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Studying the Effect of Fog and Rain on Visible Light Communication Based on Chaos Encryption

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Abstract

The outdoor uses of visible light communications (VLC) technology have received less attention than their interior counterparts. This is because the level of interference and noise in outdoor VLC is significantly higher; many other communication technologies are available for use that, due to their unique characteristics, adapt better to the outdoor environment when compared to VLC technology; and the dual use of light emitting diodes (LEDs) is not always practicable in the outdoor VLC environment. There are numerous obstacles in the way of implementing these communication networks. The majority of them are associated with environmental elements like sunlight, fog, rain, dust, snow, and atmospheric disturbances.

The impact of fog and rain on visible light communication (VLC) has been the subject of several studies. These environmental conditions can significantly affect the performance of VLC systems. Fog and rain can cause attenuation and scattering of the light signal, leading to an increase in the bit error rate (BER) and a reduction in the communication range. The semi-conductor laser chaos generation is now being utilized to improve data security and protect data from theft during its transmission from transmitter to receivers

Keywords:- Chaos; chaotic encryption; Electro-optic delay; OptiSystem, Visible light communication.

Introduction

Visible Light propagation in free space is used in the emerging field of free space optics, a technique for line-of-sight communication that offers a number of benefits including high bandwidth, fast data rate, ease of installation, free license, and secure communication. VLC modernizes the current streetlight system without becoming overly intrusive. It reduces the total power consumption of the system by combining the functions of illumination and communication. Additionally, VLC is becoming more and more interested in business and research [1]. As the name implies, VLC uses light-emitting diodes (LEDs) to transport data through light in the visible range of the electromagnetic spectrum. For line of sight communication, the free space optical link is an ideal solution since it offers minimal installation costs, speed, and security. Since optical communication offers a higher level of security than other forms of transmission, VLC is able to provide both high data rates in Gbps and secure transmission. [1] The visible communication technique is employed for short-distance data transfer in point-to-point or point-to-multipoint, inter-satellite, and inter-building communication within a line-of-sight range [2].

It is necessary to understand the properties of the emitter, receiver, and optical signal's propagation circumstances in order to evaluate the performance of VLC communication systems. An RGB (Red, Green, Blue) LED emitter with reference peak wavelengths of 630, 530, and 475 nm, respectively, and a photodiode receiver are typically found in the VLC equipment. The degree to which the optical signal is affected will depend on the environment in which the system is installed. In fact, the attenuation and disruption on the signal vary depending on whether it is indoors or outdoors [3]. The interactions between light waves and atmospheric particles, as well as weather variability, are the key impactors on outdoor VLC equipment that enhance the medium's overall attenuation. These particles include dust, fog, and perhaps even smoke from pollutants or fires. Scattering and absorption are among the processes brought on by these interactions. [4]

However, it's also critical to examine and talk about the many different factors that could interfere with or reduce the dependability of communication in order to identify a solution and push this technology to its maximum potential. The implications of varying weather conditions on transmission pose the largest obstacle to VLC communication [5]. Since VLC communication occurs in free space, we must take into account the various effects of various weather conditions. [6]Within the context of FSO communication, a long-range LASER-based communication system, the effects of atmospheric phenomena on optical communication have been investigated. The effects examined in the literature include cloudy circumstances [7] .

R W Zaki [8]and E.P.Shettle [9] presents a simulator that was constructed in optisystem using the features of VLC equipment, chaotic signals, and models of fog and rain that were sourced from scientific refrences.

The present work proposes a methodology that assesses fog and rain impact on a VLC system thanks to a simulator. Three scenarios that could be found in free space. The first one is a VLC system with chaotic signal in ideal case. The second and third scenario deal with the effect of fog and rain on visible light using chaos theory [10].

Effect of Fog in Free Space Optical

The main cause of the signal quality reduction is fog. The size of fog particles is comparable to the transmission wavelengths of visible light and near infrared waves, which is the primary cause of the noticeably large attenuations caused by scattering in various fog conditions [10]. Studies have revealed that during the winter, optical attenuations can reach up to 120 dB/km in mild continental fog environments (such as Graz, Austria), whereas during the summer, they can reach up to 480 dB/km in deep marine fog environments. In addition to varying fog conditions, snow and rain limit the availability of FSOs [10] [11].

Fog Attenuation model:

As previously discussed, the factor that degrades optical transmission the greatest is fog. The Kim model and the Kruse model are widely recognized models [11]. Two further models, Al naboulsi Advection and Al naboulsi Convection, are provided together with a description of the limits of these two models in [12]. Therefore, the literature review was used to find these four models for the fog attenuation computation. The following formula can be used to determine the damping coefficient for the Kruse model:

$$\boldsymbol{\alpha_{fog}} = \frac{\mathbf{3 \cdot 912}}{\boldsymbol{v}} \left(\frac{\boldsymbol{\lambda}}{\boldsymbol{\lambda_0}}\right)^{-\boldsymbol{q}} \ [\boldsymbol{km^{-1}}] \qquad (1)$$

Where:

V=visibility at $\boldsymbol{\lambda} = \lambda_0[km]$

λ=Signal wavelength

$\lambda_0 = refrence\ wavelength\ for\ mesurment\ of\ V[nm]with$

$$q_{kruse}= \begin{cases} 1 \cdot 6 & v \geq 50km \\ 1 \cdot 3 & 6km \leq v < 50km \\ 0 \cdot 585 v^{\frac{1}{3}} & v < 6km \end{cases} \qquad (2)$$

The Kim model equals the Kruse model for visibilities > 6 km. For lower visibilities the Kim model is more accurate[13]. Factor q for Kim model is given by:

$$q_{kim}= \begin{cases} 1 \cdot 6\, v + 0 \cdot 341 & km < \ v \leq 50km \\ v - 0 \cdot 5 & 0 \cdot 5km < v \leq 1km \\ 0 & v \leq 0 \cdot 5km \end{cases} \qquad (3)$$

Effect of Rain in Free Space Optical

Because raindrop particles are larger than wavelengths, the effects of rain on the deterioration of optical pulses are less severe than those of fog. Because the size of the snow particles is much larger than the wavelength, the effect of a snowstorm is smaller than that of rain [14]. However, rain causes optical pulse scattering events, which weakens the optical signal. Rainfall rate must be taken into account since rising rain rates lead to increased scattering, which deteriorates optical signals. Therefore, it can be concluded that rain has a far less effect on the FSO link than fog does [8]. Therefore, it may concluded that the range of degradation caused by rain will be smaller than that caused by fog, and the BER value under rain will be lower than that under fog. From the research study the attenuation of rain =6[8].

The impact of rain on visible light communication (VLC) can vary with different types of LED lights due to factors such as the wavelength of the emitted light, the intensity of the light[15], and the material composition of the LED. Here are some possible causes of the impact of rain on VLC:

Wavelength-dependent attenuation: different wavelengths of visible light may experience varying levels of attenuation due to environmental conditions such as fog, rain, or smoke. Some wavelengths may be more affected by rain than others, leading to changes in the performance of VLC systems [16].

Intensity-dependent attenuation: the intensity of the light emitted by LEDs can also affect the attenuation in rainy conditions. Stronger LEDs may cause more significant attenuation due to their higher power output [17].

The attenuation, γ_{rain} (dB/km), because of rain is a function of the amount of precipitation, R (mm/h), and is not affected by the wavelength because the droplets are big in relation to the wavelength. Consequently, the attenuation can be obtained by applying the geometric optics limit as [14]. [15]

$$\gamma_{rain} = a \cdot R^b \tag{4}$$

The raindrop size distribution and values obtained from measurements at a particular place are what determine the power law parameters a and b[18].

Proposed Method

Both transmitting and receiving sides of the plane, as shown in figure. 1, which illustrates the proposed security solution, are outfitted with two chaotic systems that are quite similar to each other. The chaotic signal, c(t), which is generated at the transmitting end by the double delay feedback mechanism, obscures the first data signal, d(t). By doing this, a secure signal, represented by s(t), is created and conveyed via the optical fiber channel. To create optical chaos through a chaotic laser, we utilize a method called direct modulation, which involves connecting a semiconductor laser and a current source. The settings of the semiconductor laser and current source are changed to produce chaos with the desired properties as show in table 1. Potential invaders are deterred by this signal (s(t)), which also hides the original data (d(t)) in its transmissions. Subtraction of another chaotic signal, c(t), which is analogous to s(t) but is produced by a second chaotic semiconductor laser at the receiving end, occurs after the signal, represented by s(t), has been transferred across the channel. The initial data (d(t)) may be effectively extracted using the subtraction formula because all of the parameters of the second chaotic laser are maintained in the same way as the parameters of the transmitting laser. While the attributes of the two chaotic lasers must be the same, synchronization between them is also a crucial objective. All it takes for this scheme to be entirely useless is a very minor misalignment between these lasers.

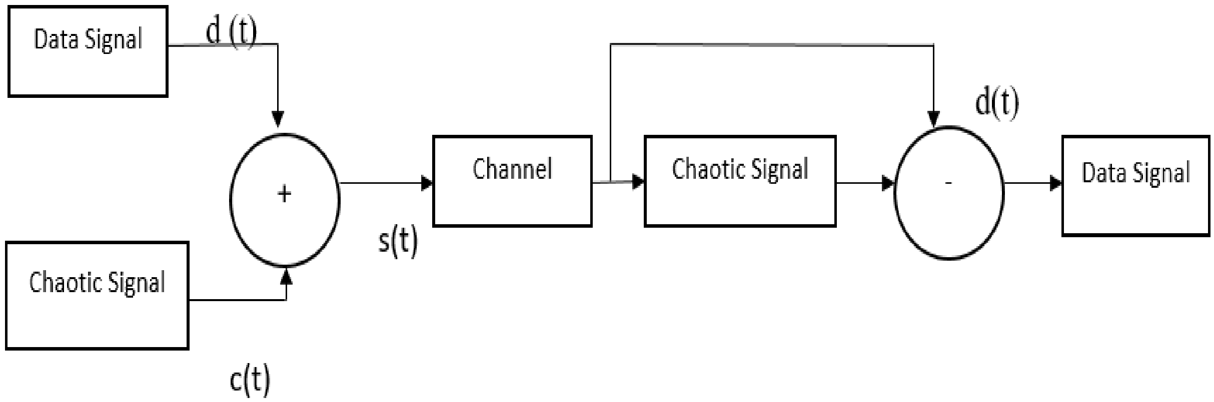

FIGURE 1. A Layering of Additive Chaos as a Mask.

Table1.The Main Parameters of Proposed System

Parameter	**value**
Data rate	10 Gbps
power	10mw
Wavelength	500nm
Channel	FSO
Channel length	(100m -2 km)
Attenuation	Ideal =0 dB/km Fog= (100-120) dB/km Rain= 60 dB/km

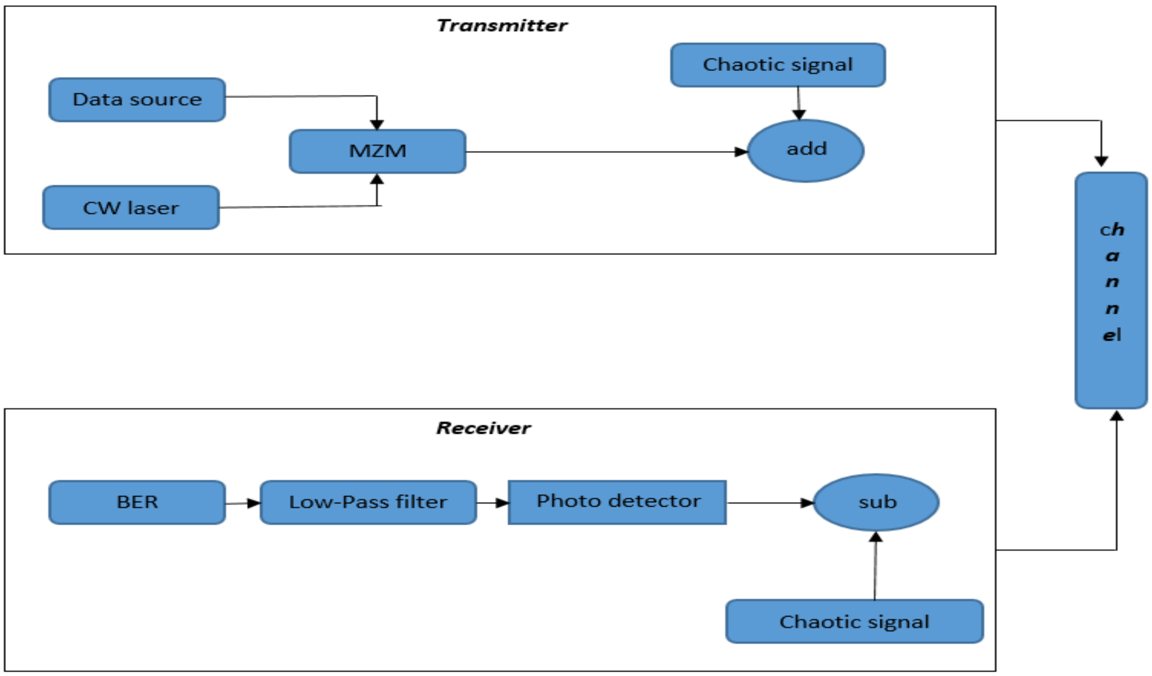

Figure 2. Design communication circuit of VLC.

In figure (2) the input signal is fed and pre-processed into a MZM rectifier our suggested plan for the security of the communication system through optical chaotic. The MZM rectifier modulates the input signal using the light a result of the CW laser. To transmit the signal with less attenuation loss. To enable the modulation of the input signal with the laser light, the extinction ratio of the MZM, which is defined as the ratio of two levels of optical power to the digital signal created by the laser, was set at a value of 50:50. This ratio is defined as the ratio of two levels of optical power to the digital signal generated by the laser. The chaotic semiconductor laser's optical output was then provided to the MZM, where it was combined with this waveform. The semiconductor laser's operating frequency was maintained at approximately 500nm, allowing the two waveforms—the light produced by the input waveform modulated by the CW laser and the semiconductor laser's generated chaos must be correctly blended. The optical adder output is sent across a single-mode fiber following the safekeeping of the input signal in the optical field. On the receiving side, a signal was removed from a comparable chaos (that was produced using one of the aforementioned techniques) before The photodiode picked up the signal or optical receiver, the chaos was produced and placed on both sides. The signal was first picked up by the optical receiver, whose job it was to convert it from the visual field to the electric field once it was discovered. After then, a low-pass filter was used so that the input signal could be recovered while the influence of the noise was further reduced.

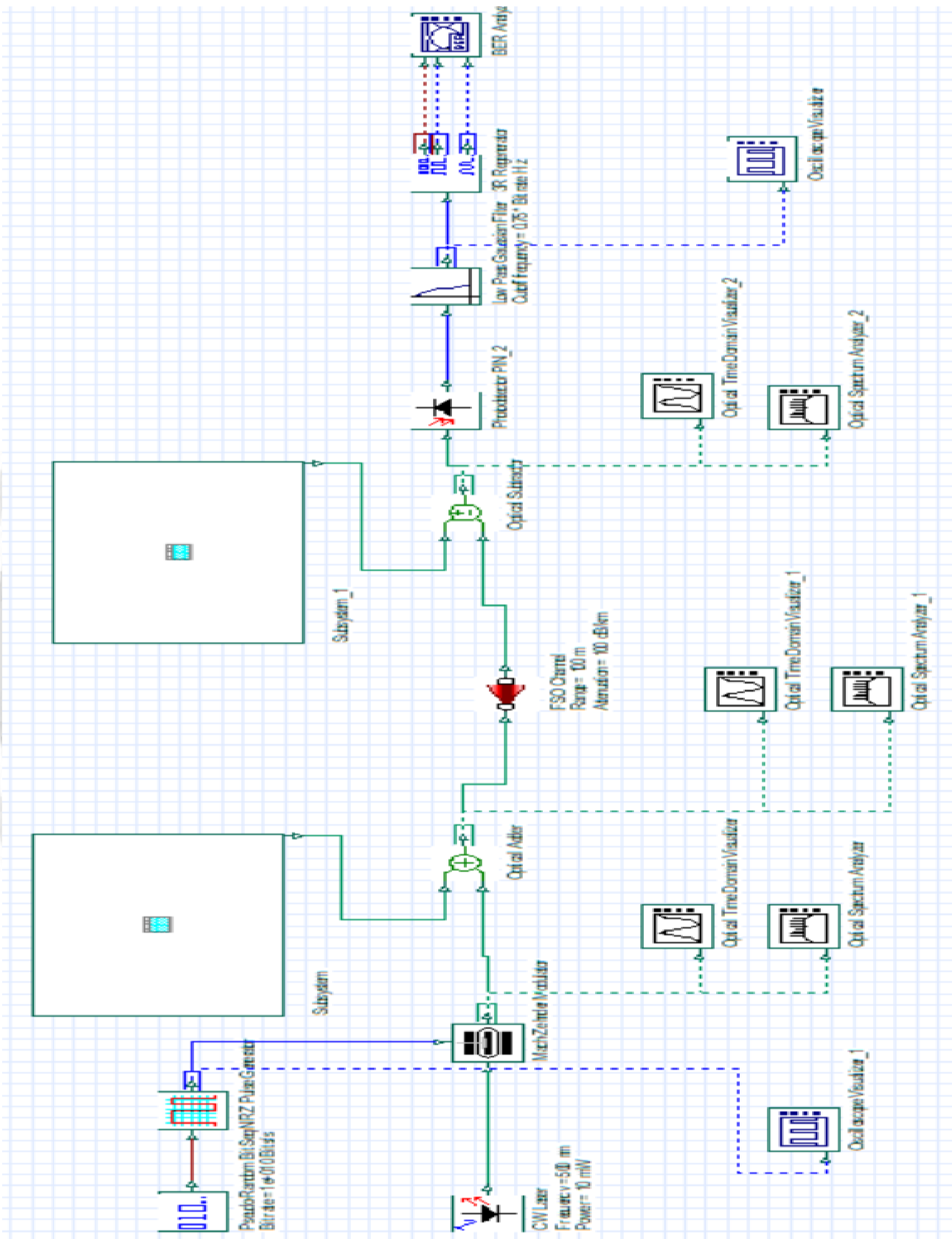

Figure 3. Simulation of VLC Circuit.

In Figure (3) the input signal is fed and pre-processed into a MZM rectifier our suggested plan for the security of the communication system through optical chaotic. The MZM rectifier modulates the input signal using the light a result of the CW laser to transmit the signal with less attenuation loss. To enable the modulation of the input signal with the laser light, the extinction ratio of the MZM, which is defined as the ratio of two levels of optical power to the digital signal created by the laser, was set at a value of 50:50 This ratio is defined as the ratio of two levels of optical power to the digital signal generated by the laser. The chaotic semiconductor laser's optical output was then provided to the MZM, where it was combined with this waveform. The semiconductor laser's operating frequency was maintained at approximately 500nm, allowing the two waveforms—the light produced by the input waveform modulated by the CW laser and the semiconductor laser's generated chaos must be correctly blended. The optical adder output is sent across a single-mode fiber following the safekeeping of the input signal in the optical field. On the receiving side, a signal was removed from a comparable chaos (that was produced using one of the aforementioned techniques) before The photodiode picked up the signal or optical receiver, the chaos was produced and placed on both sides. The signal was first picked up by the optical receiver, whose job it was to convert it from the visual field to the electric field once it was discovered. After then, a low-pass filter was used so that the input signal could be recovered while the influence of the noise was further reduced.

Results and Discussion

In this work, defining relevant and realistic outdoor scenarios to assess the fog and rain impact on a given visible light communication and with using chaotic is a necessity as no reference scenario is available in the scientific literature. Therefore, a typical VLC system with chaotic signal with clear weather with (scenario 1) and a VLC with effect of fog (scenario 2) and the third with effect of rain were created as depicted in tables.

Case 1

Simulations are performed with varying the length of the channel, with data rate of the system 10 Gbps, and with the ideal case or clear weather. Figure (4) and Table (2) present the BER and Q factor at a rate of 10 gigabits per second without any noise.

TABLE 2. Result of the Simulation of Proposed System with Ideal Weather

Channel length	BER	Q-factor
100 m	0	283.58
500 m	0	122.53
1Km	1.41086e-295	36.7258
2Km	4.8838e-111	22.3411

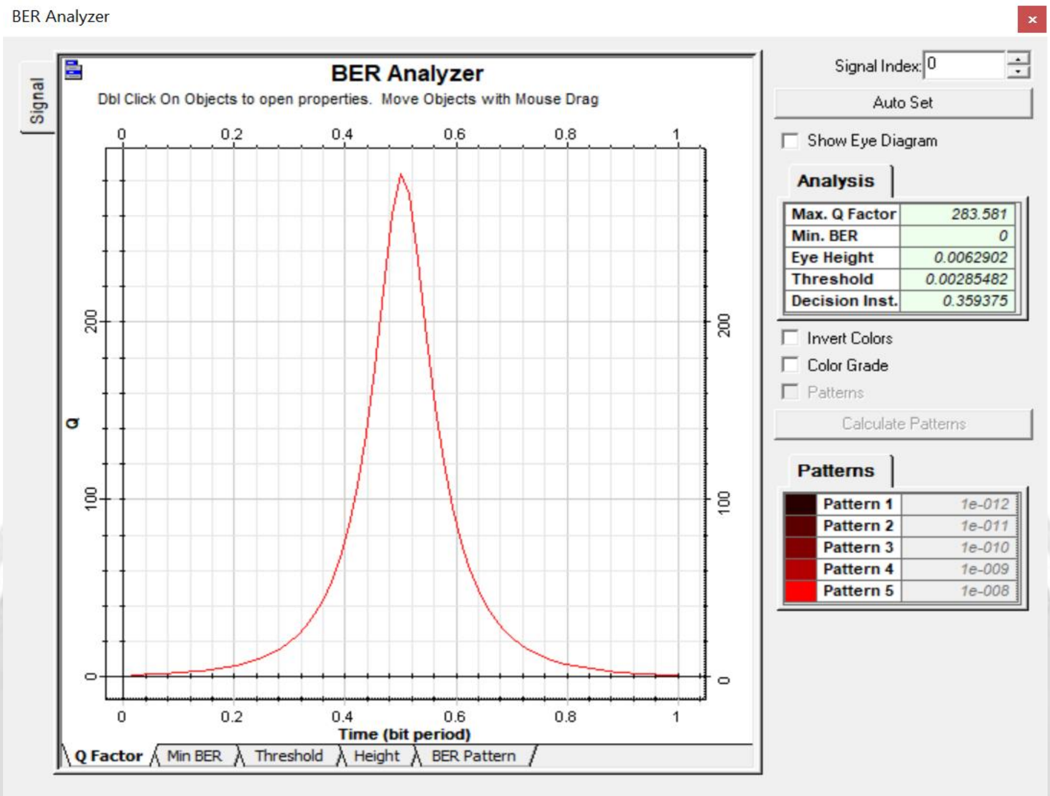

Figure 4. BER and Q Factor Simulation Result at 100m with Rain.

Case 2

Currently a well-established access technique, free space optics (FSO) is most recognized for its dependability when it comes to sending massive amounts of data while using little energy. However, cloud cover, severe weather, and atmospheric turbulence have a negative impact on an FSO ground-link's BER performance. Rain and fog reduce the availability and dependability of the link by attenuating optical energy transferred in terrestrial free-space. Over a link distance of (100m-1km), we measured the BER of the received optical signal level during continental fog and rain.

According to research studies, it was found that the rain attenuation value is)6 to 10(dB/km, and 6 dB/km.Likewise, the attenuation in the presence of fog is 100 dB/km.

When transmitting at 10Gbps with rain, the numerical results of bit error rates (BERs) and link distances are presented in the table (3). Figure (5) describe the chaotic signal at channel length 1km and the result of simulation BER and Q factor.

Table 3. Result of the Simulation of Proposed System with Rain

Channel length	BER	Q-factor
100 m	0	283.40
500 m	0	67.739
1Km	1.00954e-006	4.6835
2Km	1.00932e-006	4.6831

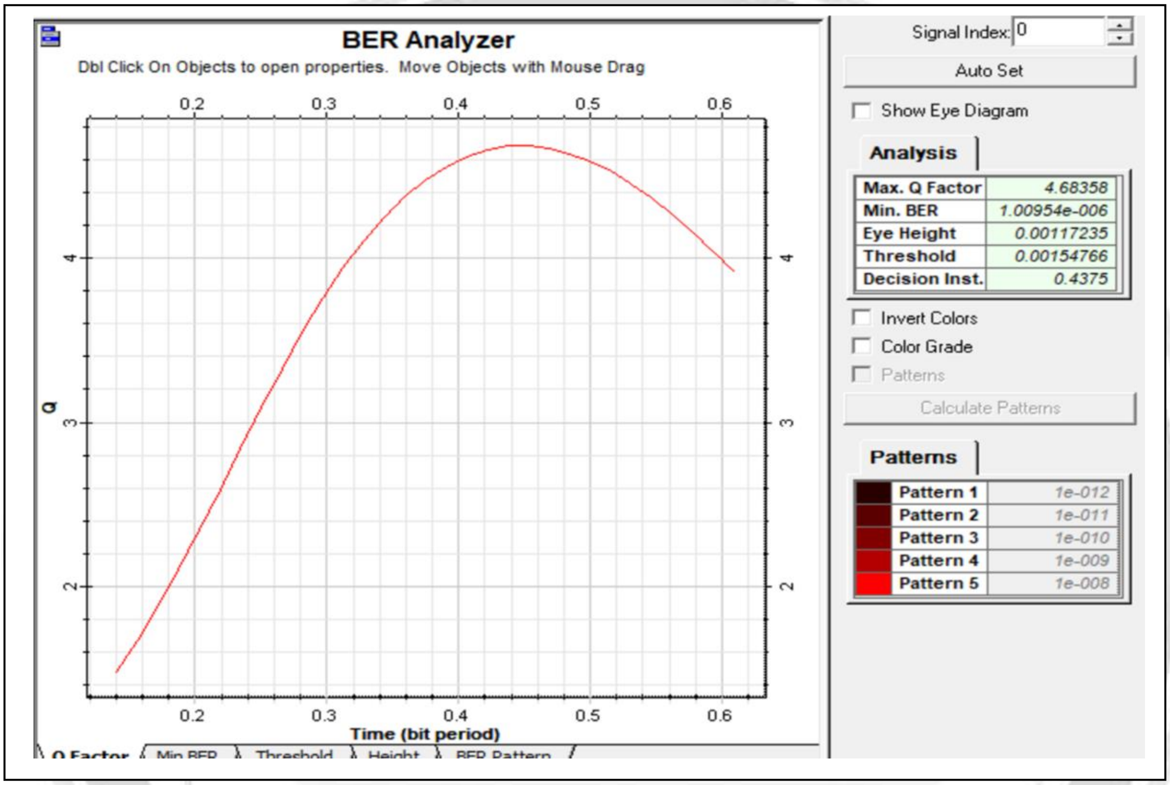

Figure 5: BER and Q Factor Simulation Result at 1km with Rain.

Table (4) shows the numerical results of bit error rates (BERs) and link distances when transmitting at 10Gbps with fog. The chaotic signal at a channel length of 100 meter, as well as the BER and Q factor from the simulation, are shown in Figure (6).

TABLE 4. Result of the Simulation of Proposed System with Fog

Channel length	BER	Q-factor
100 m	0	180.03
500 m	1.00926e-006	4.6836
1Km	1.00925e-006	4.6832
2Km	1.0090e-005	4.68301

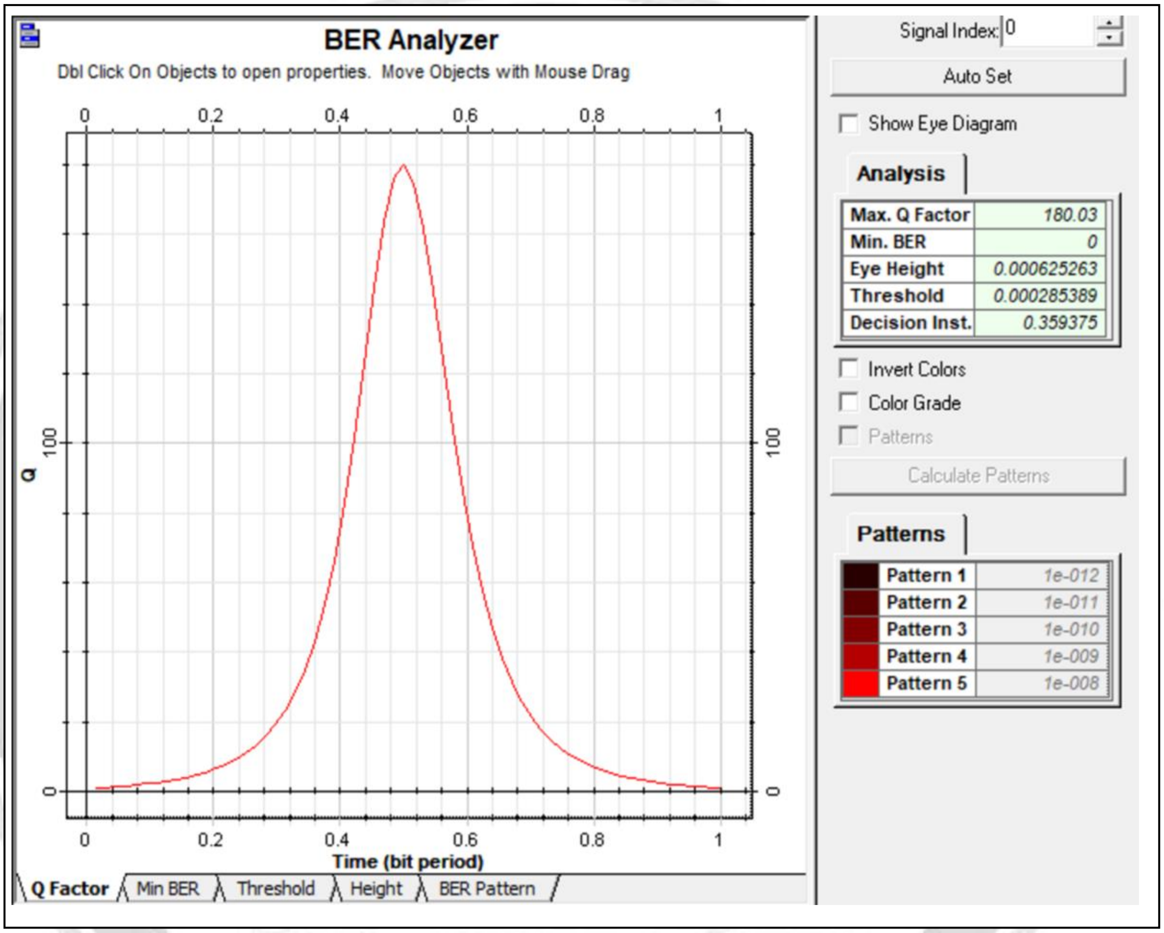

Figure 6. BER and Q Factor Simulation Result at 100m with Fog.

The BER performance versus the coverage area is displayed in Figures for different weather turbulences under different length schemes. Tables (2,3and 4) show the maximum achievable distance for the different weather condition at 2km channel length and a data rate of 10 Gbps. It is observed that clear weather achieves higher distances than at rain and fog condition, as shown in tables.

The volume of information received and the BER coverage area of the proposed system are used to gauge its performance. as you show the BER at 2 Km is 1.00932e-006but it was in ideal case is 4.8838e-111.

It is discovered that in the event of fog, the system is more attenuated than in the event of rain. For the same channel length, the BER is equivalent to 1.0090e-005, the last is found to cover a shorter distance with higher BER values. The maximum achievable distance and the amount of received information depend on the type of modulation scheme used, which has been calculated.

Conclusion

In order to examine the effects of optimal weather, rain, and fog attenuation on a VLC system encrypted using a chaotic signal, a mathematical model is implemented in this work. Through the use of an outdoor application system simulation, the impact of this attenuation has been seen. Attenuation of rain is measured Through light absorption or scattering, this type of attenuation affects light communication and is stronger as communication distance grows. It was found that communication with visible light is affected by fog more than rain, because the wavelength of fog is close to the wavelength of visible light, and therefore it causes an increase in the BER rate. However, in the case of rain, it is affected to a lesser degree because the rain grains are larger in size.

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تأثير الضباب والامطار على الاتصال بالضوء المرئي المعتمدة على التشفير الفوضوي

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الخلاصه:

حظيت الاستخدامات الخارجية لتقنية اتصالات الضوء المرئي بأهتمام اقل من نظيراتها الداخلية وذلك للاسباب التالية: مستوى التداخل والضوضاء في الضوء المرئي الخارجي اعلى بكثير ,تتوفر العديد من تقنيات الاتصال الاخرى للاستخدام نظراً لخصائصها الفريدة تتكيف بشكل افضل مع البيئه الخارجية مقارنة بتقنية الضوء المرئي والاستخدام المزدوج للثنائيات الباعثة للضوء ليس عملياً دائماً في بيئه الضوء المرئي الخارجية. هناك العديد من العقبات في طريق تنفيذ شبكات الاتصالات هذه وترتبط معظمها بالعناصر البيئية مثل ضوء الشمس والضباب والمطر والغبار والثلج والاضطرابات الجوية .

كان تأثير الضباب والمطر على اتصالات الضوء المرئي موضوعاً للعديد من الدراسات. يمكن ان تؤثر هذه الظروف البيئية بشكل كبير على اداء انظمة الاتصالات بالضوء المرئي يمكن ان يتسبب الضباب والمطر في اضعاف وتشتت الاشارة الضوئية، مما يؤدي الى زيادة معدل خطأ البت وانخفاض نطاق الاتصال. ويتم الان استخدام توليد الفوضى بالليزر شبة الموصل لتحسين امان البيانات وحمايتها من السرقة اثناء نقلها من جهاز الارسال الى جهاز الاستقبال.

الكلمات الداله: الفوضى، التشفير الفوضوي، تأخير الكهروضوئية، الاتصالات بالضوء المرئي.