Improved Filtration Based Q-Factor for Free Space Optical Communication under Effect of Haze

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***Abstract*: In recent times, the FSO communication has became more prominent than other optical communication systems due to its inimitable characteristics like high bandwidth, license free spectrum, easy implementation, high security, etc. However, there are several constrains that limit the performance of FSO system and the most significant one is the effect of different weather conditions and atmospheric attenuation. This climatic turbulence greatly affects the FSO system performance that is associated with the visibility of various climatic states. It has been analyzed that as compared to other weather conditions, haze condition mainly affects the FSO and leads to increase in attenuation. which then results in high Bit Error Rate and degraded quality factor. Therefore, to overcome this issue, the optical filter is introduced in this paper in order to reduce the noise. Along with that, the amplification technique is introduced in the proposed system in order to boost the signal. It will help to minimize the attenuation which can lead to enhanced quality factor and minimum BER which can then make the system more efficient. The proposed approach is then implemented and various parameters are considered for the simulation i.e. BER, Q-factor and power attenuation at different distances in the haze weather condition.**

***Index Terms*: *FSO, Atmospheric turbulence, Haze effect, Optical filter, Amplification*.**

I. Introduction

The demand for communication devices having high data rate is growing rapidly that leads to great interest in wireless communication. The RF (Radio Frequency) is saturated by the number of wireless communication standards. The modern communication essentially requires an alternate to the RF communication. The FSO (Free Space Optical) communication emerges as an alternate to the RF. In the wireless communication field, this technique is rising at a fast rate.

FSO is the LOS (Line of Sight) communication technique. It makes use of light propagation for transmitting the data from the source to the destination via free space [1]. In figure 1, the FSO system block diagram is illustrated. As shown, the FSO system includes transmitter, free space channel and receiver. The FSO working principle is alike Fiber Optical Communication (FOC), though, they only differ by their transmission channel. In the FSO, the data is sent via unguided free space. The FSO supports various kinds of multilevel and binary modulation formats. Though, in order to choose the modulation formats, various parameters must be considered such as transmission energy and bandwidth requirement and enviable FSO application speed.

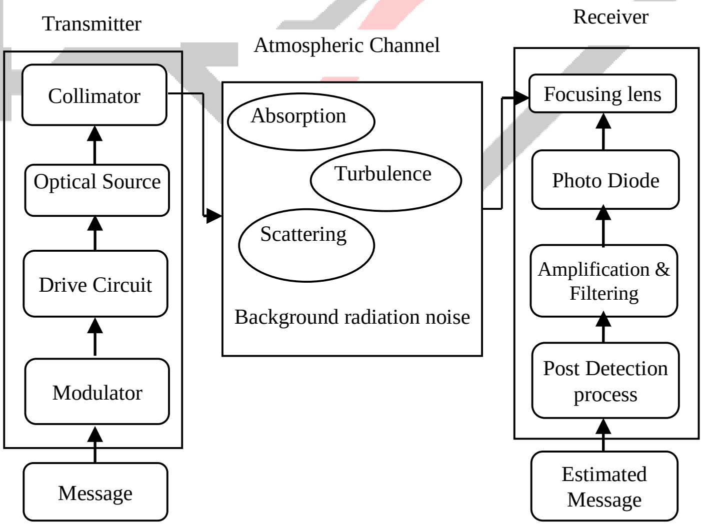

Figure 1: Block Diagram of FSO System

Due to utilization of optical carrier, the maximum bandwidth and the spectrum free from license is allowed in FSO. The optical signal interception is extremely intricate that leads to great communication security. Thus, for the broadband networks having fast speed, FSO is more appropriate than RF transmission as it has high level of security, great bandwidth, license-free spectrum, easy implementation and low energy utilization [2]. Also, for the utilization of the transmission channel, not any permission is required in FSO. Due to this, the cost of deployment and time of setup get reduced. In addition, the places where fiber placement is intricate, FSO can be implemented there.

Thus, the numerous advantages of FSO makes it more efficient than conventional communication techniques, however, there are various factors that hindered its growth such as:

- **Building Motion:** For FSO communication, the alignment among transmitter and receiver is the main requirement. There is improper alignment among transmitter and receiver because of Building motion that effects in losing total connection at receiver, along with lowering the standard of signal. Building motion takes place due to continues movement of different factors such as wind, vibration of high load machines or thermal expansion.
- **Atmospheric Losses because of Weather (because of fog, rain, haze, etc.):** The atmospheric losses are caused mainly because of absorption and scattering of optical signal. These two effects greatly depend upon wavelength.CO2, ozone and water molecules cause absorption in the FSO. And the different particles present in atmosphere (smoke, fog, dust, snow and raindrops) cause scattering [3], [4].
- **Atmospheric Turbulence:** Due to atmospheric turbulence, there occurs arbitrary fluctuation in the received signal's intensity and phase. This results in degraded quality of the received signal and minimizes the distance of link deployment. It can also take place in the clear climatic condition and even during day and night. Therefore, it is major issue of the FSO system [5].

These factors decrease the distance of link deployment or interject the communication. The issue of building motion can be addressed by automatic beam monitoring system or high beam divergence. In order to overcome the atmospheric losses because of bad climatic condition, FSO can be operated at higher wavelength. Though, not any efficient measure is there for issue of atmospheric turbulence. Various researchers has analyzed the effect of atmospheric turbulence and weather conditions on the FSO and also presented different diversity techniques, FSO channel models and various other turbulence mitigation techniques and some of these are discussed in the next section:

II. Related Work

The factors such as distance and weather affect the performance and quality of FSO adversely. The author in paper [6] scrutinized and simulated the impact of number of receiver and transmitter on the FSO system performance under various climatic states like clear, fog and haze. The use of transceivers was made for improving the FSO system nature.

In [7], the evaluation of FSO availability was performed on the basis of forecasted climatic attenuations because of haze and rain. With the help of CDF (cumulative distribution function), the combined impact of rain and haze was demonstrated.

The authors [8] contrasted the integrated results of rain, fog and turbulence on the links of FSOI and an appropriate modulation approach was presented for enhancing the spacing among transmitter and receiver. Thus, in this paper, an idea was provided that which modulation approach is efficient for the outdoor atmosphere and for number of users.

The paper [9] presented the examination of link budget for FSO and different studies for minimizing the effect of attenuation for enhancing the FSO link.

The author in paper [10] contrasted the different modulation approaches performance i.e. NRZ-OOK and RZ-OOK, in the FSO in various climatic states like clear weather, haze, fog, haze, medium and mild rain, at 1550 nm wavelength. It was observed that performance of NRZ approach is better as compared to RZ and for all the climatic conditions.

The authors in [11] examined the attenuation coefficient for various climatic conditions. The impact of different weathers such as snow, rain, and fog on the FSO link performance was analyzed with respect to attenuation coefficient and provided a study of FSO link turbulent nature using Gamma-Gamma Turbulence Model.

In [12], a novel approach was described for mitigating the intensity fluctuations induced by turbulence i.e. fading of signal (under rain and haze effects). The precedence in optimizing transmission factors was determined in the novel approach for attaining the transmission with high data rate and low BER and link attenuation.

The paper [13] aimed to integrate the spatial diversity approach to the FSO OFDM in order that establishment of improved FSO link can be done.

In [14], the MIMO spatial diversity approaches effect was studied when utilized in FSO communication link under turbulence and different weather states like clear air, haze, drizzle, fog etc.

The spatial diversity FSO system performance in terms of BER was examined in [15] utilizing OOK modulation. In this study, the author has taken into account interrelated log-normal FSO channels and path losses because of effect of weather by utilizing intensity modulation as well as direct detection approaches.

However, the spatial diversity is extremely complex and expensive.

The paper [16] aimed to provide the FSO link scrutiny and simulation with the real data, on the haze condition under 2 wavelengths i.e. 850nm and 1550nm. The various attenuation rate performing operation among transmitter and receiver and their effect on the link margin measurement was discussed in this paper.

In paper [17], author had utilized Optisystem simulation for measuring the FSO performance in Haze climatic condition in Malaysia by considering different distances from 30 m to 1.5 km. The efficient results in FSO in haze weather were provided by the calculation in which maximum 1 BER was measured for the 1500m distance and -34.42 dBm of power transmission loss was measured. Thus, from the analysis, it has been analyzed that the haze condition leads to increase in attenuation.

Though, due to increased attenuation, the noise can get introduced in the system which then results in high BER and degraded quality factor. Thus, it is required to reduce the noise factor in order that an efficient system can be achieved.

III. Present Work

After studying the previous work that has been done in the field of optical communication, it has been analyzed that haze condition majorly effects the attenuation of signal due to which the noise can get introduced in the system which then leads to degraded system performance in terms of BER and quality factor.

Therefore, to overcome this issue, the optical filter will be introduced in the proposed work in order to reduce the noise. The filter rejects all inputs above a certain frequency or outside of a small band of frequencies near the signal. Bessel Optical filter will be used in the proposed work as it has more flat phase delay and group delay and better shaping factor. Also, it has been analyzed that its performance in terms of Q-factor is efficient than other filters.

Along with that, the amplification technique will be introduced in the proposed system in order to boost the signal. The amplification will help to minimize the attenuation which can lead to enhanced quality factor and minimum BER which can then make the system more efficient. For amplification, the techniques i.e. post-amplification and pre-amplification will be analyzed in the proposed work. Therefore, the proposed work will help to achieve a system with low attenuation and high quality.

This proposed FSO system is implemented in simulink environment and its performance is analyzed in terms of different parameters and the results obtained from the simulation are discussed in the next section:

IV. RESULTS AND DISCUSSION

In the simulation of proposed work, the FSO link has been created in the hazy conditions. The simulink model of the proposed FSO system is represented in figure 2:

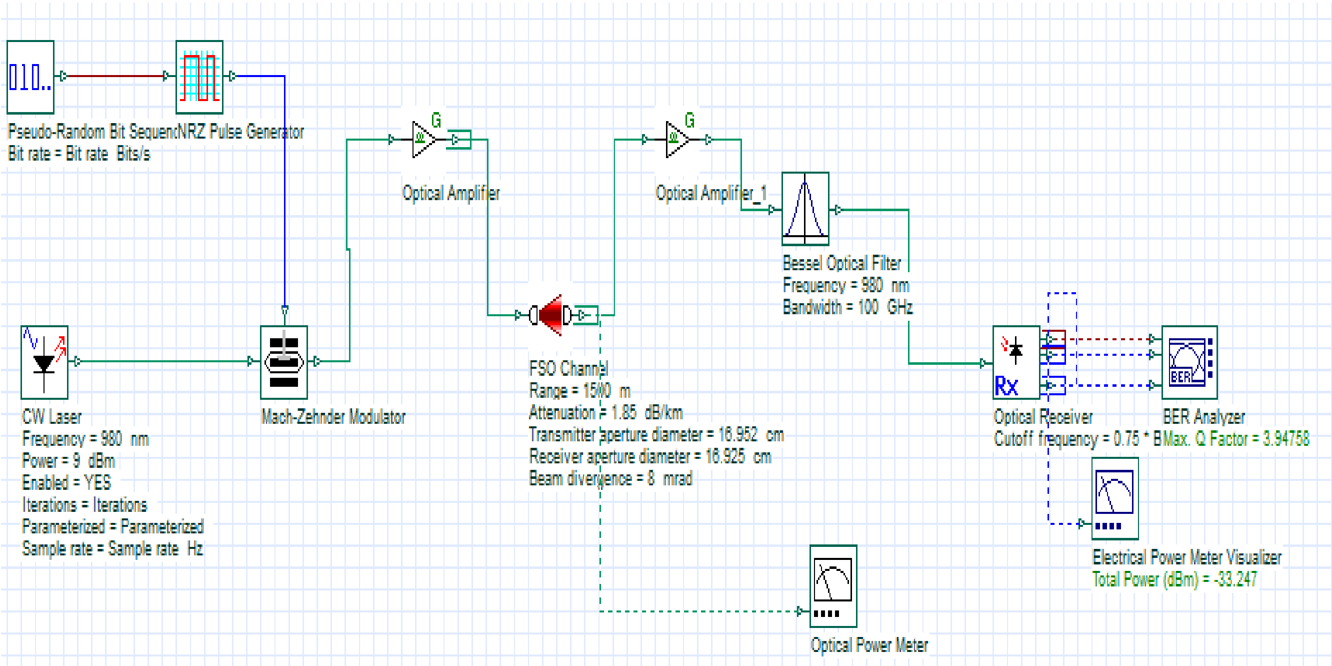

Figure 2: Simulink model of the proposed FSO system

Firstly, the optical transmitter is placed utilizing laser having 980nm wavelength and 9dBm of optical power. In order to produce data, a Pseudo-random bit sequence generator with Non-Return to Zero (NRZ) pulse generator is utilized and the produced data is modulated using Mach-Zehnder modulator. After this, the transmission of signal is performed via atmosphere, where length of FSO link and atmospheric attenuation set to different distances. Before, transmitting the modulated data to the FSO channel, the pre-amplifier is implemented before FSO channel that will amplify the signal. The amplifier will help to boost the signal strength. Then, the post-amplifier is also implemented after FSO channel. After performing amplification, the signal will then filtered using optical filter for which Bessel Optical filter is used. This filter helps to reduce the noise due to attenuation. The optical receiver is placed at another end which transforms the optical signal back to the digital data. In order to evaluate the FSO performance, the BER analyzer, electrical power meter visualizer and optical power meter are used for visualizing the simulation value.

The performance of this proposed model is analyzed in terms of different parameters i.e. BER, Q-factor and eye diagram for different distances. The results obtained from the simulation are discussed as below:

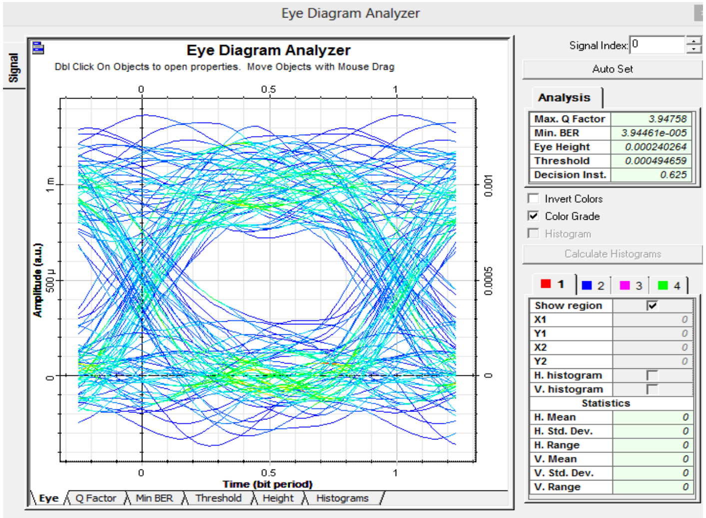

Figure 3: Eye Diagram at 1500m in haze

The largest distance considered in the proposed work is 1500m and in terms of this distance, the eye-diagram is analyzed for the hazy weather, the obtained graph of which is represented in figure 3. The obtained graph clearly represents that at high distance, the signal is highly distorted.

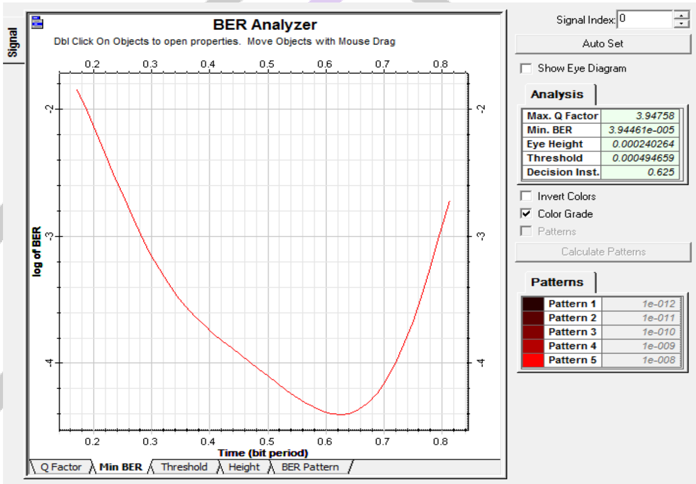

Figure 4: BER at 1500m in haze

The effect of hazy weather on the BER performance of the proposed FSO communication system is analyzed and the resultant graph is represented in figure 4. As shown in graph, at initial times, the value of BER is high which then started decreasing gradually with increase in time, however, by reaching at certain bit period, it then started increasing. Here, the minimum BER value obtained is 3.94461e-005.

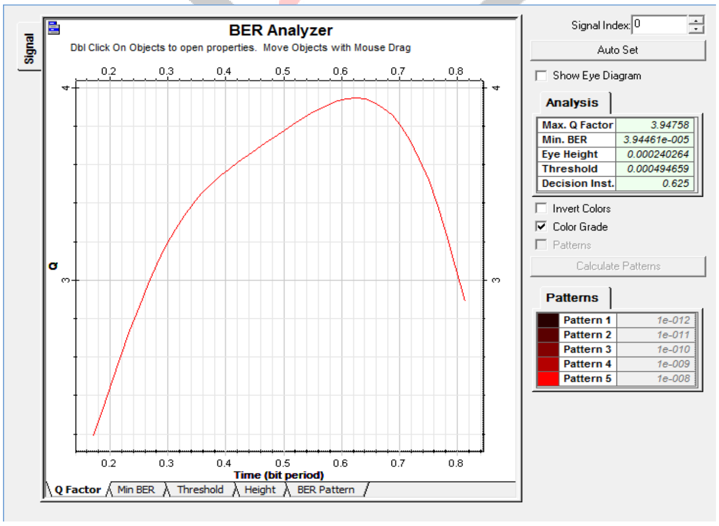

Figure 5: Q-Factor at 1500m in haze

The effect of haze on the Q-factor performance of the proposed FSO system is also analyzed and the obtained result is exemplified in graph 5. It can be seen from the obtained graph that at initial times, the Q-factor value is low and with increase in time, it also get increases, and by reaching at certain bit period, it then started decreasing. The maximum Q-factor value attained at distance of 1500m in the haze condition is 3.94758.

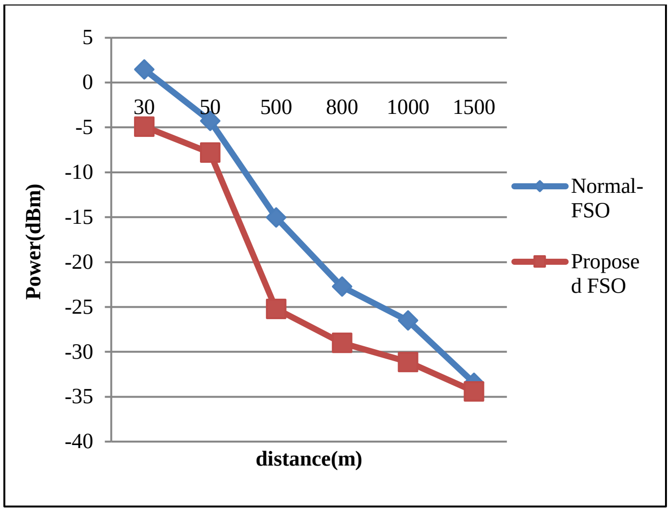

Figure 6: Comparison in terms of haze power attenuation at different distances

Also, the comparison analysis has been performed between proposed FSO and previous normal FSO system in terms of haze power attenuation at different distances, and the obtained graph of comparison analysis is shown in figure 6 this graph, the value of power is calibrated along y-axis which varies from -40 to 5 dBm, and value of distance is shown along x-axis that has different values i.e. 30m, 50m, 500, 800m, 1000m and 1500m. The graph represents that in both the FSO systems i.e. proposed and normal, the power levels drop rapidly with increase in distance. However, the power attenuation in case of proposed FSO is less than that of normal FSO. The power attenuation of proposed FSO system is -4.9 dBm at distance 30m, whereas, that of normal FSO at same distance is 1.465 dBm, which is higher than proposed one. Similarly, at all different distances, power attenuation of proposed FSO is minimum than normal FSO. Also, the values imply that FSO system is efficient for small distances only.

V. Conclusion and Future Scope

The FSO is gaining a great interest in recent times. The reliability of FSO link is adequately high rather than in stern climatic conditions like dust, fog, rain, haze, etc. In fact, haze is regarded as a main challenge for FSO as it result in high attenuation and BER and thus the link performance gets adversely affected due to it. Thus, in order to alleviate the system performance impairments in this climatic condition, an enhanced FSO system is designed in the proposed work in which optical filter and amplifier (pre-amplifier and post-amplifier) are used in order to reduce the noise due to attenuation and boost the signal strength. The proposed FSO system is then implemented in the simulink environment. In order to analyze the performance of the proposed system, various significant parameters of simulation i.e. BER, eye diagram height, power attenuation and QoS are considered. While designing FSO system, the haze attenuation and different distances i.e. 30m, 50m, 100m, 800m, 1000m and 1500m are regarded. The comparison analysis of the proposed FSO system and normal FSO system is also performed and it illustrates that in terms of power attenuation, proposed FSO system has efficient performance as it has low attenuation than normal FSO system. As proposed FSO system has enhanced performance than previous normal FSO system in haze condition, however, its efficiency decreases with increase in distance.

Thus, in future, the multi-beam FSO can be used in order to reduce the haze attenuation effect and BER and to increase Q-factor.

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