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Performance Analysis of Optical Fiber Communication System based on BER and Power Budget model using different Modulation Formats

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Abstract:
This Paper Investigate a technique how to determine the link of power Budget Model in terms of Q- Factor,Bit Error Rate (BER) for various attenuation & fiber-length. OPTISYSTEM and MATLAB tools software to find out the simulation the network which parameter is used classification of coding (NRZ, RZ), optical fiber length, Photodiode(PIN, APD), wavelength, power exposure,data rate, classification of noise, classification of modulator. Results in tabular and graphs forms are collected

Keywords: *Optical Fiber Communication; Q factor; Bit Error Rate (BER); Link budget model; Receiver sensitivity; OPTISYSTEM; MATLAB, System Simulation.*

I. INTRODUCTION

Since more than 30 years before the introduction of the first generation of optical fibers communication systems, viable data speeds transmission through one single optical fiber have more than 10,000 times increased and data network traffic has also risen by over 100[1,2]. More than 90% of digital data has to date been transmitted by optical fibers, which form the bulk of the nationaland international telecommunications infrastructure. In the last three decades, active information ability for these networks increased considerably through the implementation and growth of multiplexing, higher-level modulation formats, digital signals, advanced optical fibers and amplification techniques [3,4]. This technology facilitated the transformation of communication systems and the growth of the Internet toward high-speed and longer-range communications [2,3].Impairments in transmission channels and laser sources can dramatically degrade the quality of long-haul high-speed optical fiber communication systems. Such systems design and evaluation, which normally includes several signal streams, various topologies, nonlinear structures, and non-Gaussian sources of noise, is highly complex and dynamic. Advanced software tools quickly and efficiently design and analyze these systems [5].

The increasing demand for commercial simulation software and design of optical communication systems has led to several different software solutions being available. The optisystem program is more common of these as we noted in [6,7]. In optical communications a variety of performance metrics such as Bit Error Rate (BER) can be employed in the evaluation of transmitted signal reliability [8-10]. BER is the most convincing merit statistics for advanced modulation formats relative to other performance metrics, allowing an established pattern, e.g. a training collection, for continuous performance monitoring to be transmitted in optical networks. In other words, the higher the Q factor value, the better the SNR and the lower the risk of bit errors. The signal transmission is to share information such as photo, voice, or data from the transmitter over a distance transmitted on the other side of the two-point communication system [11].

II. Simulation Model

A binary Pseudorandom (PRBS) sequence is the same as a real random sequence in statistical conduct, it is difficult to predict when generated by means of a determinist Algorithm [12]. PRBS can be used in telecommunications, in particular in analog to information conversion [13], but also in authentication, simulation, comparison and flight times. Mach-Zehnder is a typical optical waveguide modulator consisting of a laser source, an optical detector and an MZI modulator structure with a field sensing range. EO conversion Mach-Zehnder modulator, optical connect, O-E conversion Mach-ZehnderLiNb (Lithium noibate).

Laser CW is not energized and can cause heating and tissue unwanted damage. The optical attenuator is also known as the optical fiber attenuator used in free space to reduce the level of optical signal strength in the optical fiber. This PIN photodiode transforms the optical signal to an electrical signal that is then amplified to make up the power loss due to the fiber attenuation by means of an electrical amplifier.For reality, optical forces are seldom directly measured. In order to calculate the current, the optical energy is transformed in a relative electrical current via a system such as a PIN photodiode. The ratio between power output and optical energy accidents is referred to as responsivity (described mathematically by symbol R). Ampere units are available per watt (A / W) [14]. For group delay and shaping efficiency, the Bessel filter is used and is very similar to the Gaussian filter. An eye diagram describes the high-rate communication systems and the short or long-haul communication system.

Mathematical Modeling Formulation

Compared to other performance metrics for advanced modulation formats, BER is the most convincing merit statistic, requiring an established pattern, e.g. a learning series, to be transmitted for continuous performance monitoring in optical networks.

The BER is the chance of a bit misconceive due to electrical noise ω(t). Considering a bipolar NRZ conveyance, we have$x_1\ (t) = A + \omega(t)$for a one or $x_0\ (t) = -A + \omega(t)$for a zero. Each of $x_1\ (t)$ and $x_0\ (t)$ has aintervalofT.

Knowing that the noise has a symmetrical spectral density $\frac{N_0}{2}$.

$x_1\ (t)$:- $\mathcal{N}\left(A, \frac{N_0}{2T}\right)$&$x_0\ (t)$:- $\mathcal{N}\left(-A, \frac{N_0}{2T}\right)$.

Returning to BER, we have likelihoodof a bit Misinterpretation

$\mathcal{P}_e = \mathcal{P}(0|1)\mathcal{P}_1 + \mathcal{P}(1|0)\mathcal{P}_0$

$\mathcal{P}(1|0) = 0.5erfc\left(\frac{A+\lambda}{\sqrt{N_0/T}}\right)$&

$$\mathcal{P}(0|1) = 0.5erfc\left(\frac{A-\lambda}{\sqrt{N_0/T}}\right)$$

Where λ is the threshold of determination, set to zero when $\mathcal{P}_1 = \mathcal{P}_0 = 0.5$

We can use the average energy of the Signal

$E = A^2 T$ to find the final Expression-

$\mathcal{P}_e = 0.5erfc\left(\sqrt{E/N_0}\right)$.

Simulation Parameter-Using the commercial optical device simulator Optisystem 13, the planned optical network was positively modeled and analyzed. It is a system-level simulation based on fiber-optic communication systems being pragmatically modeled. With the inclusion of user modules, its capacity can be easily extended and can be reliably connected to a wide range of tools. The optical module architecture and netlist, component designs, and presentation graphics are controlled by a robust Graphical User Interface (GUI).The calculations of the proposed system started as soon as the run button was on, then it is easy to see a BER and Q-factor. In addition to the Q element, an eye diagram was developed for displaying the BER values, eye opening. The comprehensive library of active and passive components incorporates wavelength-dependent functional parameters. Sweeping parameters allow you to examine the impact on system performance of different software specifications. You can insert parameters that can be calculated from actual devices using the OptiSystem Module Library. It combines various vendors with test and measurement tools.Table 1 displays simulation parameters.

framework	Significance
Network	Optical-Fibers
Coding	Unipolar, Bipolar
Attenuation	38.2
Data Rate	2.5 GBPS
Wavelength	1550, 1310
Detection	PIN, APD
Power	0 dBm
Length	129
various Noise	Additive Noise Gaussian
various Modulator	Laser

Table1. Parameters for simulation.

Then we have adjusted the performance of the attenuator to reach optimum BER values (10^{-9}), after variable Q factor 6, it has been identified that the recipient needs minimal optical power (PIN).

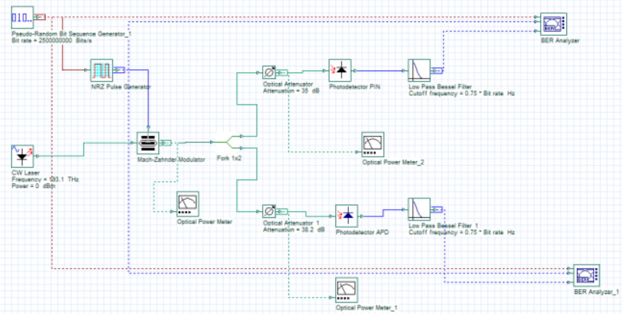


Figure1. Sensitivity of the receiver and minimal input power.

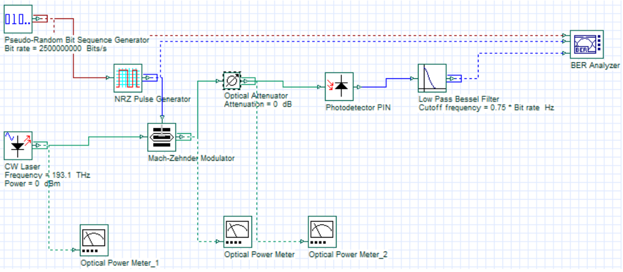


Figure2. System model-power budget with NRZ.

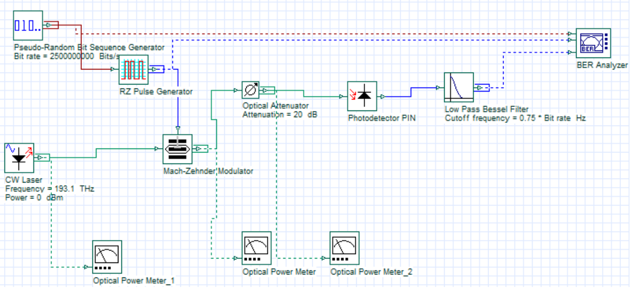


Figure3. System model-power budget with RZ.

The best power for the sources and detectors is to be found in the project using unipolar, bipolar signals and most wave lengths to detect a perfect length (1550 nm, 1310 nm). This will be complete by putting the BER to (10^{-9}) and the Q to 6 parameters. If a small adjustment is made to the value of the optical attenuator, then the BER value and the Q value may change until the output parameter values are identified.

III. Result and Discussions

Adaptable attenuation and duration value show the table and chart term effects and is plotted using the program MATLAB.

Receiver sensitivity result-

Alterations of power Versus Q factor and BER for PIN is shown in Table 2.

Alterations of power Versus Q factor and BER for APD is shown in Table 3.

The receiver performance assessment can be seen in the BER and eye diagram simulation process. Modulation technique is used to modulate signal and transform light signal to electrical signal using PIN detection to test optical output by bit error rate, BER in dB (Figure 4). BER is affected by various conditions, such as Q factor, when Q factor increases the BER will decrease (Figure 5). BER against attenuation will increase the attenuation by using PIN detection when the likelihood of bit error increases (Figure 6). Strength against attenuation is the inverse relationship by using PIN detection (Figure 7) to increase the attenuation when the strength decreases.

Q Factor opposed to attenuation will decrease with the use of PIN detection when the Q factor raises attenuation (Figure 8).

The technique for modulating signal is used to detect APD for the BER-bit error rate optical output in dB. There are various BER situation effects, such as the Q variable, as well as its reverse correlation (Figure9).

Q Factor opposed to attenuation will increase with the use of APD detection when the Q factor reduces the attenuation (Figure 10).

Attenuation	Power receiver	Q factor	BER
30	-33.148	17.60	$1.28*10^{-69}$
31	-34.148	14.08	$2.44*10^{-45}$
32	-35.148	11.25	$1.12*10^{-29}$
33	-36.148	8.98	$1.29*10^{-19}$
34	-37.148	7.17	$3.71*10^{-13}$
35	-38.148	5.72	$5.179*10^{-9}$
36	-39.148	4.57	$2.42*10^{-6}$
37	-40.148	3.65	0.00013
38	-41.148	2.92	0.0017
39	-42.148	2.34	0.0095
40	-43.148	0	1

Table2. Alterations of power Versus Q factor & BER for PIN.

Attenuation	Power receiver	Q factor	BER
34	-37.148	17.07	$1.30*10^{-65}$
35	-38.148	13.74	$3.06*10^{-43}$
36	-39.148	11.06	$9.736*10^{-29}$
37	-40.148	8.89	$3.01*10^{-19}$
38	-41.148	7.13	$4.857*10^{-13}$
39	-42.148	5.71	$5.42*10^{-9}$
40	-43.148	4.57	$2.36*10^{-6}$
41	-44.148	3.66	0.000125
42	-45.148	2.92	0.00169
43	-46.148	2.34	0.00952
44	-47.148	0	1

Table3. Alterations of power Versus Q factor & BER for APD.

Attenuation power is the inverse correlation when the attenuation power increases, reduced using APD detection (Figure 11).

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

Power budget result

Power alterations Versus Q factor and BER is shown in Table 4 for NRZ at 1550 nm.

Power alterations Versus Q factor and BER is shown in table 5 for NRZ at 1310.

Power alterations Versus Q factor and BER is shown in Table 6 for RZ at 1550 nm.

Power alterations Versus Q factor and BER is shown in table 7 for RZ at 1310.

Eye diagram for 1550 nm with attenuation and (RZ& NRZ) format is shown in Figures 12-13.

Eye diagram for 1310 nm with attenuation and (RZ & NRZ) format is shown in Figures 14-15.

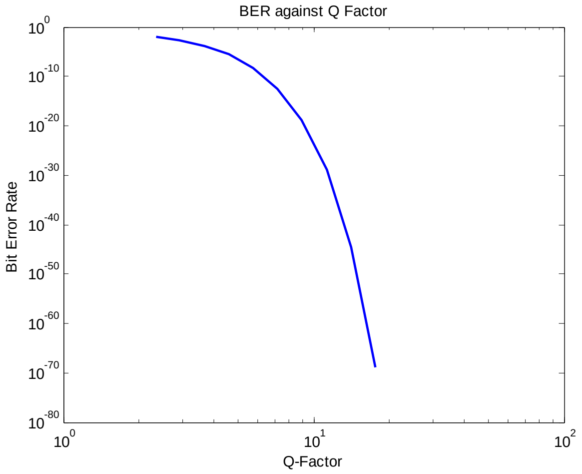


Figure4. BER Versus Q Factor for NRZ with PIN.

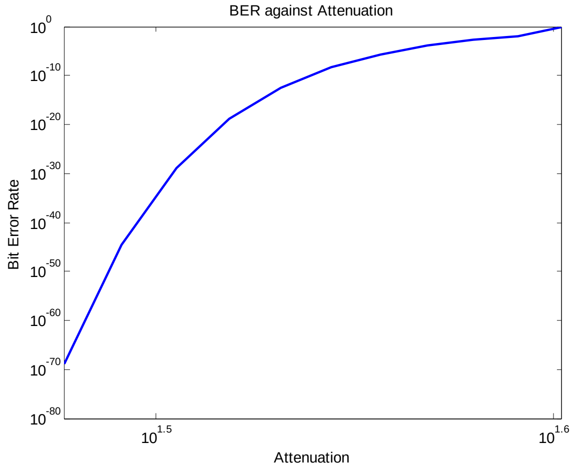


Figure5. BER Versus Attenuation for NRZ with PIN.

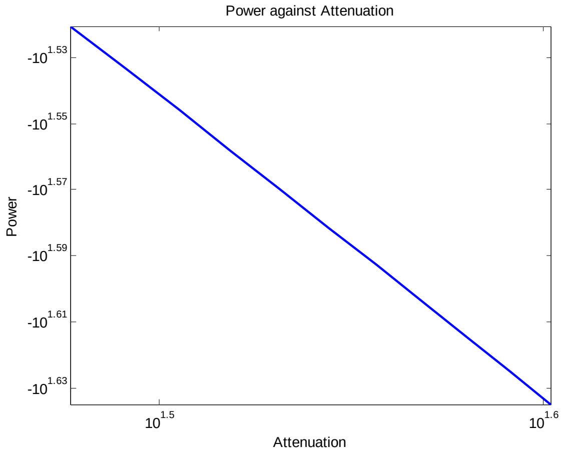


Figure6. BER Versus Attenuation for NRZ with PIN.

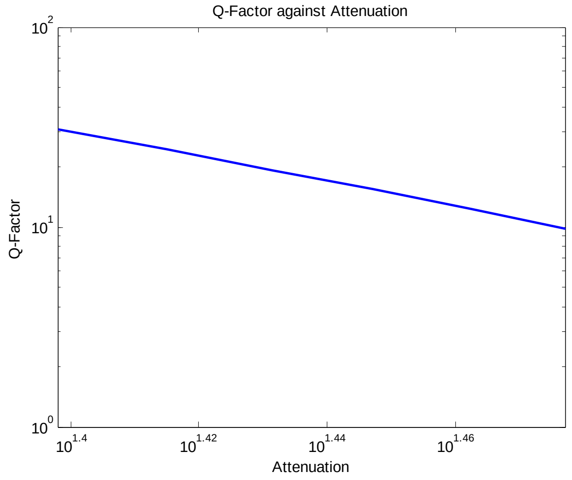


Figure7. Q-Factor Versus Attenuation for NRZ with PIN.

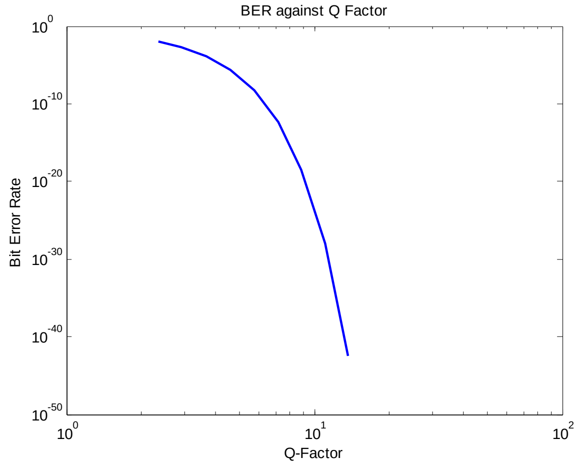


Figure8. BER Versus Q Factor for NRZ with APD.

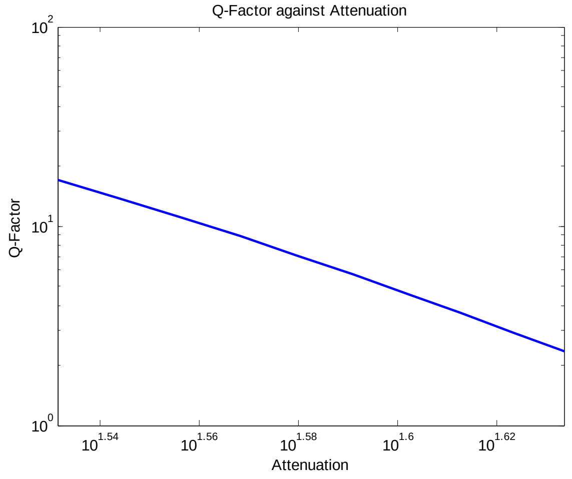


Figure9. Q Factor Versus Attenuation for NRZ with APD.

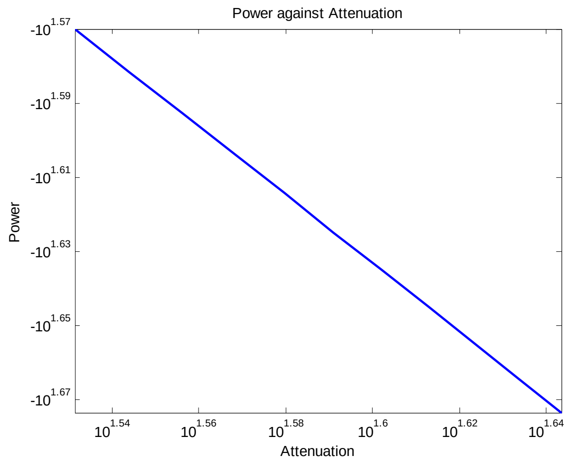


Figure10. Power Versus Attenuation for NRZ with APD.

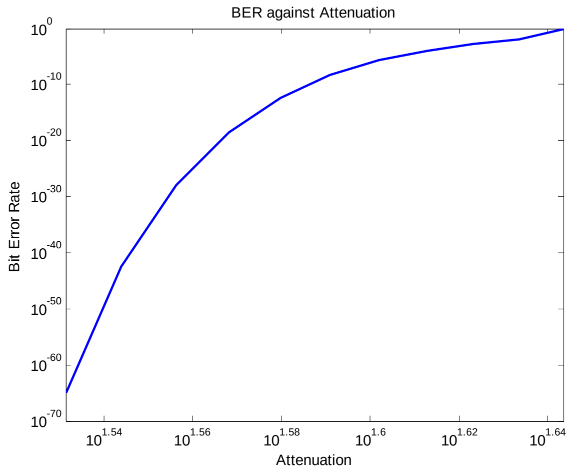


Figure11. BER Versus Attenuation for NRZ with APD.

Atten-uation	**Power source**	**Power receiver**	**Q factor**	**BER**
25	-3.910	-28.910	30.67	$7.03*10^{-207}$
26	-3.910	-29.910	24.37	$1.82*10^{-131}$
27	-3.910	-30.910	19.34	$1.18*10^{-83}$
28	-3.910	-31.910	15.40	$7.54*10^{-54}$
29	-3.910	-32.910	12.29	$5.15*10^{-35}$
30	-3.910	-32.910	9.81	$4.88*10^{-23}$

Table4. Power alterations Versus Q factor and BER for NRZ at 1550 nm.

Atten-uation	**Power source**	**Power receiver**	**Q factor**	**BER**
25	-3.910	-28.910	30.67	$7.03*10^{-207}$
26	-3.910	-29.910	24.37	$1.82*10^{-131}$
27	-3.910	-30.910	19.34	$1.18*10^{-83}$
28	-3.910	-31.910	15.40	$7.54*10^{-54}$
29	-3.910	-32.910	12.29	$5.15*10^{-35}$
30	-3.910	-32.910	9.81	$4.88*10^{-23}$

Table5. Power alterations Versus Q factor and BER for NRZ at 1310 nm.

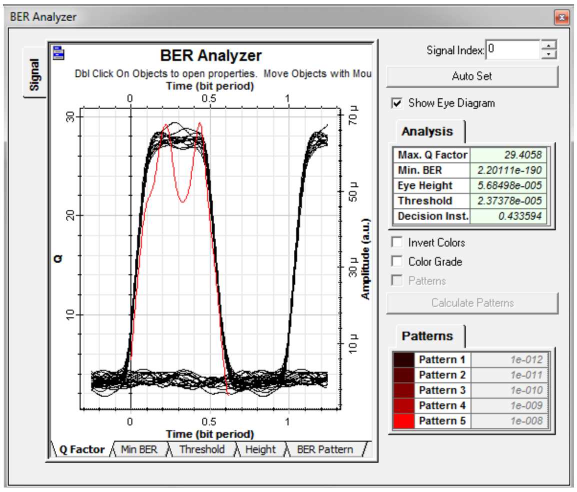
Atten-uation	**Power source**	**Power receiver**	**Q factor**	**BER**
25	-6.589	-31.588	29.406	$2.20*10^{-190}$
26	-6.589	-32.588	23.36	$4.97*10^{-121}$
27	-6.589	-33.589	18.57	$2.85*10^{-77}$
28	-6.589	-34.589	14.77	$1.17*10^{-49}$
29	-6.589	-35.589	11.75	$3.26*10^{-32}$
30	-6.589	-36.589	9.37	$3.58*10^{-21}$

Table6. Power alterations Versus Q factor and BER for RZ at 1550 nm.

Atten-uation	**Power source**	**Power receiver**	**Q factor**	**BER**
25	-6.589	-31.588	29.406	$2.20*10^{-190}$
26	-6.589	-32.588	23.36	$4.97*10^{-121}$
27	-6.589	-33.589	18.57	$2.85*10^{-77}$
28	-6.589	-34.589	14.77	$1.17*10^{-49}$
29	-6.589	-35.589	11.75	$3.26*10^{-}$

				32
30	-6.589	-36.589	9.37	$3.58*10^{-21}$

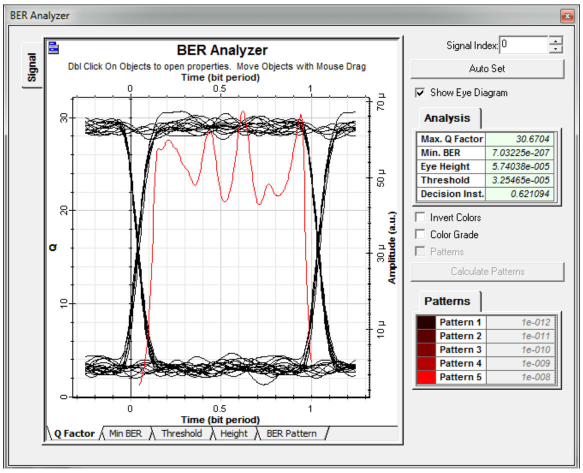
Table7. Power alterations Versus Q factor and BER for RZ at 1310 nm.



Max. Q Factor	29.4058
Min. BER	2.20111e-190
Eye Height	5.68498e-005
Threshold	2.37378e-005
Decision Inst.	0.433594

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

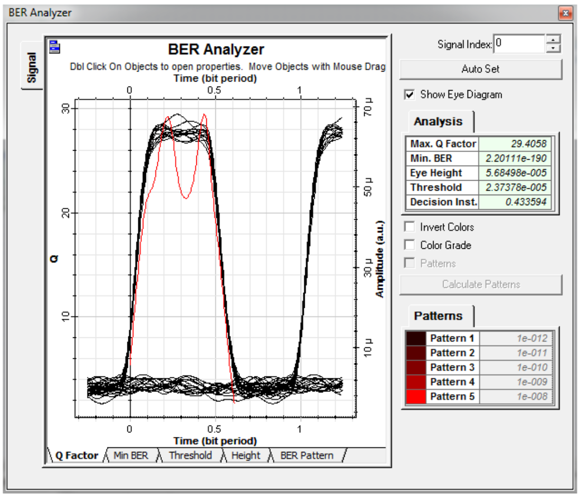
Figure12. Diagram for 1550 nm with 25 dB attenuation and (RZ) format.



Max. Q Factor	30.6704
Min. BER	7.03225e-207
Eye Height	5.74038e-005
Threshold	3.25465e-005
Decision Inst.	0.621094

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

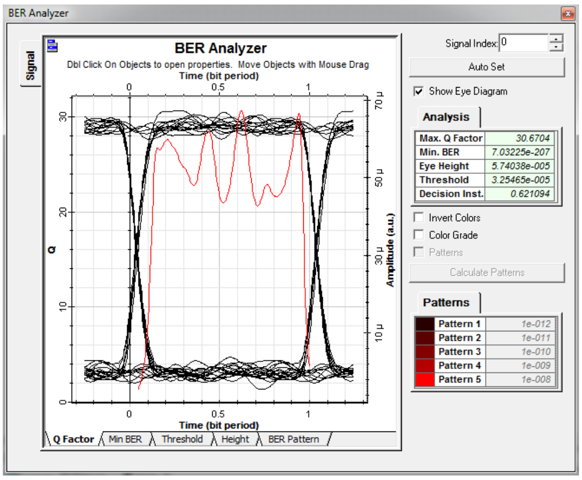
Figure13. Eye diagram for 1550 nm with 25 dB attenuation and (NRZ) format.



Max. Q Factor	29.4058
Min. BER	2.20111e-190
Eye Height	5.68498e-005
Threshold	2.37378e-005
Decision Inst.	0.433594

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Figure14. Diagram for 1310 nm with 25 dB attenuation and (RZ) format.



Max. Q Factor	30.6704
Min. BER	7.03225e-207
Eye Height	5.74038e-005
Threshold	3.25465e-005
Decision Inst.	0.621094

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Figure15. Eye diagram for 1310 nm with 25 dB attenuation and (NRZ) format.

IV. Conclusion

Receiver performance evaluation can be seen in the simulation run of the BER for optical fiber communication, the target is effective using the software program OPTISYSTEM and MATLAB. Data in terms of tables and graphs was obtained. Network, type of coding, optical fiber size, attenuation, wave frequency, data rate, power detection, noise identification and modulator classification are the parameters that were taken into account in the simulation.

The study found that for the PIN receiver the optimum energy is 35 and for APD 38.2. Findings have also shown that the APD receiver is more sensitive than the PIN detector which manages theoretical concepts. The wavelength of 1550 nm is good based on the previous criteria because it has less attenuation than 1310 nm and the NRZ signaling format provides the large range than using RZ signaling format.

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