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# IMPACT OF TRANSMITTER POWER ON ATMOSPHERIC ATTENUATION OF FREE SPACE OPTICS LINK

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*Abstract*

***The free space optics (FSO) technology has become a very important means of wireless communication in modern world. But it suffers from atmospheric attenuation as the signal travels along free space. The free space optics link is very sensitive to local weather conditions and atmospheric turbulence. These problems causing attenuation can be overcome by increasing transmitter power. The investigation of bit error rate (BER) performance of FSO link using different transmitter power is presented in the paper. The objective of the paper is to produce analysis result of the different transmitter power on the weather attenuation that put a significant effect on FSO link. The results of FSO link has been evaluated in terms of Q factor, received power and Eye diagram.***

***Index Terms—Free space optics (FSO), Bit error rate (BER), Transmitter power, Q factor, Received signal power***

## I. INTRODUCTION

Free space optics (FSO) is the combination of two technologies that are wireless and fibre optics. It transmits data through invisible, eye-safe light beams from transmitter to receiver on another end using low power infrared lasers in the teraHertz spectrum. In FSO systems the beam of light from laser source is transmitted by focusing it on highly sensitive photo detector receivers. These receivers are telescopic lenses able to collect the photon stream and transmit digital data containing a combination of data messages, videos, images, radio signals or computer files. These commercially available systems offer capacities in the range of 100 Mbps to 2.5 Gbps, and these

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systems can provide data rates as high as 160 Gbps as the signal travels along the channel with the speed of light [1]-[2].
FSO systems can function over distances of several kilometres. As long as there is a clear line of sight between the optical transmitter and the receiver and sufficient transmitter power, FSO communication is possible. FSO is an optical technology that is different from radio and microwave systems. It does not require any spectrum licensing or frequency coordination with other users. Interference from or to other systems or equipment is not a concern, and the point-to-point laser signal is extremely difficult to intercept, and therefore secure. Data rates comparable to optical fibre transmission can be carried by Free Space Optics (FSO) systems with very low error rates, while the extremely narrow laser beam widths ensure that there is almost no practical limit to the number of separate Free Space Optics (FSO) links that can be installed in a given location.[3]-[4]
However, this technology is highly affected by the atmospheric attenuation due to different weather conditions and scintillations. Many researchers have studied these turbulence in terms of Bit error Rate (BER) and signal to noise ratio (SNR) [5]- [7]. So, the power and accuracy of the received signal decreases as it travels along the free space. Furthermore, FSO systems are also highly dependent on the power of the transmitter. The link equation for a FSO system is given as:

$$P_{received} = P_{received} * \frac{d_2^2}{[d1+(D*R)]^2} * 10^{(-a*r/10)} \quad (1)$$

Where, P = power,
d1 = transmit aperture diameter (m),
d2 = receive aperture diameter (m),
D = beam divergence (mrad), R = range (km),
a = atmospheric attenuation factor (dB/km).
In Eq. (1), the amount of received power is proportional to the amount of power transmitted and the area of the collection aperture but inversely proportional to the square of the beam divergence and the square of the link range. It is also inversely proportional to the exponential of the product of atmospheric attenuation coefficient times the link range [8-9].
In this paper this dependence of FSO link on transmitter power is analysed for different values of transmitted signal power at fixed signal attenuation.
The remainder of this paper is organised as follows. Section II comprises of system description and basic setup of the FSO technology. In the Section III, results are discussed for different behaviour of FSO link with variation in parameters. The conclusions are drawn in Section IV.

## II. SYSTEM MODEL AND PARAMETERS

The difference between FSO system and wired fibre optic communication system is only in the propagation medium. In FSO signal is transmitted in free space. The moisture, temperature and

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atmospheric pressure causes intensity fluctuations in the transmitted signal thus changing its refractive index and signal attenuation [10]. The block diagram of FSO link is shown in figure 1 below.

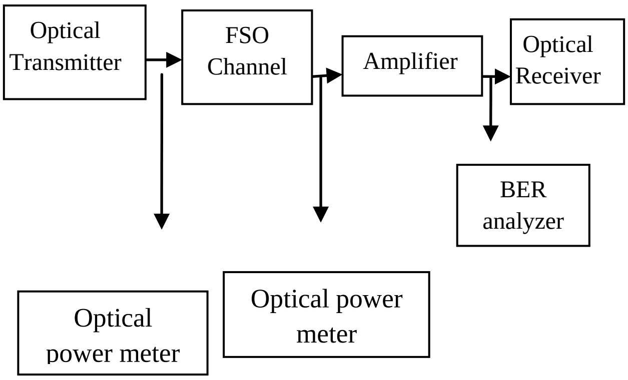


**Fig 1:** Block diagram of FSO system

**Table 1:** FSO link Specification

| Operating parameter | Value and Unit |
|---|---|
| Operating signal wavelength | 1550 nm |
| Link distance | 1 km |
| Signal transmitted power | 1<P, mW<45 |
| Atmospheric attenuation | 20dB |
| Transmitter lens diameter | 50 cm |
| Receiver lens diameter | 20 cm |

The optical transmitter consists of a Continuous Wave Laser, bit sequence generator, NRZ pulse generator and Mach-Zehnder modulator. The CW laser operates at the wavelength of 1550nm. The components of the transmitter should be chosen such that the signal that is to be transmitted in free space should be strong enough to mitigate the effects of atmospheric disturbances and can be recovered at receiver without much loss of information.

The receivers used in FSO systems are telescopic lenses that are able to collect the stream of light and transmit digital data containing a mixture of Internet data, video, images or computer files.

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The High sensitivity of receiver can be achieved by using detectors with internal gain mechanisms or, using small, low-capacitance photo detectors such as APDs. APD receivers can provide improvement of over 5-10 dB gain as compared to PIN detectors, along with increased cost and a more complex high voltage bias circuit. The FSO channel has very large bandwidth as it uses light as a carrier medium [11]- [12].

The output of FSO link is taken along BER analyser. BER is a criterion used to evaluate a performance of a FSO system, where it is the probability of non precision decision for the received bit stream. The performance of BER depends on the average received power, scintillations and receiver noise. The value of BER increases with the increase in link distance between transmitter and receiver. For reliable and efficient communication the minimum acceptable BER and Q factor is $10^{-9}$ and 6 [13]- [15]. The bit error rate can also be expressed in terms of signal to noise ratio (SNR) as:

$$\frac{2}{\pi.SNR}.\exp\left(-\frac{SNR}{8}\right) \qquad (2)$$

## III. RESULTS AND DISCUSSIONS

The FSO link with a link length of 1 Km operating at a wavelength of 1550nm with 20 dB atmospheric attenuation is evaluated in this paper. The wavelength used is compatible to 3rd window of optical communication and it is safer to human eyes as compared to other wavelengths [16].

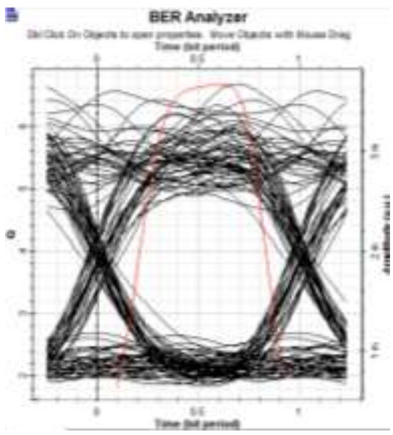


**Fig 2:** Output of BER analyser at 2mW transmitter power

The fig 2 presents the output of BER analyser at the transmitter power 2mW. It is clear from the above figure that the effect of attenuation on the signal having low transmission power is more as the curve of Q factor is having less sharpness and the height of eye diagram is very small in this case. It is clearly illustrating that the BER deteriorates with the distance and atmospheric attenuation at less transmitted power.

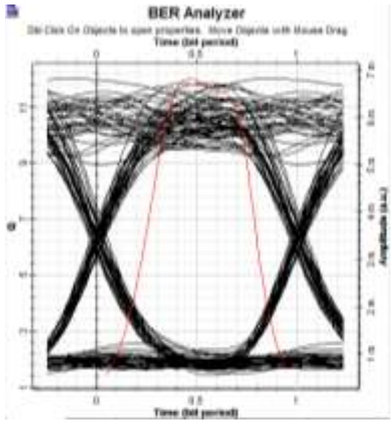


**Fig 3**: Output of BER analyser at 2mW transmitter power

Above figure is illustrating the output of BER analyser with transmitter power 5 mW. Here the value of Q has increased to 12 and received signal power is 2.520887 mW. Here it can be clearly visualised that eye diagram has improved with a slight increase in transmitter power.

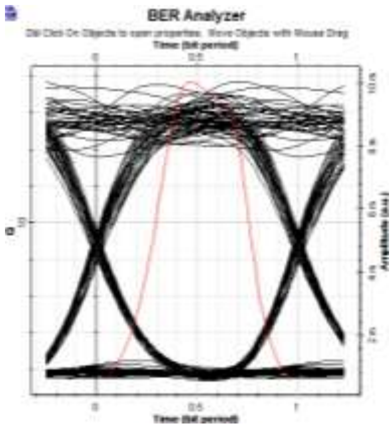


**Fig 4:** Output of BER analyser at 8mW transmitter power

Figure 4 illustrates the BER output against the transmitter power 8mW showing a marked improvement in the performance of analyser. Here the Q factor has increased to 17.7 and received signal power is 3.9301825 mW. The signal received at the receiver end in this case is more accurate and reliable in this case.
Under the transmitter power 10mW the performance of FSO link can be observed in figure 5 where Q factor has reached to 18.48 and received signal power is 4.9 mW. The figure shows that increase in power of transmitter can reduce that effect of atmospheric turbulence on FSO system.

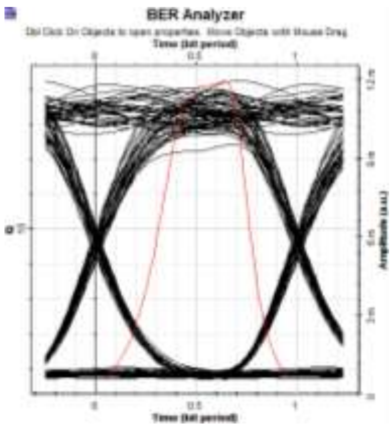


**Fig 5:** Output of BER analyser at 10mW transmitter power

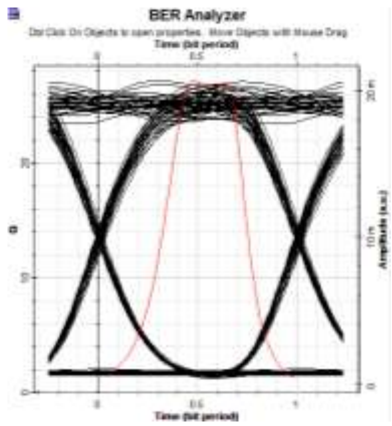


**Fig 6:** Output of BER analyser at 20mW transmitter power

When the transmitter power is increased to 20 mW the performance of FSO link can be analysed on BER analyser. In Figure 6 the height of eye diagram increases and the curve of Q factor become sharper. The received power is 8.7814544 mW which shows that signal received is good in quality and efficient.

To address the effect of highest transmitter power that is chosen, the figure 7 is introduced. It is showing the output of BER analyser with transmitter power 40 mW.

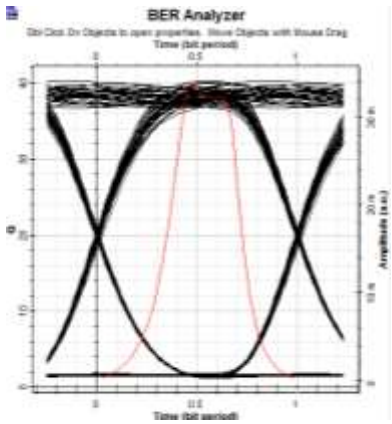


**Fig 7**: Output of BER analyser at 40mW transmitter power

Here Q factor has achieved a value 40.25 and received power a value of 15.18 mW. The curve of Q factor is sharper than previous values. The minimum bit error rate has achieved zero value that shows there is no loss of information as the signal travels along the channel. So with the increase in input power of the transmitter there is no error in the received signal and it is makes the FSO system more accurate, reliable and efficient for communication.

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**Table 1:** Different parameters compared with increasing power of transmitter

| | Different transmitter Powers | | | | | |
|---|---|---|---|---|---|---|
| | 2mW | 5mW | 8mW | 10mW | 20mW | 40mW |
| Max. Q factor | 6.66951 | 12.0212 | 17.7008 | 18.4839 | 27.1547 | 40.2575 |
| Min. BER | 1.13009e-011 | 1.13568e-033 | 1.61922e-070 | 1.02494e-076 | 7.78234e-163 | 0 |
| Eye height | 0.00117335 | 0.00383284 | 0.00671383 | 0.00832931 | 0.0164092 | 0.02293433 |
| Received signal power (mW) | 1.0190157 | 2.520887 | 3.9301825 | 4.9009829 | 8.7814544 | 15.180027 |

The results in table 1 shows the comparison of the main parameters that are Q factor, minimum BER, eye height and received signal power at different values of transmitter power. It is clearly indicating the dependence of performance of FSO link on power of transmitter. The more is the power of transmitter, the better is the output of BER analyser. The effect of atmospheric attenuation decreases on the signal having more power. Theoretically, it also shows that with the increase in transmitter power we can also increase the link distance.

As the power increases from 2mW to 40mW a significant improvement can be visualised in Q factor and minimum BER of the FSO link which shows the received signal quality improves thus improving the overall efficiency, accuracy and reliability of the data signal.

## IV. CONCLUSION

The paper deals with the analysis of dependence of FSO link attenuation on the distance covered by the link and the transmitted signal power. It is seen that as the power of transmitter is increased the quality of signal received at the receiver is improved. It is also observed that the signal travels longer distance with increase in power of the optical source. Moreover, from the experimental results, it is shown that the FSO communication systems can deliver improved link quality which can be confirmed by visualising the output of BER analyser at 40mW. The values of all four major parameters considered are improved to great extent as the power is increased from 2mW to 40mW.

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