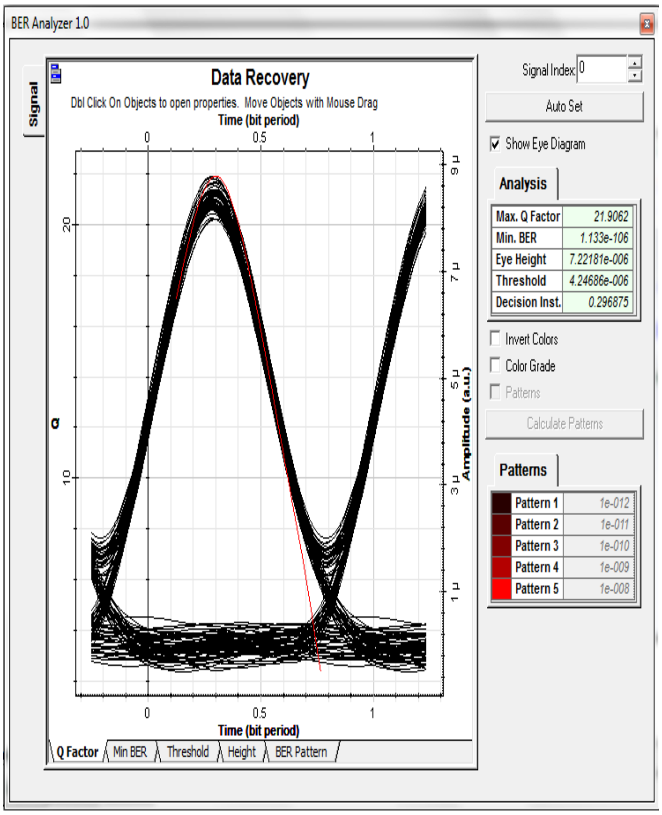

Figure 8 Eye Diagram for 1550nm with attenuation and (RZ) format

VI. 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 sys) and Matlab. 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, wavelength, 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, the receiver is more sensitive than PIN detector which deals with theoretical concepts. Depending on the previous points, 1550nm wavelength better because it has less attenuation than 1310 nm and the NRZ signalling format it gives the great distance than using RZ signalling format.

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