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Electronics And Communication Engineering, Mepco Analaysis of Visible Light Communication System Under Los And Nlos

CHANNL ENVIRONMENT

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ABSTRACT:

The fast growth of mobile technology and wireless services over the last 10 years has resulted in a huge demand for radio frequency-based solutions. In the meantime, the lighting industry has undergone a revolution thanks to the widespread adoption of more affordable and effective LED light bulbs. This eliminates the need for additional connection equipment and enables data transfer and interior illumination. This approach is known as "Visual Light Communication." Visible light communication (VLC), a ground-breaking LED-based technology that offers a free spectrum and high data rates, has the ability to work in conjunction with the current radio frequency standards in this field. Among other advantages, LEDs have a long life span.

The Lambertian radiation pattern is proposed as a model for the VLC system architecture in this research. In this study, the effect of room size and the number of transmitters with various LED spatial distributions will be evaluated in relation to the bit error rate and signal-to-noise ratio performance of data transmission quality. Numerous LED arrays with Lambertian radiation patterns are taken into account for the implementation, each of which has a mode number, field of view (FOV), and half power angle. To create an effective visible light communication system by taking into account a 12*12*3 m3 interior room setting. Using the LOS channel model, analyze the line-of-sight communication between transmitters and a single receiver in terms of its range, SNR, and BER. Finally, using Kim's channel model, the analysis is expanded to take into account various light beams (attenuations) in the same room setting. MATLAB is utilized to simulate the task.

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INTRODUCTION:

The world of today is very dependent on energy, or more specifically, energy conservation. Everyone is aware of how crucial it is to start talks quickly and directly in this situation. Due to the fact that it satisfies both of the aforementioned requirements, Visible Light Communication (VLC) is seen as a strong contender for the next generation. Visible light communication is a short-range optical wireless system that uses white LEDs in the visible light spectrum (375-780 nm wavelengths) to combine lighting and communication. To put it simply, VLC used a suitable photodiode as a signal receiving component, air as a transmission medium, and an LED as a signal transmitter. Because there were not enough highly effective Blue and Green LED available, White LED did not become generally available until 1990. There are advertisements for the acquisition of high-efficiency blue and green InGaN-based LEDs. White LEDs may be created by combining the three fundamental hues red, green, and blue. High Signal-to-Noise Ratios, Cheap Energy, Superior Security measures, and the Absence of Electromagnetic Interference with Other Devices are only a few advantages of VLC over conventional wireless communication. VLC also uses unlicensed and practically infinite light spectrum, and has superior security measures. VLC devices can also be used in settings where RF communication is forbidden, such as hospitals and airports, due to the potential for RF to anode interference. VLC allowed people to concentrate better on Light-Fidelity.[Li-Fi]

Two channel types are typically used to model a VLC system. The first is a dispersed Link channel model, a non-LOS model, whereas the second is a LOS model. When using the LOS channel, the transmitter and receiver communicate by sending out narrow beams without taking into account any reflections from the walls or the environment. This kind of channel allows for high transmission rates. It's possible that the shadowing and blocking this method of transmission experiences isn't a good representation of actual circumstances when light beams travel via many channels and reflect before reaching the recipient. As opposed to this, NLOS channels evaluate the possibility that light beams could bounce off of surrounding objects and surfaces, which makes them more realistic and practical. Since there are so many reflections, it is clear that this type of channel has many path effects, but it does not experience the shadowing effect that the LOS channel does. In this article, the NLOS channel will be taken into consideration when we assess the VLC system's efficacy. The study employed modified versions of the MATLAB code implementation. We tested the LOS model for VLC in this study using the Lambertian radiation pattern of LEDs. This design, which features an LED source at the top and a photodiode at the bottom, may be used for indoor communication in an area measuring by 12*12*3 m^3. Information about VLC, LOS, and NLOS is provided in the introduction.

LITERATURE SURVEY:

In comparison to radio and visible light transmission, the author asserts that optical wireless communications have a long history. A technique called visible light communication (VLC) is being propelled by the growing use of solid state lighting (SSL) using LEDs. A VLC implementation may achieve data densities of 0.41 bits per second per Hz per square meter, according to data from experimental systems. **[1]**

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The literature has been thoroughly researched and a number of modulation techniques for optical wireless communication systems have been proposed in this study. Each modulation strategy has its own unique enticing characteristics and challenges. Some are quite simple to operate and consume little bandwidth, such as On-Off keying (OOK). Systems using pulse interval modulation (PIM) are known to be intrinsically synchronized. While pulse, subcarrier modulation (PSM) offers increased throughput, resistance to inter-symbol interference (ISI), and immunity against fluorescent-light noise near DC, PPM, which offers unmatched power efficiency in line of sight (LOS) links but suffers greatly in dispersed communication channels, also offers these advantages. We only provide a quick overview of the most often reported wireless infrared modulation techniques here, despite the fact that a lot of work has gone into analyzing these and other modulation strategies under various channel and environmental conditions**. [2]**

The outcome shows that VLC can still be used for wireless communication despite the close proximity of the transmitter and receiver. A software-based VLC was demonstrated in 2011 and tested for real-time video transmission across a 3 meter connection distance**. [3]**

The authors provided a broad overview of VLC technology that included its physical properties, system architecture, most frequent applications, and current research problems. There is also an overview of the field's current research platforms and anticipated advances. **[4]** Provides a study of OWC that includes, among other things, an overview and review of VLC, Li-Fi, optical camera communication (OCC), and FSO.

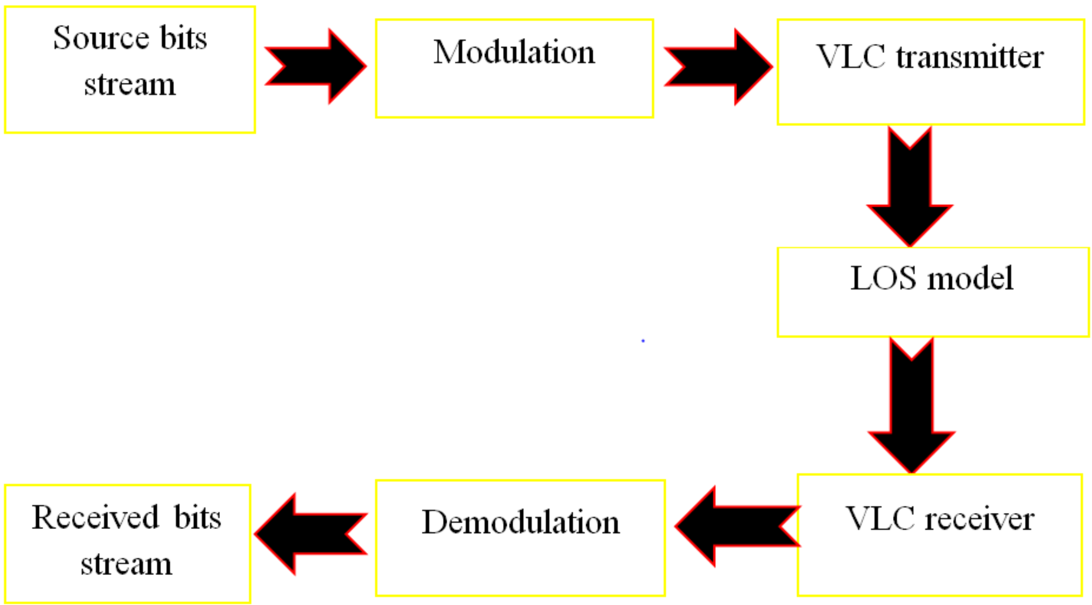
It was claimed in a separate poll in **[5]** that VLC and Wi-Fi technologies were being integrated into fifth-generation (5G) technology. The authors described the underlying concepts, supporting technologies, and challenges of the aforementioned inclusion. Indoor VLC has been given a thorough analysis in **[6]**, with a focus on the special applications of the technology and a variety of practical design factors. Among these components are the channels' propagation characteristics, their modulation schemes, and their capacity to provide dimming with little flicker in order to minimize spectral efficiency degradation.

In **[7]**, the literature on developing the VLC physical layer for an indoor setting is thoroughly explored. A related study **[8]** looked at VLC's possibilities on 5G networks. **[9]** explores the properties of outdoor VLC in the form of FSO, focusing on IR. For both fixed and mobile situations, **[10]** provided many FSO components. A study of channel modeling multiplexing, solid-state lighting (SSL) management, noise, dimming techniques, drivers, propagation models, and directionality within the FSO framework were some of the topics covered in this research. **[11]** Conducted a survey on how VLC is used both indoors and outside.

PROPAGATION MODELS:

Line Of Sight Propagation Model:

The fundamental goal of the suggested paradigm is to get towards visible light communication (VLC), which would enable light-emitting diodes (LEDs) to serve both as wireless communication devices and as lighting sources. The physical distance separating the photo detector acting as the receiver from the LED acting as the source is known as the communication channel. Its study may be divided into three sections: the receiver's photosensitive properties, the visible light signal propagation model, and the source. Since the communication medium utilised in IR systems and VLC systems is comparable, the information gleaned from the extensive study in IR systems may be used to visible light communication.



In Fig. 1, a typical VLC system is shown. The following gives a quick overview of each block. The data bit stream is fed to a modulator as shown in Fig. 1, where an on-off keying (OOK) modulation is used.

Transmission

Along with their typical use as lighting fixtures, LEDs also serve as transmitters in VLC. Light-emitting diode is referred to as an LED. A semiconductor device known as an LED produces light via the electroluminescence process. A semiconductor substance discharges visible light when an electric current passes through it. As a result, an LED is a perfect replica of a photovoltaic cell, the unit used in solar panels to convert visible light into energy. The best transmitters right now are LEDs because of their extended lifespan, high energy economy, increased environmental performance, and lack of heat and UV emissions. A Lambertian radiation pattern with rotational symmetry may be used to simulate each individual LED, which is a component of the transmitter. Normally, in indoor lights, white LED arrays are used. Because of the close arrangement of the LEDs, a simple Lambertian distribution is assumed for simplification purposes. Therefore, the radiation pattern is expressed by,

$$RE(\varphi, m) = \frac{m+1}{2\pi}\text{PE}.\, cos^{m}(\phi) \quad (1)$$

In Equation (1), the coefficient $\frac{m+1}{2\pi}$ is the normalizing factor. This ensures that integrating $RE(\varphi, m)$ received power over the surface of a hemisphere, which results in the source power (PE) with $\varphi \in [-\frac{\pi}{2}, \frac{\pi}{2}]$ where φ is the direction angle relative to the transmitter normal axis, PE is the transmitted power, and m allows the direction of the source and named as the mode number of the radiation lobe. It is expressed by,

$$m=-\frac{\ln(2)}{\ln(\cos(hpa))} \quad (2)$$

where *hpa* means half power angle which represents the viewing angle at which 50% of the radiant energy is contained in a plane that contains the lobe's maximum value. *hpa* is also known as half-power beam width and its value is usually supplied by LED manufacturers. The position is defined by the geometric arranges (xE, yE), and orientation is stated by the elevation angle (φE). The transmitter can be then defined through

$$E=\{PE, hpa, (xE, yE), (\varphi E)\} \quad (3)$$

Reception

A photodiode is used as a receiver for signal reception. The light signal is converted into an electrical current by a PIN photodiode, which is then amplified further by a front-end amplifier. The inexpensive implementation costs, compact size, and great light sensitivity of the photodiode are its benefits. The operating signal collection area (Aeff) and the field of vision (F0V) angle, both of which are denoted by the symbols

$$Aeff(\sigma)=\begin{cases} Ad.\cos(\sigma) & |\sigma| < FOV \\ 0 & |\sigma| \geq FOV \end{cases} \quad (4)$$

where Ad is the physical area of the detector and σ is the direction of the incident light ray and the angle between the receiver axis RN.

The position and orientation of the receiver in relation to the system's origin must be specified for the reception model to be complete, much like with the gearbox model. The orientation is determined by the incidence angle (R) and the location is determined by the geometric coordinates (xR, yR), resulting in

$$R=\{Ad, FOV, (xR, yR), (\sigma R)\} \quad (5)$$

Optical filtering should also be assumed at this point. Sunlight and ambient light can damage OWC systems. Therefore, before the incoming electrical signal is detected by the photo detector, an optical filter can be utilised to limit the impact of undesirable noise components. In light of this, the receiver model with optical filter is now explained as,

$$R=\{Ad, FOV, (xR, yR), (\sigma R), T\ filter\} \quad (6)$$

The transmission coefficient of an optical filter can be broken down into several components, but for now, it is defined as a T filter.

LEDs' Spatial Distribution and illumination calculation

Different frameworks have been investigated where the quantity of transmitters, their placements, and the length, breadth, and height of the room have been changed in order to test the efficiency of VLC for various spatial distributions of LEDs. Additionally, it has been noted that the quantity of light rays employed in modelling the channel and replicating the geographical distribution of the LEDs may also be having an impact on the system's performance. In order to create a mesh arrangement of LEDs, the space was divided into equal horizontal and vertical grids based on the number of LED transmitters, with one transmitter assigned to each mesh. The distance between the source and receiver is measured by using,

$$d_{t-r} = \sqrt{(x_r - x_t)^2 + (y_r - y_t})\hat{}2 + \sqrt{h\hat{}2} \quad (8)$$

This is estimated with simple trigonometry manipulation as given in the equation,

$$\theta = \cos^{-1}\left(\frac{h}{d_{t-r}}\right) \quad (9)$$

To calculate the channel gain (G) is given by,

$$G = \frac{(n+1)\times DA \times \cos(\varphi)^{(n+1)}}{2\pi \times d_{t-r}^2} \quad (10)$$

where DA is the photo- detector area. The estimation of received power (p_r) using the equation by,

$$p_r = P_t \times G \times C \times F \quad (11)$$

where P_t the transmitted power and C is the optical concentrator gain and F is the optical filter gain. The probability of the error is given by,

$$P(e) = Q(\sqrt{SNR} \quad (12)$$

Where SNR = $\frac{p_r}{p_n}$ and p_n is the noise power at the receiver and Q(.) is the Q function is given by

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{\frac{y^2}{2}}\, dy \quad (13)$$

In order to analyse the usefulness of the mesh arrangement on the illuminance intensity,

The illuminance due to the locating of LEDs is calculated using the smooth illumination E_h given by,

$$E_h = \frac{I(0) \times \cos^n \varphi}{d_{t-r}^2} \times \cos\theta \quad (14)$$

This will outcome in the power distribution for a single array of LEDs at a single point, i.e., one ceiling lamp. As important function of the VLC system is to provide efficient lighting. Hence, the LEDs illumination efficiency for different scenarios has been evaluated.

NON-LINE-OF-SIGHT COMMUNICATION:

Indirect communications between transmitting stations use the electromagnetic signaling technique known as non-line-of-sight (NLOS) signal propagation, often referred to as beyond-line-of-sight propagation, which makes use of advanced modulation algorithms to account for signal barriers. This communication method has gained importance as wireless traffic has increased and there are more connected devices than before. The requirement for connected devices and faster wireless communications has been met by the use of two technologies: radio wireless communication, such as Wi-Fi, and optical wireless communication.

NLOS propagation occurs when a radio transmitter and receiver are not in the same direct line of sight. By using a variety of signal propagation routes, antennas, and other pertinent communication tools, NLOS propagation may be avoided. The strength of a signal can be considerably influenced by the separation between the emitter and receiver. NLOS is a significant issue for the majority of computer networking

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systems, and it is typically resolved by placing relays in many locations to maintain signal transmission around obstructions without compromising data or transmission quality.

By increasing the degrees of freedom of the channel, non-line-of-sight (NLOS) paths are frequently known to affect channel fading, inter-user interference, or offer spatial diversity for multiplexing in such systems. At these lower frequencies, there is often no distinction established between a specular reflection and diffuse scattering since broadcasts are typically quasi-omnidirectional and not in the form of directional beams. The scenario is extremely different and more analogous to the realm of optics at frequencies between 100 and 500 GHz. Because the bulk of anticipated uses in this frequency range, such as sensing, communications, and imaging, are likely to rely on highly directed broadcasts (i.e., beams), the relevance of NLOS pathways is dramatically different. One important illustration comes from the notion of wireless communication links.

One of the important characteristics of FSO systems is their ability to transmit a very narrow optical beam, which improves security. The beam, however, scatters as a result of diffraction. As a result, only a fraction of the signal from the beam may be picked up by the receiver aperture. The residual uncollected beam is what causes the beam divergence loss. 2 mrad beam divergence is typically used at greater data rates, whereas 68 mrad beam divergence is typical for systems with relatively modest data rates. The quantity of the beam divergence is really controlled by the optical channel and aiming jitter. The quantity of optical power concentrated on the detector is determined by taking into account the configuration of an FSO communication connection and applying the thin lens approximation to the diffuse optical source whose irradiance is symbolized by I_s.

$$p_{r=\frac{I_s A_t A_r}{L_p^2 A_s}} \tag{15}$$

where As is the area of the optical source and Lp is the path length, and At and Ar are the transmitter and receiver effective aperture areas, respectively. This demonstrates unequivocally that increasing the received optical power necessitates a source with high brightness Is/As and large apertures. The size of the picture created at the reception plane for a nondiffuse, tiny source like a laser is no longer dictated by the thin lens approximation; rather, diffraction at the transmitter aperture determines it. It is well known that a collection of concentric rings makes up the diffraction pattern created by a circular aperture with a diameter of dt and uniform illumination.

The obtained optical power then becomes into

$$p_r = p_t \left(\frac{4}{\pi}\right)^2 \frac{A_t A_r}{L_p^2 \lambda^2} \tag{16}$$

Thus, the geometric loss in dB due to diffraction restricted beam spreading is given by

$$L_{gl} = -10\left[log\left(\frac{A_t A_r}{L_p^2 \lambda^2}\right) + 2log\left(\frac{4}{\pi}\right)\right] \tag{17}$$

Thus, the decibel loss in terms of geometry

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$$l_{geom} = -20log\left[\frac{d_r}{d_t+\theta_s L_p}\right] \quad (18)$$

Equation (17) beam spreading loss for the diffraction-limited source is, as one might assume, lower than Equation (18) for the non-diffraction-limited case since the diffraction-limited case's picture size is reduced by dt.

In terrestrial FSO systems, it is evident from the aforementioned that a source with a very small angle of divergence is preferred. To alleviate the alignment requirement, account for building sway, and avoid the need for active tracking devices, broad divergence angle sources are nonetheless preferred in short-range FSO connections, although at the penalty of greater geometric loss. For systems without and with tracking, a typical FSO transceiver has optical beam divergence in the range of 2-10 mrad and 005-10 mrad, respectively. This translates to a beam spread of 2-10 and 5 cm to 1 m at 1 km connection range.

IMPLEMENTATION OF THE SYSTEM PARAMETERS:

The system parameters are established in the table 1 provided in this work, and we will establish the values for MATLAB.

VLC Link	Parameter	Values
ROOM	SIZE	12m12m*3m
SOURCE	Location of six Transmitters coordinates	1. Centre(6,6,3) 2. (6,0,3) 3. (0,6,3) 4. (12,6,3) 5. (6,12,3)
	Semi Angle at half power	60°
	Transmitted power	5mW
	Transmission coefficient of optical filter	1
RECEIVER	Received power	Pt*G*C*F
	Detector physical area of PD	1 cm^2
	Refractive index of lens at PD	1.5

Table 1 lists the system parameters for Line Of Sight model.

RESULTS AND ANALYSIS:

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This part will include the outcomes of the article and the findings of the MATLAB simulation. Signal to noise ratio (SNR), received power, bit error rate (BER), and distance between source and receiver are used as performance measures.

SIMULATION ANALYSIS

For the purpose of creating the simulation programme, we assume the physical parameters. The office space is 12m x 12m x 3m in size, with LED lighting put in the ceiling; the desk's height is unspecified, and the receiver is positioned on the working plane. Table 1 includes the remaining simulation settings.

Figure 2 depicts the relationship between the distance between the LED and photodiode and the total received power in comparison with LOS model and Kim's model. Because of the nature of light, which prevents it from passing through opaque materials, transmission is limited in range. It is believed that the emission source has a lambertian radiation pattern. According to the concept of lambertian emission, the light intensity emitted from the source is cosine-dependent on the angle of emission with respect to the surface normal. We make two assumptions regarding the position of the LEDs on the ceiling in order to examine the LED lighting system's illuminance distribution. The position for one transmitter is in the center of the ceiling, and for several transmitters, the transmitters are spaced evenly apart. Maximum power is received at the closest distance. The received power will drop as the receiver travels farther from the closest point. The VLC system's photodiode analysis takes into account the distance between the LED sources and the receiver in terms of received power. The photodiode height is 3m, and D is the hanging distance between LEDs. It is discovered that as the distance between the LED source and receiver rises, the received power is shown to be diminishing. In particular, we found that at D=1 in a 12*12*3 m^3 room dimension, we had satisfactory results for LOS model. In particular, we discovered that the simulation results for the line of sight model had a high received power.

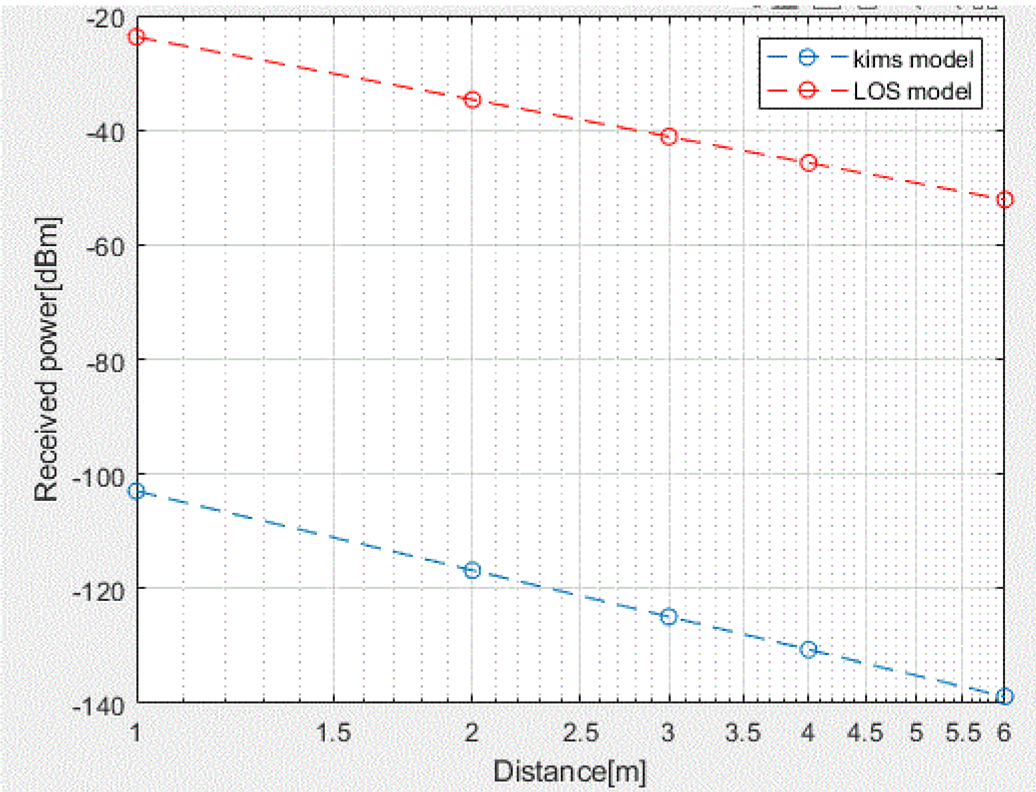

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FIGURE 2: TOTAL RECEIVED OPTICAL POWER VS DISTANCE

The quality of the communication signal in wireless communications is significantly influenced by the separation between the transmitter and receiver. Equation 1 states that the relationship between the received optical power and distance is inverse. Therefore, a longer distance would result in a lower received power, a lower SNR, and a larger BER. The results of this MATLAB simulation clearly show that received power decreases with increasing distance. Similar to Figures 3, 4 the SNR declines dramatically, which causes the BER to rise.

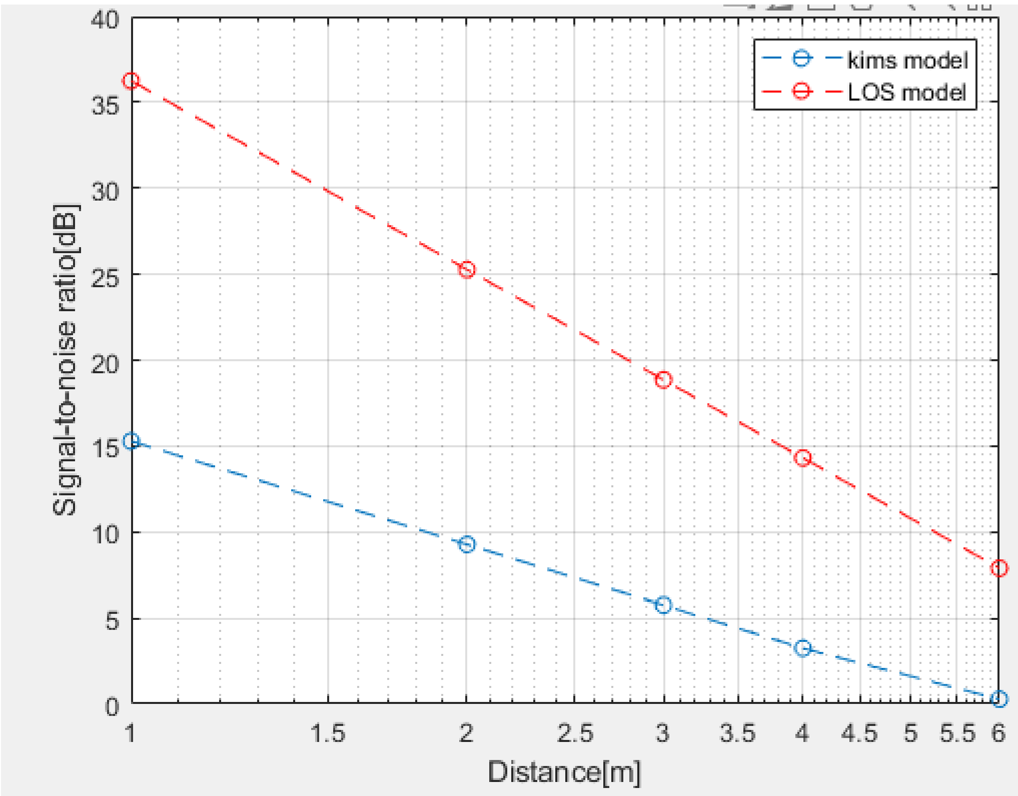

FIGURE 3: SNR [dB] VS DISTANCE[m]

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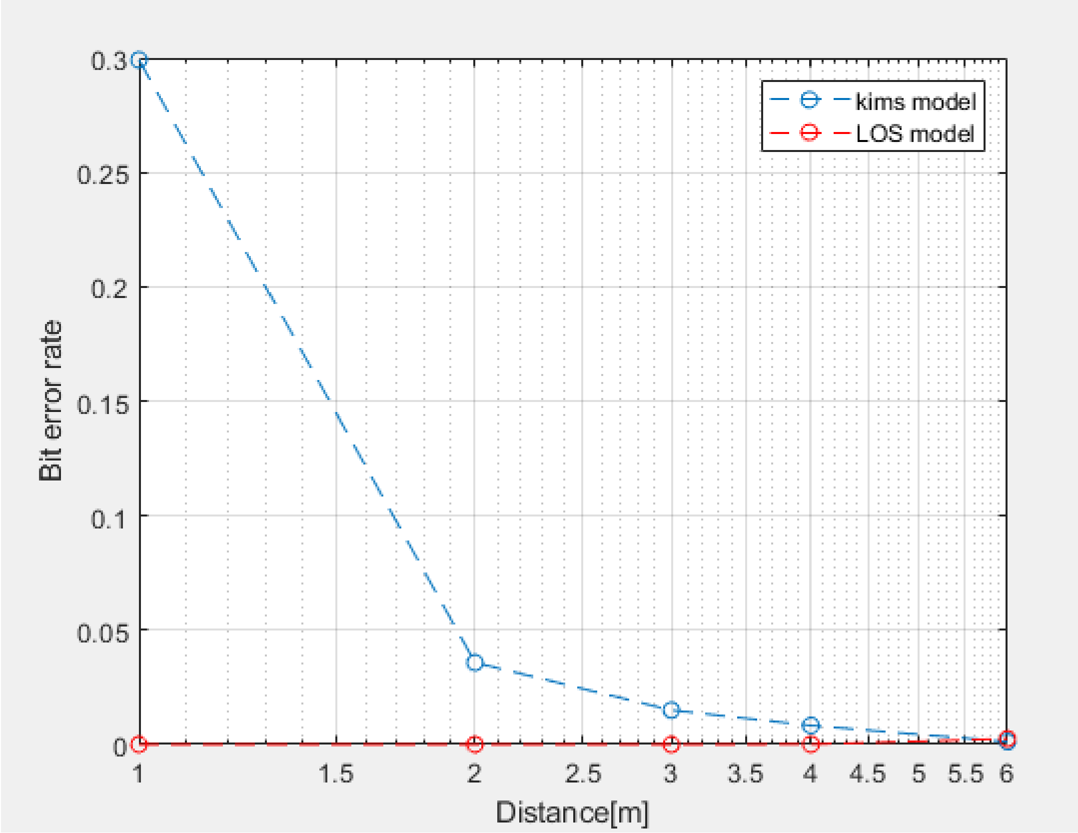

FIGURE 4: BER VS DISTANCE[m]

In this work, two types of models were taken into consideration. One is the Line of sight model, while the other is Kim’s model (i.e., NLOS). NLOS reduces the received power’s effective level. Better antennas can often handle near-line-of-sight applications, while non-line-of-sight applications typically call for other routes or multipath propagation techniques. Both models are designed to operate in indoor environment. Finally, we found that the Line of sight propagation model produced good results when compared to the findings of the aforementioned comparison.

CONCLUSION:

Future prospects for this technology are excellent. Without needing to make significant adjustments to the existing infrastructure, this technology offered a solution to the issue of integrating Visible Light Communication technology. One area of communication that is expanding quickly is visible light communication. Utilizing VLC has several benefits. There are a lot of obstacles as well. VLC will be able to address many of the concerns that people have been dealing with for a long time, particularly those related to the environment and energy use. Although VLC is still in its infancy, advancements are being made quickly, and soon this technology will be used in our daily life. Despite the research issues, we think that the VLC system will emerge as one of the optical wireless communication industry's most promising technologies in the future.

With LED serving as the source and photodiode serving as the receiver, the VLC system is created. Lambertian radiation pattern model is taken into account for the light-wave channel between the transmitter and receiver. Received power, bit error rate, and signal to noise ratio (SNR) distribution of LED arrays

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spatially. A method for communicating with visible light has been developed taking both non-line-of-sight and line-of-sight propagation into account.

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