Research Article

Study of Various Adverse Weather Conditions in Free Space Optical Communication Network and Their Impact on FSO link

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ABSTRACT

Using light propagation in free space, Free Space Optics (FSO) is a new technique for Line-of-Sight communication that offers a number of benefits including high bandwidth, fast data rate, ease of installation, free licence, and secure communication. As a result, FSO is a developing technology with a wide range of Line-of-Sight Communication applications. However, the various effects, such as attenuation on the FSO communication link due to environmental factors and weather conditions, such as fog, rain, dust, sandstorms, clouds and temperature, as well as the other factors, such as range, are an important topic for study and are covered in this paper. We used the Opti system software to simulate the impacts of fog and rain on the FSO communication link.

KEYWORDS

FSO, Line of Sight communication,Weather condition,Environmental factors

1. INTRODUCTION

The need for high data rates in many applications is growing daily in our digital age. Hence, a system that can offer a solution with low cost implementation, trustworthy outcomes, and secure data transmission is required. A great solution that can offer Line of Sight communication speed, security, and low-cost implementation is a Free Space Optical (FSO) link. As we are aware, optical communication offers a greater level of security for transmission than other types of transmissions, and FSO can give such high data rates in Gbps. Since FSO has significant benefits including a large bandwidth, secure transmission, high data rate, low cost implementation, free licencing, and many more, it may be used in a variety of applications.

The FSO communication technology is used for short-range point-to-point or point-to-multipoint data transfer, line-of-sight inter-building communication, and inter-satellite communication. Yet, it is also crucial to analyse and talk about a variety of different impacts that can disrupt or make FSO communication less dependable so that, in accordance with the study, we can discover a solution and make this technology fully advance able.

The impact of various weather conditions on transmission is the largest obstacle for FSO communication. Since FSO communication occurs in free space, we must take into account the various effects of various weather conditions. As a result, FSO loses its reliability for data transmission in bad weather. Over the many benefits of FSO communication, this is a significant flaw. Hence, the effects of various weather circumstances like fog, rain, sand storms, and extreme temperature should be investigated with the real implementation parameters like range, input power, optical source, wavelength, and numerous other factors before setting up a link of FSO communication.

The impact of weather conditions, particularly fog and rain, is the main problem with the FSO communication link. So, we ran simulations in the Opti system to determine the best implementation settings for a variety of weather scenarios, including fog and rain, for the FSO link. Some of the weather conditions are described below.

A) FOG

Visible radiation is significantly reduced by fog. The obstruction brought on by fog absorbs, scatters, and reflects optical beam of light. The main goal of Mie scattering, also known as fog scattering, is to increase the transmitted power.

B) RAIN

Rainfall causes rain to attenuate, which is a non-selective scattering. This kind of attenuation doesn't depend on the wavelength. The fluctuation effects in laser delivery can be created by rain. The amount of rain has an impact on the FSO system's visibility. When it rains heavily, the solid water droplets can either change the characteristics of an optical beam or prevent it from passing by because the optical beam is absorbed, scattered, and reflected.

C) HAZE

Haze particles can linger in the atmosphere for a longer period of time, which might weaken the atmosphere. As a result, attenuation values depend on the current visibility level. There are two ways to collect data on attenuation for evaluating the operation of an FSO system: first, by temporarily placing the system at the site and evaluating its functionality; and second, by using the Kim and Kruse model.

D) SANDSTORMS

The most common issue with outdoor connection communication is sandstorms. They can be distinguished in two ways: first, by the size of the wind particles, which is dependent on the texture of the soil; and second, by the wind speed required to blow the particles up in a short amount of time.

E) SMOKE

It is produced by the burning of several materials, including carbon, glycerol, and domestic emissions. It has an impact on the transmission medium's visibility.

F) CLOUDS

Earth's atmosphere is primarily composed of cloud layers. Condensation or deposition of water above the earth's surface causes clouds to develop. It can entirely obstruct optical beam portions that are transferred from the earth to space. Because of the diversity and in homogeneity of the cloud particles, it is difficult to calculate the attenuation brought on by clouds.

G) SNOW

The bigger particles in snow are what contribute to the geometric scattering. The impact of the snow particles is comparable to Rayleigh scattering.

2. DESCRIPTION OF FSO LINK

The fundamental technology of the FSO transmission link is described, as well as the impact of different weather situations including rain and fog.

2.1 FSO Link Technology

The FSO operates on the same principles as optical fiber communication. However, we do not need optical fibre in FSO. Instead, we employ empty space as a conduit. We use an optical source, such as an LED or laser, to turn the incoming data bits "1" and "0" into pulses of invisible light for line-of-sight communication with the FSO. The transceiver then transmits the narrow-beam laser pulses that were targeted into the air. Another transceiver that is operating as a receiver within line-of-sight range takes in optical pulses using lenses and converts them into bits of "1" and "0" using an avalanche photodiode or phototransistor before connecting to a network.

As attenuation is least at 1310 nm and 1550 nm, these optical transmission windows are preferred as is required by system. Since the frequency spectrum is in GHz, there is a sizable amount of bandwidth that may be used for transmission, allowing for high data speeds. Since laser sources are more reliable than LED sources, they are chosen.

The range fluctuates depending on different free space factors. There are many benefits, including low cost, simple implementation, no side lobes, secure transmission, large bandwidth up to 2.5 GHz, fast data rates, and no licencing fees.

2.2 Weather conditions' effects on the FSO link

Different environmental factors, such as changing temperature, air refraction index, density, and various pollution particles, as well as various weather conditions, such as fog, rain, sandstorms, snow, and low clouds, reduce visibility and have negative effects, particularly attenuation of optical pulses at different intensities in FSO links, which lowers the signal quality and makes communication unreliable. So, without really putting up an FSO link, long-term analysis for the consequences of these many parameters must be done with real implementation settings. We simulated the FSO link using the Opti system software with implementable real-world settings, and we then analysed the outcomes for bad weather situations including fog and rain. Other than weather, a number of physical and environmental factors also weaken the optical pulses.

2.2.1 Fog's Impact on FSO Link

Since the size of fog particles is almost identical to the wavelength of a carrier optical signal, which is 550 nm, fog is the main cause of signal quality degradation. As a result, the signal attenuation is much greater than the attenuation caused by other parameters. Increased attenuation causes a large range reduction, making it impossible for receivers outside of the degraded range to receive optical pulses. This results in a high BER rate or broken communication link.

Now, if we consider the degraded range of 300 m and since the attenuation due to fog is quite large so we consider the attenuation factor of 100 dB/km, then the Q factor is found out to be of value 20.

The pulse degrades quickly since the energy loss is significant and the Q factor, as can be seen, is quite low. The attached eye diagram illustrates the impacts of fog on the FSO link taking into account these factors, and it is described in the Results section.

2.2.2 Rain's Impact on FSO Link

Because raindrops are larger than the wavelength of light, their impact on the deterioration of optical pulses is less than that of fog. Snowstorms have a smaller impact than rainstorms because the size of the snow particles is much larger than the wavelength. Yet rain causes optical pulse scattering events, which weakens the optical signal. We must take the rain rate into account since it affects scattering, which worsens optical signals as the rain rate rises.

We obtained a Q factor of 88 by combining a rain rate of 25 mm/hour with an attenuation coefficient of 6 dB/km (smaller than the fog coefficient), which is significantly higher than the fog-related Q-factor of 20. So, we can conclude that rain has a far less effect on the FSO link than fog does.

Hence, we can conclude that the range degradation caused by the impact of rain will be smaller than that caused by the impact of fog for the same snr and the ber value for rain will be lower. The accompanying eye diagram, which is addressed in the Results section, shows the influence of rain on the FSO connection for the parameters and their values mentioned above.

3. SIMULATION SETUP

A planned FSO system in an Opti system is depicted in Figure link depicts a laser source with 1310 nm wavelength. Next is a Machzender modulator, low pass Bessel filter at the cut-off frequency of the external bandwidth, and PRBS (Pseudo Random Bit Sequence) generator. After that Free Space Optics channel is provided which consists a link range as per demand, attenuation factor, Tx and Rx aperture diameter and beam divergence.

The receiving portion is then given is an APD (Avalanche Photo Detector) having ionisation ratio 0.9 and 10nA dark current which converts the optical impulses into electrical signals. The last block is a low pass Bessel filter with an order of 4 and a cut-off frequency of 0.75*bit rate. The bit rate in this case is 10 Gbps.The eye diagram and Q-factor of the chosen system are then calculated using the BER analyser.

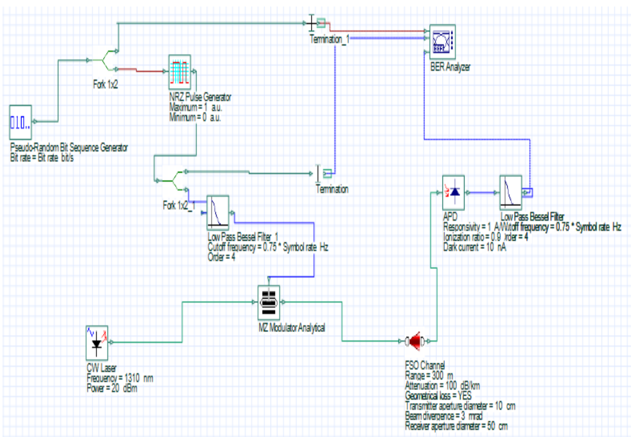

Figure 1. FSO Link Simulation setup

3.1 Key Simulation Parameters

The parameters of all blocks for the rain and fog are as stated in Table as under

Table 1 Simulation Parameter

Parameter	Value
CW Laser	Frequency:1310nm Bandwidth: 5 Mhz
FSO	For Rain • Attenuation: 6db/km • Link range:1000m For FOG • Attenuation: 100db/km • Link range:300m
APD photodiode Responsivity:	1 A/W Dark Current: 10nA Ionizationratio:0.9
Low pass Bessel filter	Cut off frequency:0.75*Bit rate Order:4

Table 2 Reference Parameter

Data rate	10gbps
Input power	20dbm
Sequence length	128 bits
Samples per bit	64
No of samples	8192
Beam divergence	3 mrad

4. RESULTS

An oscilloscope display is essentially an eye pattern or eye diagram. In the eye pattern, a continuous sampling of a digital signal from the receiver is sent into the vertical input, and the horizontal sweep is initiated by the data rate. Eye diagrams allow us to assess how channel noise and Intersymbol Interference (ISI) affect a baseband pulse-transmission system's performance. As described in the sections Effects of fog on FSO connection and Effects of rain on FSO link, the eye patterns for different weather conditions for specified parameter values are simulated and shown below.

4.1 Rain's Impact on FSO Link

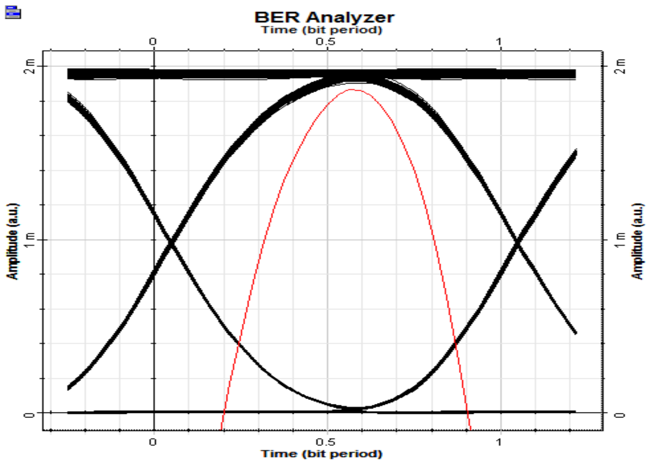

Figure 2. Eye diagram for simulation setup for rain attenuation

4.2 Fog's Impact on FSO Link

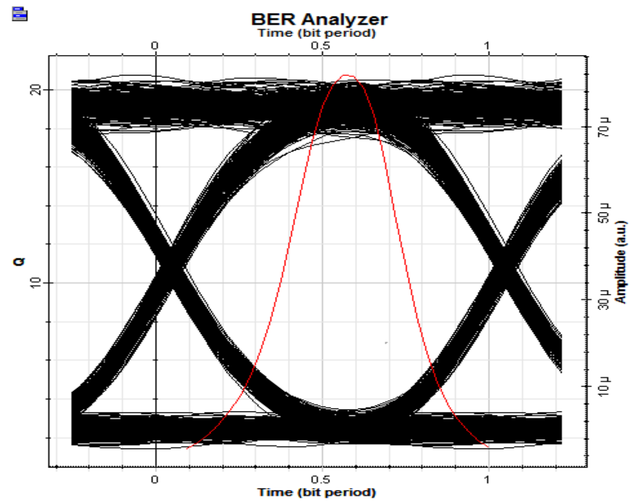

Figure 3. Eye diagram for simulation setup for fog attenuation

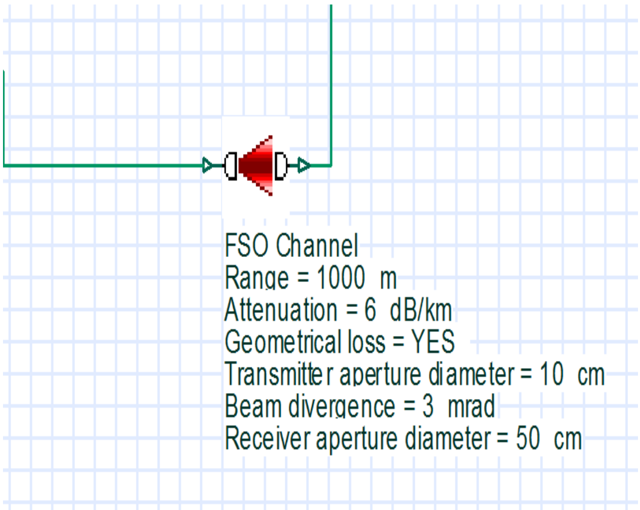

Figure 4. FSO channel parameter for rain attenuation

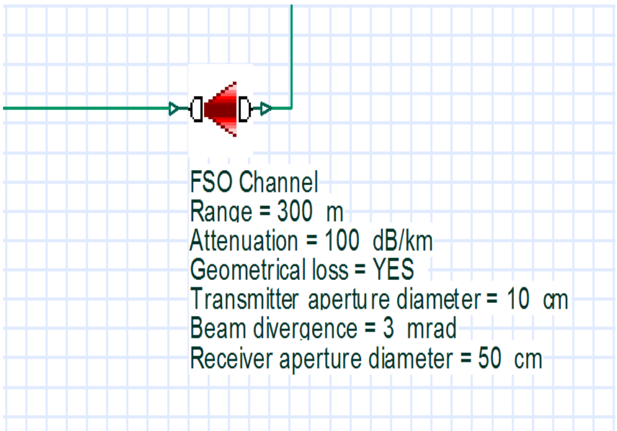

Figure 5. FSO channel parameter for fog attenuation

The eye diagram for rain in Figure 2 is far better than the eye diagram for fog in Figure 3, as can be seen in Figures 2 and 3 for rain and fog, respectively.

5.CONCLUSION

Line-of-sight communication using free space optics (FSO) has many benefits, including high bandwidth, fast data rates, secure communication, and many more. However, the negative impacts of weather and other environmental factors reduce the dependability of this communication method. In order to analyse the negative effects of fog and rain on an FSO system we have successfully gathered eye diagrams in the Optisystem software for the impacts of fog and rain on an FSO system.

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