Enhancing of SNR and Optical Power Distribution in Indoor Visible Light Communications Systems

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***Abstract*— There are many difficulties that limit the applications of indoor visible light communication systems (VLC) such as nonuniformed power distribution, high signal to noise ratio (SNR). This paper proposed mathematical models for diffuse channel configuration and light of sight (LOS) channel configuration. All models in this paper assumed to have an arrangement of four LEDs on the room ceiling along the orthogonal axes. The paper investigated the indoor light power distribution and SNR in each layout model of LEDS. The results selected the optimized deployment in a room of 8m length, 8m width and 3 m height. The best deployment of the LOS configurations where selected to guarantee the uniform optical power distribution is received with acceptable SNR value. The diffuse channel configuration shows high interference rate when the sources are located closed to walls.**

***Index Terms*— Diffuse Channel; Lifi; LOS Channel; SNR.**

I. Introduction

High speed of transmission and mobility of users make the optimization of wireless communication systems over guided transmission of data. Optical wireless communication have many advantages for short ranges communication, such as the available spectrum, unlike RF communication, which has restricted spectrum. Further, it can be available in forms such infrared (IR), ultraviolet (UV)[1]. Visible light communication (VLC) is the new generation of optical wireless communication that used visible light to transmit data, it is used widely in indoor communications systems and besides its low cost due to the used of LED as transmitter and photodiode as receiver, this technology does not cause any side effects on the human eyes [2].This paper studied the optical power distribution and SNR on the system in two types of channel diffuse channel and line of sight channel (LOS). MATLAB software was used for analysis and simulation of VLC model system. The paper focused on selecting the best deployment of transmitters on the orthogonal axes of the room. The optimized deployment is given best results of power distribution and SNR values.

II. Related Work

VLC system is a promising technology which is very attractive for many researches to explore in its performance, limitations and optimum configuration. The significant of this study is improving the SNR and receiving optical power distribution (ROPD) in VLC system by selecting the optimum configuration of transmitters. Table 1 summarizes some of the related works published in this field.

The proposed design in this paper offers better performance than Hongfei.L[9] which presented VLC system using four LED_s placed on the room corners in rectangular configuration. The results of the measured SNR in his model was 82.2 ~ 87.2.

Table 1
Summary of related works

Author	Year	Summary
Nakagawa [6]	2004	Showed example of design and explained the relation between the data rate and the FOV
Kavehrad [7]	2006	Designed a white LED system for with no blind spot
Zixiong [8]	2012	Proposed LED lamp arrangement with 4 LED lamps positioned in the corners and 12 LED lamps spread evenly on a circle to reduce the SNR fluctuation
Hongfei. L [9]	2014	Showed the effects of diffuse light power link and propose a method of reasonable layout of the LED array to improve the optical power distribution
Niaz [10]	2016	Considered a circular LED deployment scheme that delivers better ROPD and proposed optimization algorithm to improves the AOAR
Latif [11]	2017	Survey of the potential applications, architecture, modulation techniques, and standardization and research challenges in VLC.

III. Methodology

The common type of channel often used in VLC systems are LOS and diffuse channels. This paper described the mathematical model of LOS propagation and diffuse propagation model. The study assumed the following:

- The indoor communication environment is an 8m×8m room with a height of 3 m
- The transmitting LEDs are placed on the ceiling, and the receiving device is placed on a receiving plane. Figure 1 shows the place of receiver in the room and the arrangement of LED_s in the celling.
- The number of transmitter LED_S is four, which is distributed in circular deployment.
- The paper suggested three different deployments to be studied which are defined in the following:
  - Case (1): Four LEDs transmitter in the positions (0, 1.3), (0,-1.3), (1.3, 0) and (-1.3, 0).
  - Case (2): :Four LEDs transmitter in the positions (0,2), (0,-2) ,(2,0) and (-2,0).
  - Case (3): Four LEDs transmitter in (0, 2.6) (0,-2.6) (2.6,
  - (-2.6, 0).

The parameters of the simulation are shown in Table 2.

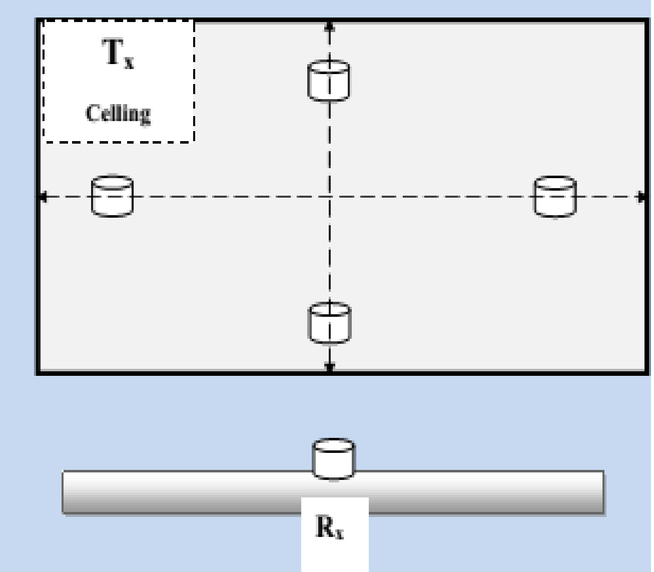

Figure 1: Orthogonal Model

Table 2
List of simulation parameters

Parameter	Equivalent Value
Single LED power	20mW
Amplifier Bandwidth	50MHz
Floor reflectivity	0.7
The size of detector	1.0cm^3
Concentrator gain	6.0
Photodiode responsively	0.4A/W
Amplifier noise density	50PA/√Hz
Ambient noise power	19.272μw
Noise-bandwidth factor	0.562
Optical filter's transmission coefficient	1.0

A. LOS Propagation Model

The line of sight channel (LOS) is point-to-point link, as shown in Figure 2. This type of optical transmission has limited coverage; but on the other side, it used low power to avoid the experience of losing the result of reflection. The LOS propagation model in this paper consists of four LEDs used as a transmitter. A photodiode was used as the detector. Lambertian radiant intensity of the LED is given by [3]:

$$R(\varphi) = [\,(n+1) / 2\pi\,]\cos^n(\varphi) \quad (1)$$

where: $R(\varphi)$ = Lambertian radiant intensity and n = Lambertian emission coefficient can be calculated by

$$n = \ln 2/\ln\cos(\varphi_{1/2}) \quad (2)$$

where : $\varphi_{1/2}$ = Semi-angle at half power .

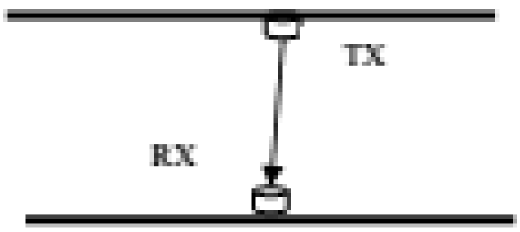

Figure 2: LOS link

The transmitted power can be given by:

$$P = P_{(LED)} \times R(\varphi) \quad (3)$$

The total power of LOS channel is given by:

$$P_{(LOS)} = \sum_{i=1}^{N} P_i \times H_{LOS} \quad (4)$$

where: N = Number of LED and H_{LOS} = the transfer function.

The received power at the receiver are given as

$$P_r = P_t * \frac{m_1+1}{2\pi d^2} cos^{m_1}(\emptyset).T_s(\varphi).G(\varphi).\cos(\varphi) \quad (5)$$

where: φ = the angle of incidence with respect to the axis normal to the receiver surface, $T_s(\varphi)$= the filter transmission $G(\varphi)$= the concentrator gain.

B. Diffuse Channel Model

Diffuse reflection model of the Indoor visible light system is in the essence a reparative reflected light power [4]. Unlike LOS channel, both the transmitter and receiver do not require to have direct link, as shown in Figure 3 [5]. Diffused channel effects by multipath interference is evident because it depends on the reflection of light over the ceiling and walls of the room. It has the advantage of wide covering area.

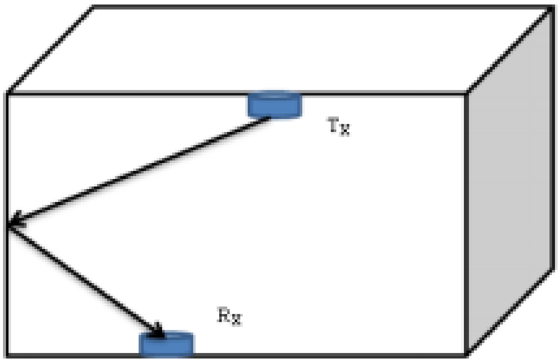

Figure 3: Diffusion channel

To calculate the light intensity due to reflection, we can use the following equation [4].

$$I = (P_{LEDS}/A) \times \rho \quad (6)$$

where I= Light Intensity, P_{LEDS}= Total power room, A = the area of walls and ρ is the reflectivity of walls.

Therefore, the received power of diffused channel can be given as:

$$P_{diff} = Receiver\ Area\ \times I \quad (7)$$

The total power of receiver is the sum of received power in direct path and the received power in reflected path:

$$P_r = (P_{LOS} + P_{Diff}) \times G \times T \quad (8)$$

where G = The concentrator gain and T = The filter coefficient.

The signal to noise ratio (SNR) can be calculated by:

$$SNR = (Photodiode\ output\ urrent)^2/\sigma^2 \quad (9)$$

where: σ^2 = The total noise variance.

IV. Results and Discussions

The simulation results of the scenarios illustrated in our assumptions as defined in the previous sections are shown in Figure 4 to Figure 12. The results illustrate the measured values of the received optical power distributes, SNR and the diffuse channel power distribution of each. The results of the first case where the LED_S have the following arrangement (0, 1.3) (0,-1.3) (1.3, 0) (-1.3, 0) are shown in Figure 4 to Figure 6. We observed that light and optical power are concentrated in the middle.

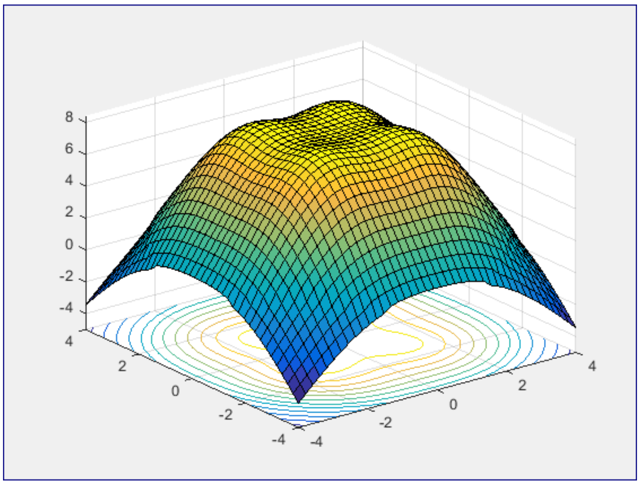

Figure 4: Power Distribution

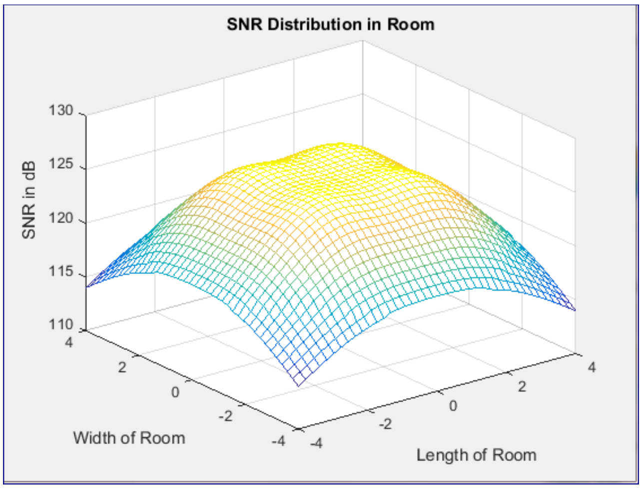

Figure 5: SNR

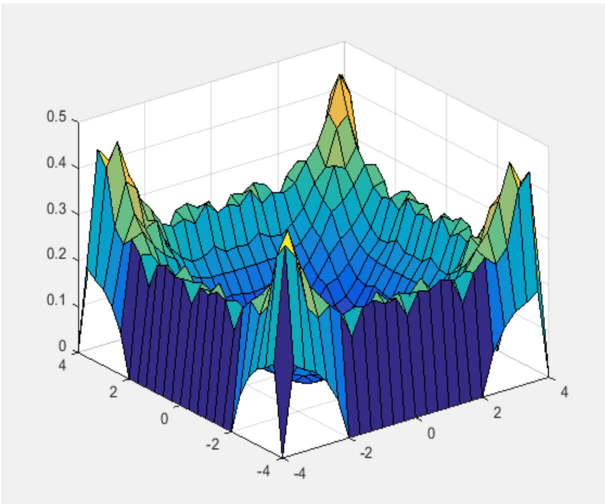

Figure 6: Diffuse channel optical distribution

The results of the second case where the LED_S have the the following arrangement (0, 2) (0,-2) (2, 0) (-2, 0) are shown in Figure 7 to Figure 9. We can see that by moving the LED further apart, the distribution of the received optical power improved.

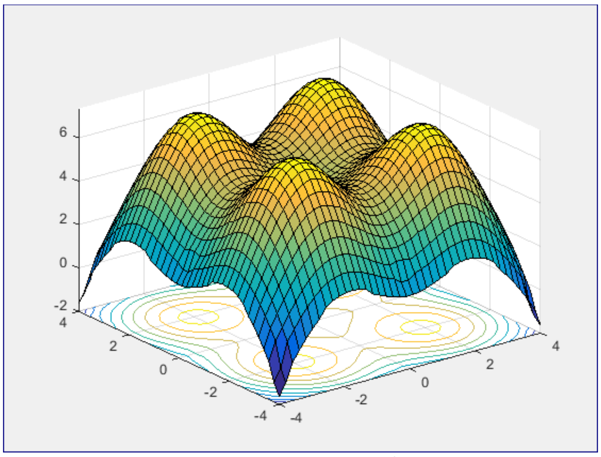

Figure 7: Power distribution for LOS

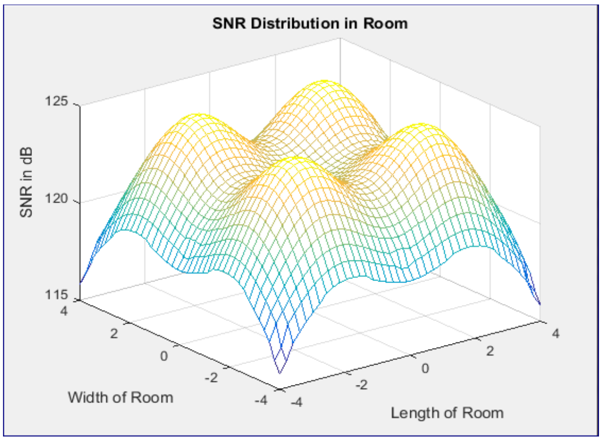

Figure 8: SNR

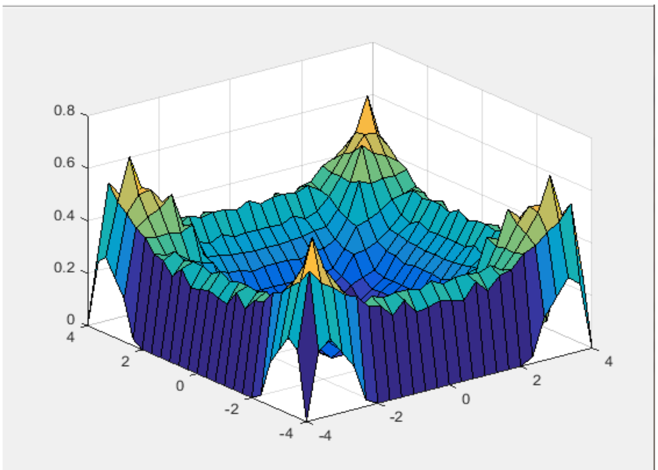

Figure 9: Diffuse channel optical distribution

Similarly, the results of the third case where the LED_S have the following arrangements (0, 2.6) (0,-2.6) (2.6, 0) (-2.6, 0), are shown in Figure 10 to Figure 12.

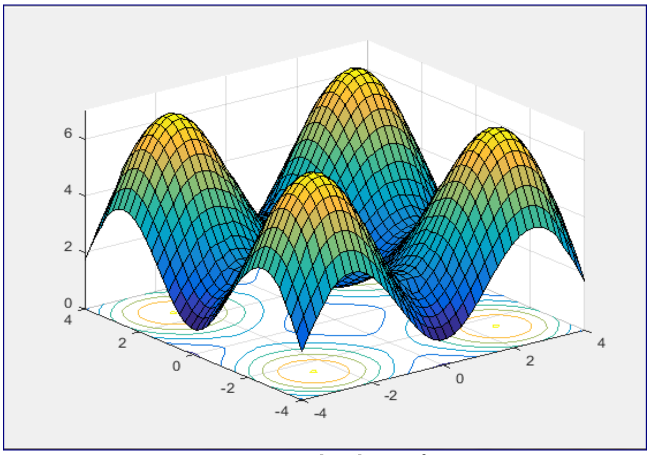

Figure 10: Power distribution for LOS

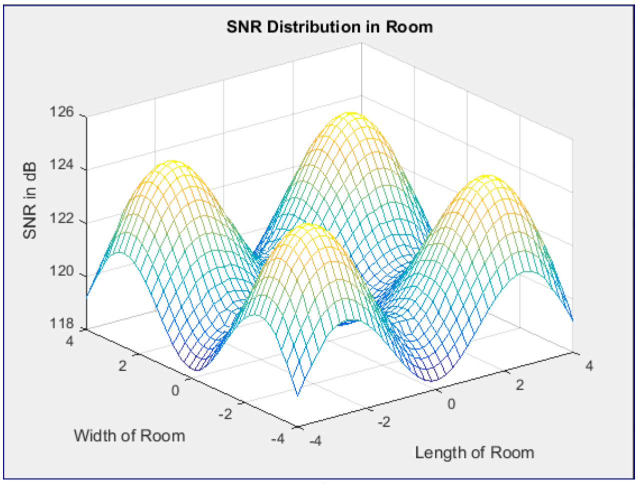

Figure 11: SNR for LOS channel

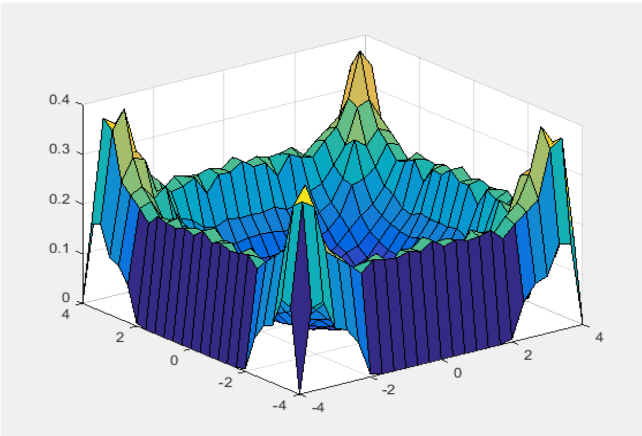

Figure 12: Diffuse channel optical distribution

The results of SNR and received optical power distirbution ROPD are important to select the optmum deplyment, which ensure high quality of signal. The results of the first case shows that the SNR is the range of 114dB to 121dB. There are many dead zones appeared in a system . The second case exhibits the best results where the SNR sets in the range of 114dB -122.5dB and the ROPD sets in the range -2dB_5.5dB, it reflects uniform ROPD. In case three, the SNR sets in the range 119dB-123.5dB and ROPD is -2dB _ 6.1dB but the ROPD is much fluctuated. Due to reflections, the results of diffuse channel showed high influence of interference increased as the LED$_s$ arrangement were close to the room walls.

V. Conclusion

This paper discussed the performance of VLC system in different configurations using MATLAB simulation tool. The paper considered two propagation models of LOS and diffuse models. The results found that a diffuse channel has a great influence on system. We considered three scenarios of LEDs arrangement, all located on the orthogonal axes of the room. The paper found that in the case where the LEDs sets at the half distance between the room center and the edge of each axes in the four directions reflects better optical power distribution and high SNR than other configurations. The comparative with other works exhibit that the circular deployment of LED$_S$ reveals better power distributions and SNR values than the deployment along the axes connects between the corners angles.

Acknowledgement

This research was given by the funding of University of Gezira- Sudan- Department of Electronics.

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