Analysis of A Free-Space Optical Communication System Under Poor Weather Conditions For OTWS And Investigation of Optimal Optical Transmission Window

K.S. Solanki[1], Pankaj Bamnia[2]
[1]Assistant Professor, Dept of Electronics and communication Engineering
[2]Dept of Electronics and communication Engineering
[1, 2] Ujjain Engineering College

Abstract- *Gigabit per second data rates are available via Free Space Optics (FSO) links with minimal system complexity. The availability of the link under diverse atmospheric circumstances is a significant worry, though. Increase in signal since these links are greatly depending on the weather Under these circumstances, attenuation lowers the link efficiency. This study assesses the impact of inclement weather on an FSO link with a range of 600 metre and an attenuation of up to 60 dB/km. This paper analyses and compares the compatibility of three optical transmission windows—850 nm, 1310 nm, and 1550 nm—with the FSO connection. Considerable care is given to simulation variables like the Quality factor, the minimal BER, and the Eye diagram. In order to determine the transmitter wavelength that will provide reliable communication under challenging weather conditions, analyser findings for multiple transmission windows are compared.*

Keywords- Analyzer, Free Space optical communication, BER Analyzer, Optical Transmission Windows(OTW)

I. INTRODUCTION

Numerous people have been captivated by the Free Space Optics (FSO) method because it has demonstrated to be the finest answer to the last-mile communication issue in cities, It has emerged as a more effective substitute for Radio Frequency (RF) technology for the dependable and practical deployment of communication networks. Although RF wireless networks can deploy quickly and have data speeds of up to several hundred Mps, the growing user traffic, range restrictions, and limited bandwidth have created a number of problems for communication utilising this technology. Since FSO technology has a very large bandwidth of up to 2.5 Gbps, it can readily replace RF technology. In actuality, multi Gbps data rate transmission is ideally suited for FSO. For high-speed wireless communication, license-free bands, robustness, high data rate transmissions, high security, and little signal interference seem promising. The FSO link's effectiveness is heavily reliant on atmospheric attenuations, which is its only downside. Different atmospheric phenomena, including as snow, fog, and rain, absorb and scatter the sent signal, attenuating it before it is received at the receiver end. The fundamental challenge in setting up communication using FSO technology, especially in the troposphere, is maintaining an apparent Line of Sight (LOS) between the transmitter and reception ends. The range and the capacity of wireless channels are lowered as a result of air attenuation. Limiting the regions and periods will hence limit the FSO link's capability.

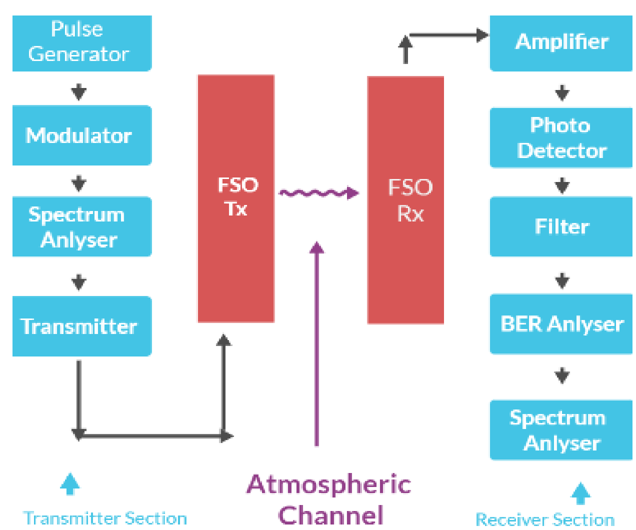

Figure 1 FSO Block Diagram

It is necessary to accurately characterise the extraordinary bandwidth of FSO technology in order to fully leverage its capabilities. using diverse optical windows of transmission to reduce the effects of growing signal attenuation and the impact of varied weather conditions. This study considers three optical transmission windows that are

Each of the wavelengths—850 nm, 1310 nm, and 1550 nm—has advantages. Equipment with an 850 nm working wavelength is typically less expensive than equipment with a greater operating wavelength.

There is 0% group velocity dispersion in the 1310 nm window. And at 1550 nm, optical fibre loss is at its lowest, with 0.2 dB/km. Low loss allows for a wide range of distances between the 3R repeater and optical amplifier. It is also safe for the eyes to use 1550 nm. If the link uses 1550 nm, an erbium-doped fibre amplifier (EDFA) can also be utilised in the FSO. The second-largest peak gain at this wavelength is provided by EDFA.

The three wavelengths described above were mostly selected from among the long wavelengths of the spectrum because they best match the transmission characteristics of the optical windows and the current light sources At these wavelengths, the attenuation of the information signal moving across empty space is significantly lower. Two variables, absorption and scattering, are the main causes of the signal attenuation that reduces the signal's quality. As a result, these three optical transmission windows are favoured over other infrared light wavelengths.

The main goal of the research is to identify the optical transmission window that, given the selected atmospheric parameters, is most suitable for FSO link. Using various optical transmission windows, comparisons are done in terms of Q factor, minimal BER, Eye diagram of received signal, and signal power. The remainder of the essay is organised as follows. The FSO system is described in Section 2.Section 3 shows the FSO Link simulation setup. In Section 4, the BER analyzer output is used to analyse the output of the FSO system. Section 5 describes the examination of the system output in terms of signal power, and Section 6 offers the conclusions reached.

II. SYSTEM DESCRIPTIONS

The transmitter, atmospheric channel, and receiver make up the FSO link. By converting the electrical information signal into an optical signal, the transmitter in the FSO connection transmits information signals in free space.

An optical signal that is travelling through empty space is picked up by a receiver and transformed into an electrical signal. A pulse generator, modulator, spectrum analyzer, and transmitter make up the transmitting module.

The link's pulse generator creates pulses that transmit information in electrical form. The scale of an input signal vs frequency throughout the device's whole frequency range is displayed using a spectrum analyzer. The signal is then sent through the transmitter over open space. Because of turbulence and other atmospheric changes, the signal is scattered, absorbed, and weakened in the atmosphere.

The following formula can be used to compute the total attenuation of a signal passing across an FSO communication link:

$$\alpha = \alpha\ fog_{\gamma} + \alpha\ snow_{\gamma} + \alpha\ rain_{\gamma} + \alpha\ scattering_{\gamma}\ , \qquad dB/km$$

where, α = attenuation and γ = is operational wavelength in µm.

For successfully retrieving the information signal, the receiver on the other end has an amplifier, light detector, filter, BER analyzer, and spectrum analyzer. The link's amplifier boosts the received signal's signal strength. After converting it to electrical form, the photo detector converts the incoming optical signal and transfers it. to filter the signal. The filter allows the signal to pass through at the correct wavelength while reducing the noise in the surrounding area. The correctness of the signal received is evaluated using the BER analyzer. The average likelihood of correctly identifying a bit out of all bits received is known as the bit error rate (BER).

III. SIMULATION SETUP

A planned Free Space Optical Communication system in an Optisystem software is depicted in Figure

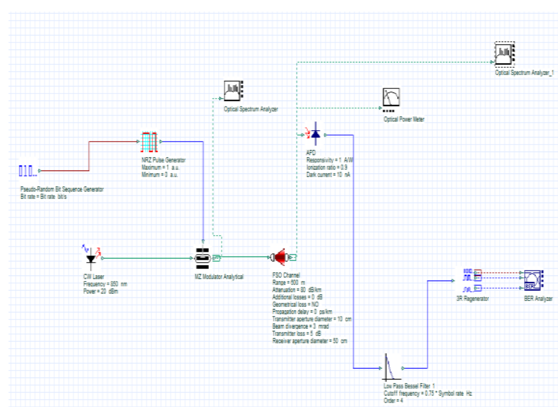

Figure 2 FSO Link Simulation

IV. ANALYSIS OF THE SYSTEM MODEL USING BER ANLYSER RESULT

Using a BER analyzer, the performance of the FSO system is examined in this section. A BER of 10^{-6} is equivalent to one error per million bits on average. For a dependable and long-distance communication system, the value of BER should ideally be 10^{-9} as the maximum error rate present in the receiving of bits.

$$\text{Mathematically, BER} = \frac{\textit{Number of Errors}}{\textit{Total number of bits sent}}$$

BER can also be defined in terms of the received information signal's signal-to-noise ratio as

$$\text{BER} = \frac{2}{\pi \text{SNR}} \cdot e^{-\text{SNR}/8}$$

Using a BER analyzer, the system's output is examined for three different optical transmission windows at air attenuation levels of 5 dB, 20 dB, 30 dB and 60dB respectively.

4.1 850nm

The initial optical transmission window to test the effectiveness of the FSO link is at 850 nm, where the transmitter is operating. The output of the FSO system, which has an operational signal wavelength of 850 nm, is shown in Figures 3, 4, 5, and 6. The signal experiences atmospheric attenuation while being sent across the atmospheric channel. The outcomes clearly demonstrate that even at an attenuation of 60 dB, the Q factor value is higher than the minimum value necessary of 6, and the minimum BER is less than 10^{-9}. The received signal power is determined to be 234.96 e^{-9}. The height of the eye at 60 dB is calculated to be 1.50705e-005.

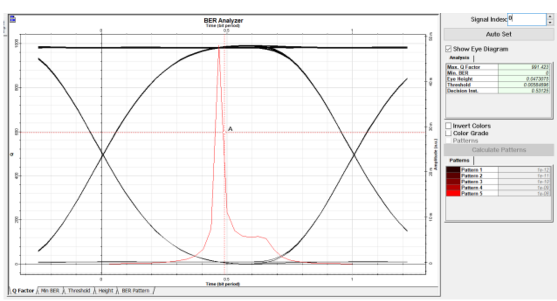

Figure 3

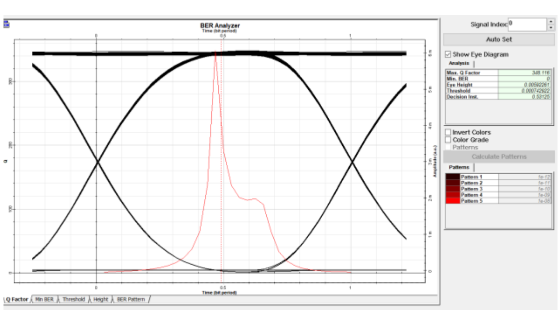

Figure 4

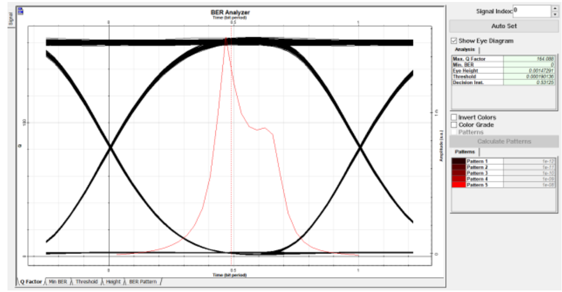

Figure 5

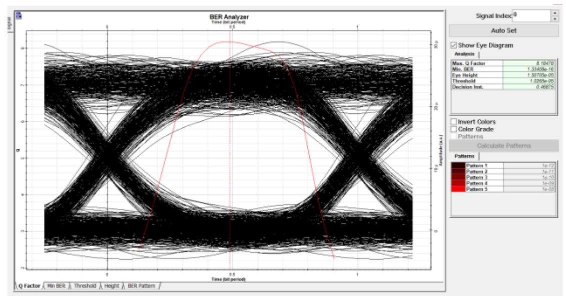

Figure 6

4.2 1310nm

1310 nm is the second optical transmission window used for the FSO link evaluation. Figures 7, 8, 9 and 10 display the FSO system's output at this wavelength. The transmitter device working at 1310 nm produces the best results, however not as well as 850 nm, as the signal attenuation increases up to 60 dB. Q factor falls to 8.42104, and BER is the lowest turns into 1.85238e-17. The predicted height of the eye diagram at this wavelength is 1.54242e-005, while the measured received signal power is 234.473e-009s.

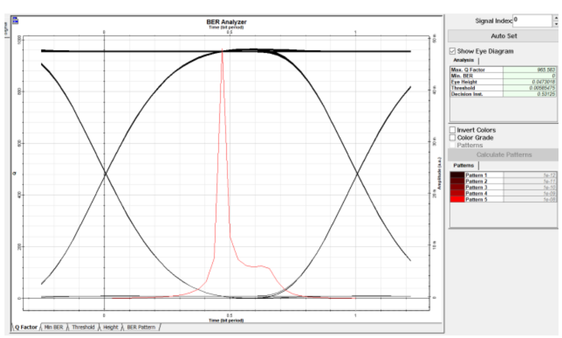

Figure 7

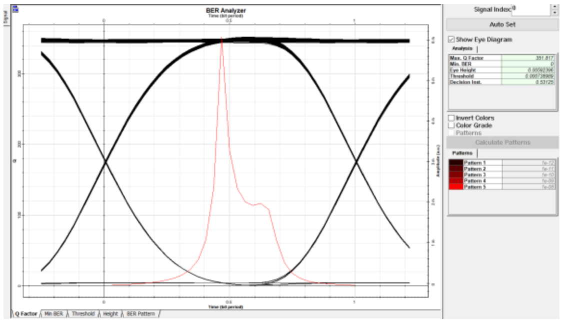

Figure 8

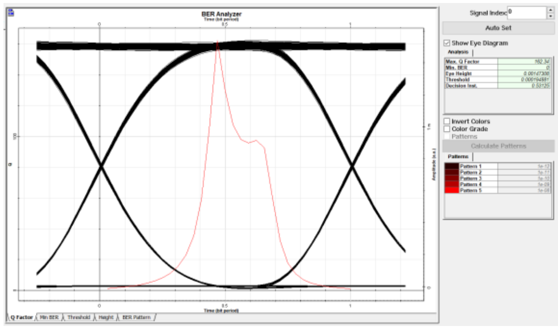

Figure 9

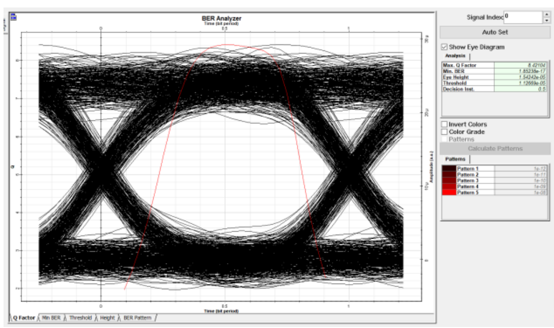

Figure 10

4.3 1550nm

Figures 11, 12, 13 and 14 display the FSO system's output at 1550 nm. The transmitter device operating at 1550 nm does not produce the best results with 60 dB attenuation since the Q factor drops to 8.3051 and the minimum BER is 4.88904e-17. The eye diagram's height is 1.5322e-005. First two optical transmission windows perform better than 1550 nm under high attenuation situations. The received signal power at this window is 236.42e-009 .

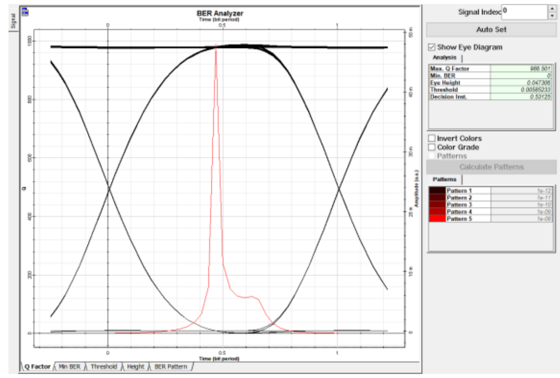

Figure 11

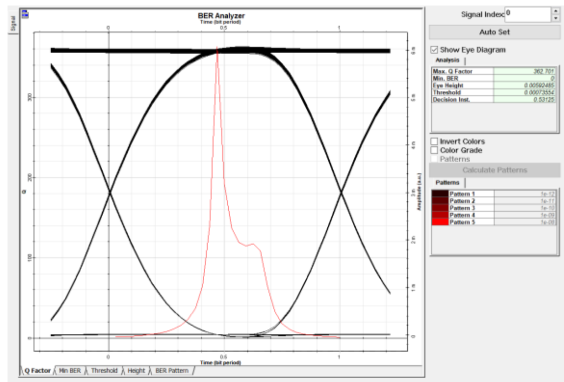

Figure 12

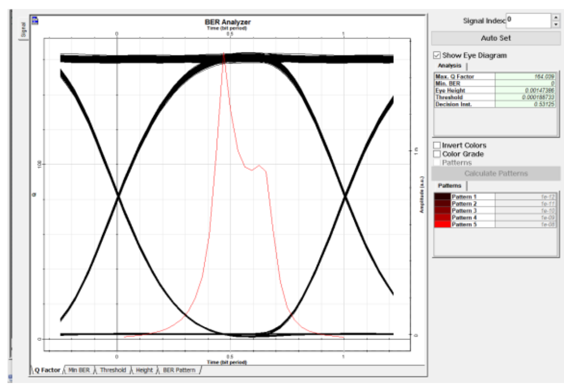

Figure 13

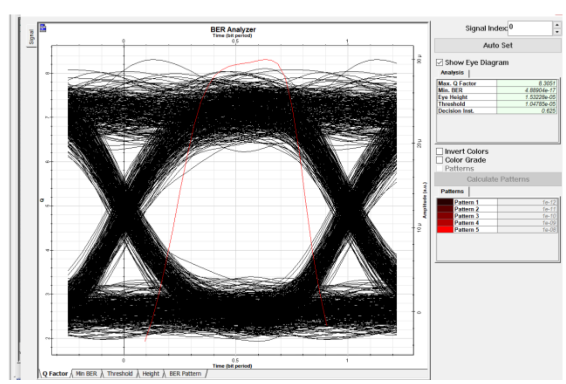

Figure 14

Table 1 compares the BER performance of links utilising various optical windows at varying attenuation levels. When compared to both windows with high optical transmission, the first optical window has displayed the lowest BER.

Table 1 Comparison chart of BER values of the signal received

Attenuation in dB/km	850 nm	1310 nm	1550 nm
5 dB/km	0	0	0
20 dB/km	0	0	0
30 dB/km	0	0	0
60 dB/km	1.33408e-16	1.85238e--17	4.88904e^{-17}

Figures 3-14 show that for all three optical transmission windows, BER rises as attenuation value increases. In comparison to the 1550nm window, the 1310nm window has provided a lower bit error rate. Because all three windows have insignificant BERs under low attenuation conditions, 1550 nm should be favoured for user safety. However, 1310 nm is advantageous under high attenuation situations because it has a higher Q factor, lower BER, and is safer than the 850 nm gearbox window.

The quality factor above compares the effectiveness of the FSO link for various optical windows. It is evident that the window at 1310 nm produces superior outcomes to the other two optical windows. Similarly, the comparison of the eye height measured at various attenuation values for various optical windows also contributes to the conclusion that this window is best used under high attenuation conditions.

V. ANALYSIS OF THE SYSTEM MODEL USING THE SPECTRUM ANLYSER'S OUTPUT

A high-precision measuring device called a spectrum analyzer displays the power distribution of a light source over a certain wavelength. Wavelength is tracked horizontally, while power is tracked vertically. One of its applications is testing LED and laser light sources.

Figures 15, 16, and 17 show the spectrum analyzer output prior to transmission, while figures 18, 19, and 20 show the output following transmission when three distinct optical transmission windows—850 nm, 1310 nm, and 1550 nm—are used. For various optical windows, it shows the transmitter signal intensity. Before the gearbox, the power is always almost exactly 17 dBm.

However, a 60 dB signal attenuation results in a reduction in signal power as seen in the spectrum analyzer output.If additional optical windows are utilised, it can be seen that the signal power at the receiver is -37.2726 dBm for 850 nm, -38.3377 dBm for 1310 nm, and -39.6268 dBm for 1550 nm after suffering an attenuation of 60 dBm.

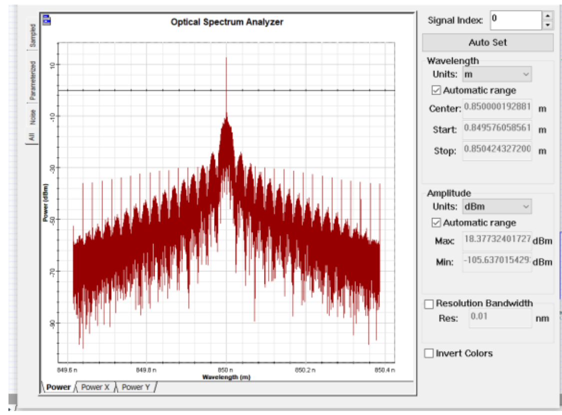

Figure 15

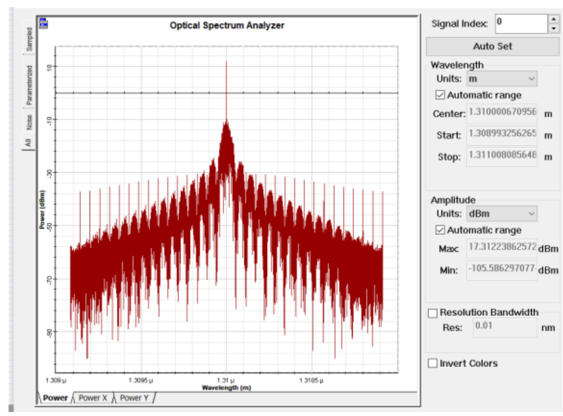

Figure 16

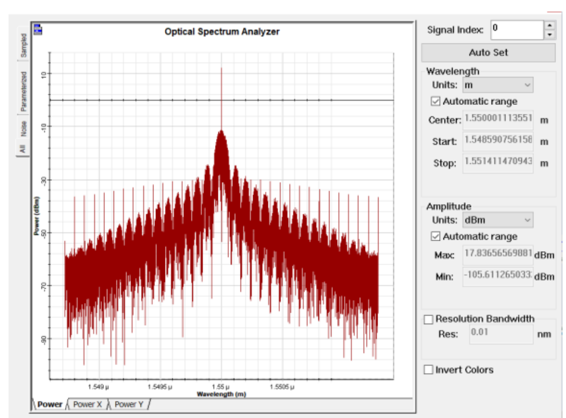

Figure 17

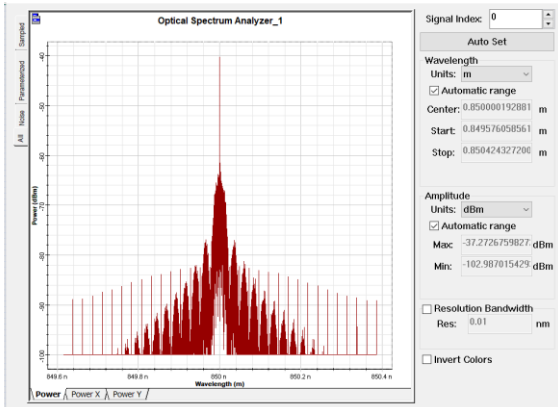

Figure 18

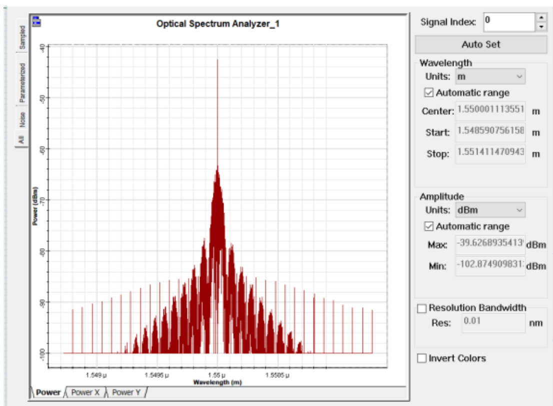

Figure 19

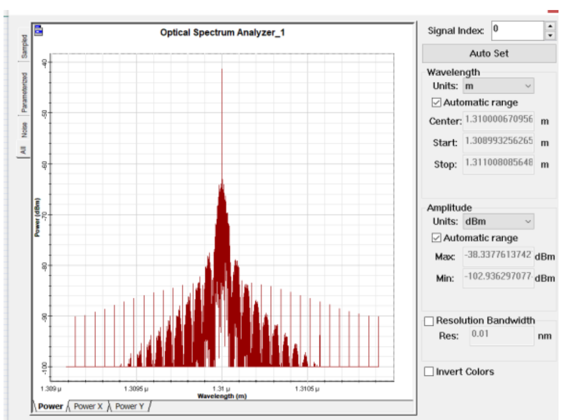

Figure 20

VI. CONCLUSION

The FSO connection has been examined using three optical transmission windows with wavelengths of 850 nm, 1310 nm, and 1550 nm under varying ambient conditions. Under low attenuation conditions, it has been discovered that at 1550 nm wavelength, propagation distance is maximised and BER is lowered. Therefore, 1550nm should be used in environments with little attenuation. The simulation results demonstrate that the 850 nm operational optical window results in a significant Q factor and height of eye and, as a result, decreased bit error rates under high attenuation conditions. The second optical transmission window, at 1310nm, works better under high attenuation conditions and is more user-friendly than the first window, at 850nm. As a result, gearbox at high attenuations is suitable in the 1310nm window.

REFERENCES

[1] Optical Networks, Last Mile Access and Applications, Journal of Optical Fibre Communications Research, vol. 2(1), pp. 56-85, (2005).

[2] Atmospheric Channel Effects on Free-Space Laser Communication, J. C. Ricklin, S. M. Hammel, F. D. Eaton, and S. L. Lachinova, Journal of Optical Fibre Communications, vol. 3(2), pp. 111-158, (2006).

[3] Free Space Optical Communication Through Atmospheric Turbulence Channels, X. Zhu and J. M. Kahn, IEEE Transactions on Communications, vol. 50(8), pp. 1293-1300, 2002.

[4] Free Space Optics in Various (Civil and Military) Application Scenarios in Combination with Other Wireless Technologies, 16th IEEE International Conference on Telecommunications Network Strategy and Planning Symposium (Networks), pp. 1–7, (2014). E. Leitgeb, T. Plank, M. Loschnigg, and P. Mandl.

[5] Multiple Scattering in Rain and Fog on Free-Space Optical Links by M. Grabner and V. Kavicera, Journal of Lightwave Technology, vol. 32(3), 2014, pp. 513-520.

[6] Integrated Service Quality Enhancement of Wireless Optical Communication Systems for Long Haul Transmission Distances, Canadian Journal on Electrical and Electronics Engineering, vol. 2(12), pp. 557–570, (2011). E. N. A. Mohamed, H. A. Sharshar, A. N. Z. Rashed, and A. El-Nabawy.

[7] Gupta, R. S. Kaler, and H. Singh, "An Unparalleled Scheduling Method for Optical Burst Switched Networks," Optik-International Journal for Light and Electron Optics, vol. 124(8), no. 8, 2013, pp. 689–692.

[8] Understanding the Performance of Free-Space Optics, S. Bloom, E. Korevaar, J. Schuster, and H. Willebrand, Journal of Optical Networking, vol. 2(6), 2003.

[9] Weather-Insensitive Optical Free-Space Communication Using Gain-Saturated Optical Fibre Amplifiers, IEEE Journal of Lightwave Technology, vol. 23(12), (2005). M. Jeong, J. Lee, S. Kim, S. Namgung, J. Lee, M. Cho, S. Huh, Y. Ahn, J. Cho, and J. Lee.

[10] Er. Sagar and Rajesh Goel, "Data rate analysis and comparing the effect of fog and snow for free space optical communication sys- -tem," ICRTEDC, vol. 1, pp. 47-51, 2014.

[11] "Weather effects impact on the optical pulse propagation in free space," VTC Spring 2009 - IEEE 69th Vehicular Technology Conference, 2009. M. S. Awan, E. Leitgeb, F. Nadeem, M. S. Khan, and C. Capsoni.
[12] "Performance of an optical wireless communication system as a function of wavelength," Appl. Opt.Applied Optics, vol. 42, no. 21, pp. 4285, 2003.
[13] "Comparison of laser beam propagation at 785 nm and 1550 nm in fog and haze for optical wireless communications," SPIE, vol. 4214, pp. 26-37, 2001. I. Kim, B. McArthur, and E. Korevaar.
[14] "Comparing the effect of fog and snow induced attenuation on free space optics (fso) and rf links," International Journal of Computer Science and Technology, vol. 3, pp. 554-556, 2012