# Analysis study of quality factor and bit error rate at wavelength change

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**ABSTRACT**

Gigabit-per-second data speeds can be achieved via free space optics (FSO) lines, which needless system complexity. On the other hand, the link's availability across a wide range of atmospheric circumstances is a major worry. As a result of the increased signal attenuation caused by the linkages being weather-dependent, their efficiency decreases. Up to 70 dB/km of attenuation can be caused by bad weather on a 500-meter free space optics link. In this work, transmission windows of 1310 nm, 850 nm, and 1550 nm are analyzed and compared using the free space optics link. by using the Simulation program opti system such as the quality factor, the minimal bit error rate (BER), and the eye diagram is taken into account. Analyzer findings are compared to establish the optimal wavelength for a transmitter under poor weather conditions.



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## 1. INTRODUCTION

An alternative to optical fiber or random forest (RF) systems, free space optics (FSO) uses light propagation in the free space to transport data between two sites. In situations where optical fibers are not an option, Figure 1 shows communications via optical wireless technology, divided into three stages: the first is the transmission, the second is the channel, and the third and final is the receiving stage. FSO systems can be utilized for a variety of purposes, including high-capacity internet access for the last mile and temporary high bandwidth data links. However, the weather can have an impact on FSO communication [1], [2]. FSO offers an unlicensed spectrum for local area networks, easy implementation, no electromagnetic signal interference, and a very fast data transfer rate, This method uses the visible and infrared wavelengths of the optical wave as a means of transmitting the information [3], [4]. Transmissions of light undergo several distortions due to atmospheric turbulence. The centroid of the transmitted beam is shifted by turbulent cells larger than the beam because of the beam's wandering distortion. By widening the beam radius, the beam spreading effect reduces the average intensity at the receiver [5]. Its extreme sensitivity to attenuation in adverse weather and turbulent air conditions makes it vulnerable to these significant free space optic advantages [6]. Fog, rain, snow, and haze all cause light beam loss due to absorption caused by molecule diffusion and scattering, turbulence, scattering, absorption, and attenuation are the basic mechanisms of signal attenuation [7], [8]. With the distortion that occurs in the atmosphere when it rains, electromagnetic waves cannot travel as far as they normally [9]. To start up communication using free space optic technology, it is necessary to maintain an apparent line of sight (LOS) between the transmitter and receiver. Attenuation produced by air conditions reduces the wireless channel's range and capacity [10]. Therefore, limiting the places and periods where the free space optic link can be used will limit its potential [4] free space optic technology relies on careful weather analysis and the use of different optical windows to limit the effects of rising signal attenuation for its bandwidth to be maximized [11].

The averaged field distributions along. the cavity length was used to construct new analytical models for semiconductor laser amplifiers. The electron concentration may be calculated using the charge conservation equation and this density. An effective spontaneous emission factor was used to quantify the total amplified spontaneous emission over wavelength without taking into consideration the link between gain and spontaneous emission and photon energy. Therefore, the goal of this contribution is to break from this basic assumption and incorporate actual models for gain and spontaneous emission as functions of photon energy and carrier concentrations. Optoelectronic amplifiers' maximum gains can be significantly increased by using anti-reflective coatings. As a result of the higher drive currents required by the amplified spontaneous emission, there is a practical upper limit to the amplifier gains that can be achieved by amplifying the device's maximum practical gain [12]. The three above-mentioned wavelengths were picked from the vast spectrum of spectral wavelengths due to the transmission qualities of available light sources. An information signal flowing through space has a substantially lower attenuation at these frequencies. Attenuation is a result of both absorption and scattering, which affects the quality of the signal. Therefore, these three infrared light wavelengths are chosen above others [13]. When wavelength division multiplexing (WDM) is used, WDM can boost system capacity because it sends many bit streams simultaneously [14].

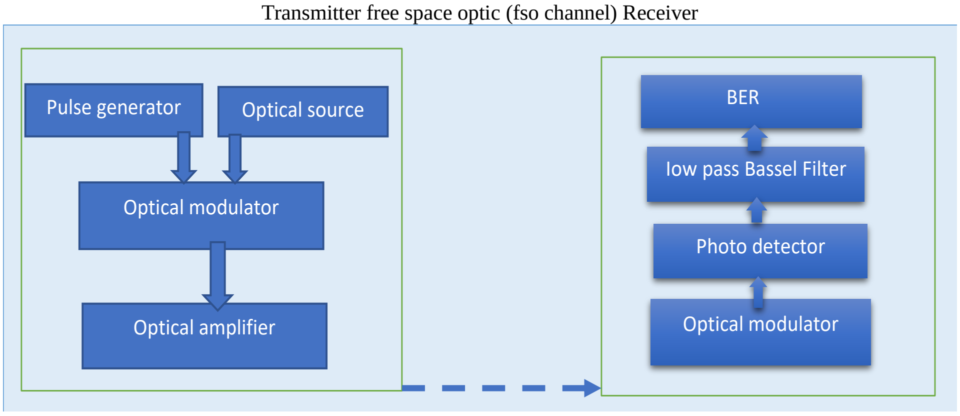


Figure 1. Communication via optical-wireless technology

## 2. SYSTEM DESCRIPTION

Figure 2 depicts the free space optic link, which includes the transmitter, atmospheric channel, and receiver. Electrical information streams are modulated into optical signals using a transmitter in the free space optic link (Figure 2) On its way through space, it is caught and turned into an electrical signal by the receiver. The transmitting module consists of a pulse generator, modulator, and transmitter. Information is transmitted using an electrical pulse generator in the link. After that, the signal is broadcast into the atmosphere by the transmitter. It is possible to transfer high-bandwidth digital data without the need for fiber optics using free-space optics (FSO). During the development of an FSO channel, the parameters describe the impacts of atmospheric turbulence and change scatter, absorb, and attenuate signals in the atmosphere. The most critical difficulty with a non-stationary link is the optical beam aiming inaccuracy (or "misalignment") between the transmitter and receiver [8], [15]-[17]. Figure 2 depicts the FSO link block diagram. Figure 2 depicts the FSO link block diagram.

The receiver, which incorporates an amplifier, a photodetector, a filter, and a BER analyzer, accurately decodes the information stream. The link's amplifier boosts the receiving signal's power. The photodetector converts optical signals into electrical signals before transferring them to the filter. The filter's primary function is to reduce external noise while allowing the intended wavelength of the signal to pass through it. Analyze the signal with the bit error rate (BER) analyzer. The BER measures the proportion of wrongly recognized bits received during transmission [18].

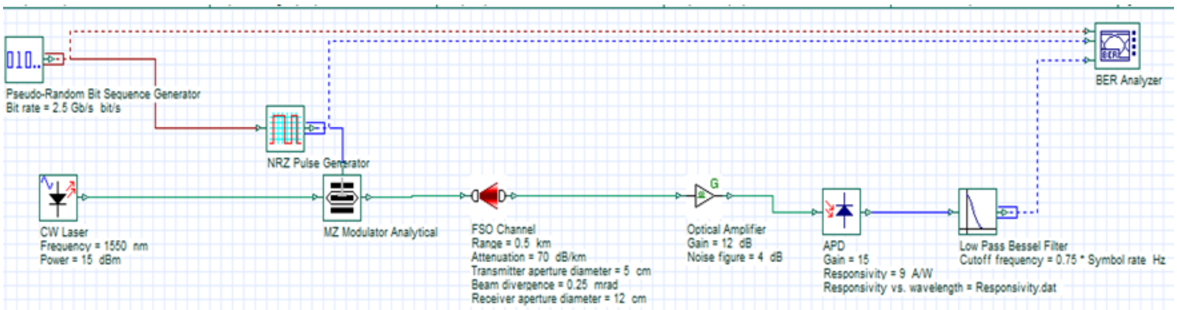


Figure 2. Depicts the FSO link block diagram

## 3. MATHEMATICAL MODEL DESCRIPTION

Many weather conditions can affect free space optic in the troposphere, which is where the transceivers are located in a terrestrial free space optic system. In states with poor visibility, such as rain, snow, fog, and clouds, communication is difficult. An empirical model can be used to estimate the attenuation effects of snow, rain, and fog [19], [20].

$$\alpha_{fog}(\lambda) = \frac{3.912}{V}\left(\frac{\lambda}{55*10^4}\right)^{-q} \quad (1)$$

Where: αfog (λ): total extinction coefficient: transmission wavelength in µm, V: visibility range in km, Q: scattering size distribution coefficient to droplet size distribution.

Approximations of the q parameter to Kim and Kruse's model for fog attenuation in clear or only foggy weather can be made [21], [22].

$$q = \begin{cases} 1.6\ (V \geq\ 50\ \text{km}) \\ 1.3\ (6\ \text{km} \leq V \leq\ 50\ \text{km}) \\ 0\ (V \leq 0.5\ \text{km}) \end{cases} \quad (2)$$

$$q = \begin{cases} 1.6 \text{ if } V > 50 \text{ km}, \\ 1.3 \text{ if } 6\text{km} < 50 \text{ km}, \\ 0.585V^{\frac{1}{3}} \text{ if } V < 6 \text{ km} \end{cases} \quad (3)$$

Absorption and scattering are two of the most common ways that optical signals lose power in open space. Water vapor, which is affected by carbon dioxide, humidity, and altitude, is the most common cause of absorption. Another mechanism of optical power loss is scattering, which results in a decrease in optical beam intensity over distance. Using (4), it is possible to calculate the scattering of an optical beam [23], [24].

$$\alpha_{scat}(\lambda) = \frac{17}{V}\left(\frac{550}{\lambda}\right)^{0.195V}, \text{db/km} \quad (4)$$

{λ}: is a transmission wavelength (in micrometers), and V is the visibility range (in Km). Atmospheric conditions affect the total attenuation of wireless signals.

$$\propto = \propto_{fog}(\lambda) + \propto_{snow} + \propto_{rain} + \propto_{scat}(\lambda), \text{dB/km} \quad (5)$$

Rain and fog can degrade the optical communication signal as it travels through the atmosphere. Fog is the primary source of attenuation for optical wireless links. We can't ignore the attenuation effect of rain in areas where fog is more common. With increasing droplet size, the refraction and reflection processes increase. The rain droplet's attenuation for a wireless optical link can be provided by [25], [26].

$$\propto_{rain} = 1.076\ R^{0.67}\ \text{dB/Km} \quad (6)$$

The mm/hour is the rate of rainfall (R). In terms of decibels per kilometer, snow's specific attenuation is given by [27] as (7).

$$\propto_{snow} = a\, S^{b}\, \frac{dB}{Km} \tag{7}$$

In computing, a "bit error rate" (BER) is a measure of how likely it is that an incorrectly identified bit will occur. The inverse relationship between BER and signal to noise ratio (SNR) may be seen in the graph below. The noise in large avalanche photodiodes (APD) receivers is thermally restricted, which is independent of the signal current. The following expression can be used to calculate BER to SNR [28].

$$\text{BER} \approx \left(\frac{2}{\pi.\text{SNR}}\right).\exp\left(\frac{-\text{SNR}}{8}\right) \tag{8}$$

## 4. ANALYZING SYSTEM MODELS BASED ON BER ANALYZER OUTPUT

We measure quality factor and bit error rate by bit error rate analyzer (BERA). Using three wavelengths (850 nm, 1310 nm, and 1550 nm). With each wavelength we use atmospheric attenuation (5, 20, 40, 70) dB/km for a distance of 500 m.

### 4.1. Distance 500 m with wavelength 850 nm

When connecting the circuit by using a distance of 500 m and a wavelength of 850 nm to find out the effect of the signal carried by the wavelength on the attenuation. We took the attenuation in the limits (5, 20, 40, 70) dB/km as shown in Figures 3 to 6). The results are in Table 1.

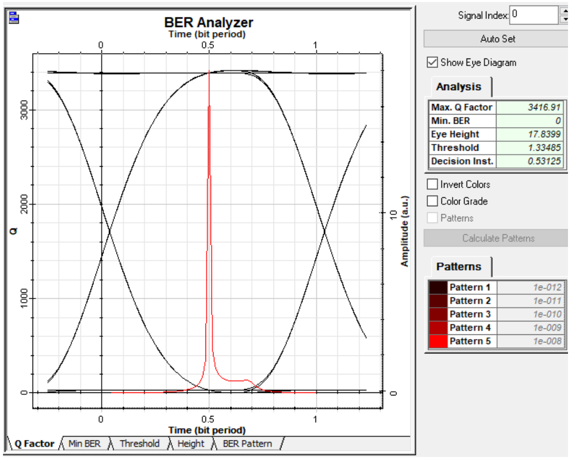


Figure 3. Analyzer output at 5 dB/km attenuation

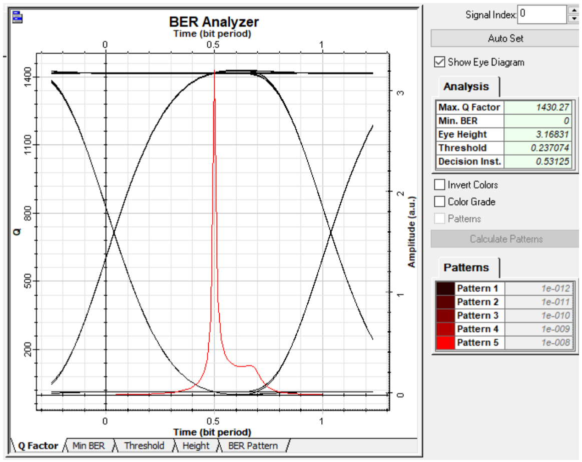


Figure 4. Analyzer output at 20 dB/km attenuation

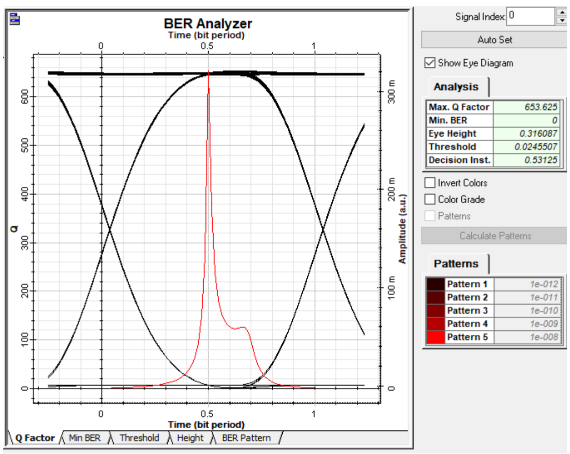


Figure 5. Analyzer output at 40 dB/km attenuation

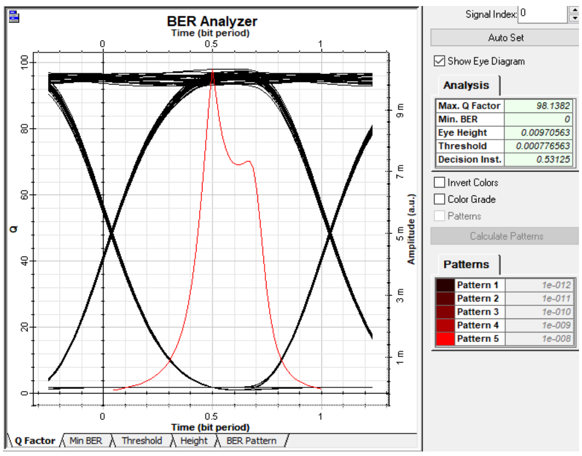


Figure 6. Analyzer output at 70 dB/km attenuation

Table 1. Wavelength 850 nm, distances 500 m

| Attenuation dB/km | Quality factor | Bit Error Rate (BER) |
|---|---|---|
| 5 | 3416.91 | 0 |
| 20 | 1430.27 | 0 |
| 40 | 653.625 | 0 |
| 70 | 98.1382 | 0 |

### 4.2. Distance 500 m with wavelength 1310 nm

When connecting the circuit by using a distance of 500 m and a wavelength of 1,310 nm to find out the effect of the signal carried by the wavelength on the attenuation. We took the attenuation in the limits of (5, 20, 40, 70) dB/km as shown in Figures 7 to 10). The results are in Table 2.

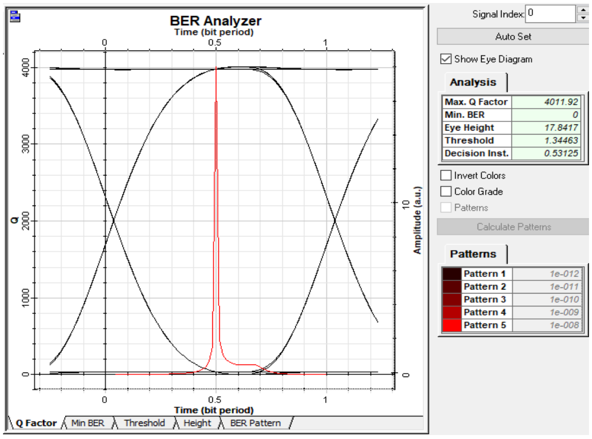


Figure 7. Analyzer output at 5 dB/km attenuation

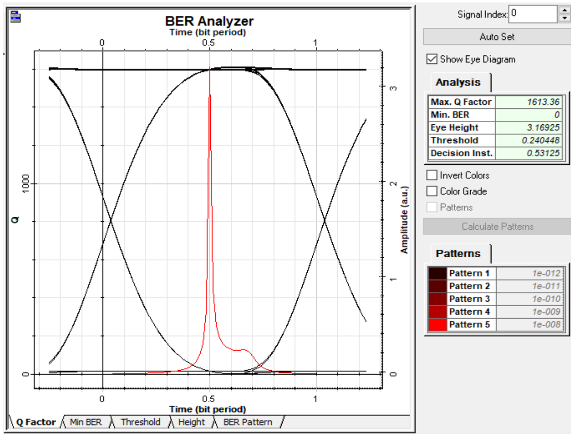


Figure 8. Analyzer output at20 dB/km attenuation

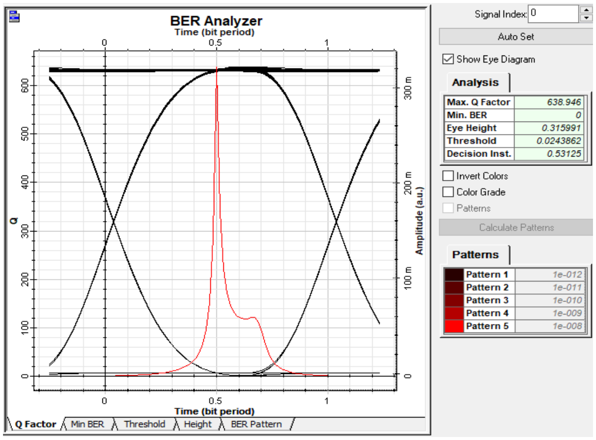


Figure 9. Analyzer output, 40 dB/km attenuation

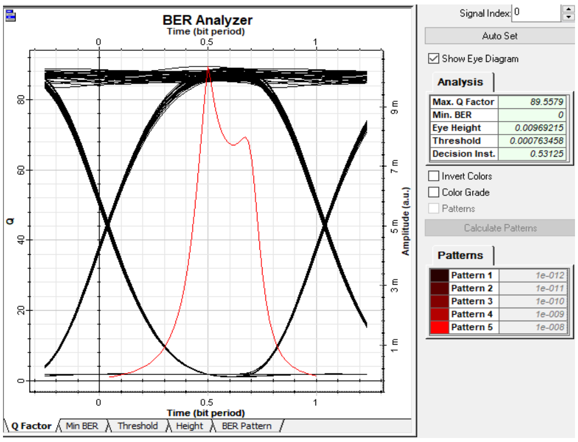


Figure 10. Analyzer output at70 dB/km attenuation

Table 2. Wavelength 1310 nm, distances 500 m

| Attenuation dB/km | Quality factor | Bit Error Rate (BER) |
|---|---|---|
| 5 | 4011.92 | 0 |
| 20 | 1613.36 | 0 |
| 40 | 638.946 | 0 |
| 70 | 89.5579 | 0 |

### 4.3. Distance 500 m with wavelength 1550 nm

When connecting the circuit by using a distance of 500 m and a wavelength of 1550 nm to find out the effect of the signal carried by the wavelength on the attenuation. We took the attenuation in the limits of (5, 20, 40, 70) dB/km as shown in the Figures 11 to 14. The results are in Table 3.

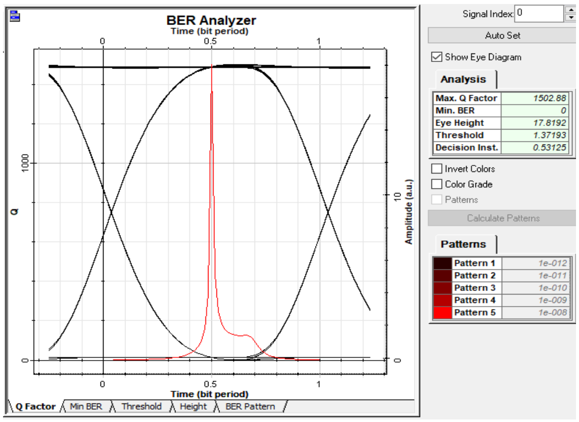


Figure 11. Analyzer output, 5 dB/km attenuation

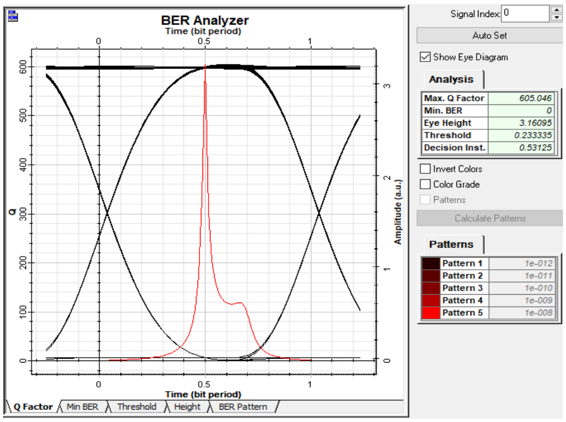


Figure 12. Analyzer output, 20 dB/km attenuation

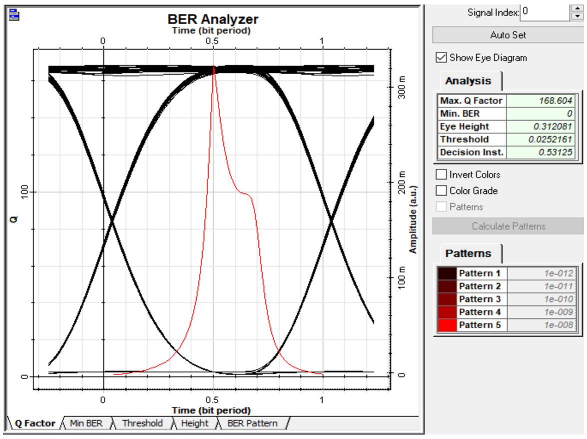


Figure 13. Analyzer output, 40 dB/km attenuation

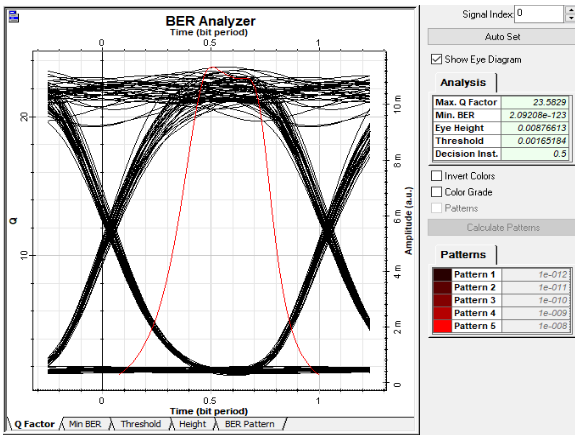


Figure 14. Analyzer output,70 dB/km attenuation

Table 3. Wavelength 1550 nm, distances 500 m

| Attenuation dB/km | Quality factor | Bit Error Rate (BER) |
|---|---|---|
| 5 | 1502.88 | 0 |
| 20 | 605.046 | 0 |
| 40 | 168.604 | 0 |
| 70 | 23.5829 | 2.09208 $e^{-123}$ |

Comparison between the results of Shaina and Gupta [13] and the proposed work, of the extent to which wavelengths are affected by attenuation on the quality factor and error bit adjustment, for a distance of 500 m as shown in Table 4. Using the origin program, to draw the relationship between Q-factor and attenuation, was plotted using three windows at 850 nm, 1310 nm, and 1550 nm for a distance of 500 meters, in the Figure 15 shown here the lower the distance the higher the quality factor and vice versa was found to be the case.

Tabel 4. A distance of 500 m

| Attenuation dB/km | 5 dB/km | | 20 dB/km | | 40 dB/km | | 70 dB/km | |
|---|---|---|---|---|---|---|---|---|
| | Q-factor | BER | Q-factor | BER | Q-factor | BER | Q-factor | BER |
| Wavelength 850 nm, 500 m Shaina and Gupta [13] | 2860.26 | 0 | 1112.54 | 0 | 195.015 | 0 | 8.1304 | 0 |
| (Proposed Work) | 3416.91 | 0 | 1430.27 | 0 | 653.625 | 0 | 98.1382 | 0 |
| Wavelength 1310 nm,500 m Shaina and Gupta [13] | 3000.90 | 0 | 1156.01 | 0 | 192.498 | 0 | 7.95898 | 8.66465e$^{-016}$ |
| (Proposed Work) | 4011.92 | 0 | 1613.36 | 0 | 638.946 | 0 | 89.5579 | 0 |
| Wavelength 1550 nm,500 m Shaina and Gupta [13] | 255.869 | 0 | 108.37 | 0 | 30.27 | 9.17421$e^{-202}$ | 2.95239 | 0.00153508 |
| (Proposed Work) | 1502.88 | 0 | 605.046 | 0 | 168.604 | 0 | 23.5829 | 2.09208$e^{-123}$ |

Quality factor (Q-factor), Bit error rate (BER)

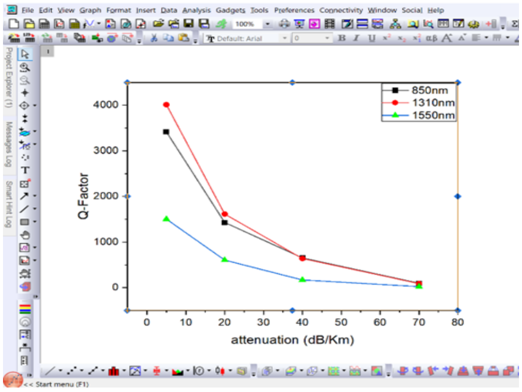


Figure 15. Relation between Q-factor and attenuation at (850, 1310, 1550) nm to distance 500 m

## 5. CONCLUSION

The 850 nm, 1310 nm, and 1550 nm optical transmission windows were utilized to evaluate the free space optic communication link in varied air circumstances over distances ranging from 500 meters. Under low attenuation conditions, propagation distance and bit error rate are observed to be greatest at 1550 nm wavelength. As a result, 1550 nm should be the wavelength of choice for low attenuation. It exhibits lower bit error rates under high attenuation situations because of its big Q factor and eye height, according to simulation data. Optical transmission at 1310 nm gives better outcomes and is safer for users than 850 nm transmission at 850 nm spectral lines 1310 nm attenuation values are the best for transmitting. Attenuation and quality were shown to increase in direct proportion to the distance traveled.

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