"The usage of optical wireless communication for an indoor channel link"

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Abstract :-

Optical wireless communication using white LEDs is the latest research field for next-generation communication by using new technology termed as Light Fidelity or more commonly known as Li-Fi. This term indicate to the data transition in an indoor channel. In this paper we investigated the performance of Li-Fi for indoor channel and take into account the line of the sight (LOS) and non line of sight (NLOS). There are different metrics used to assessment system such as quality factor (Q-Factor) and bet error rate (BER). The results show that the Li-Fi technology can be working with a good performance. Also, the increase in optical link leads to a weak in the record signal.

1- Introduction :-

In the last decade, the world has witnessed a big increase in communications traffic through telecommunications networks, including wireless networks. Optical Communication (OWC) is one of an important parts of communication. The term OWC mention to any optical transmission in an unnavigable media although its variance based on the operating frequency might have different use as function in the following OWC systems operating in the visible bandwidth (390-750 nm) are usually referred to a visible light communication (VLC). VLC systems take benefit of light emitting diodes (LEDs) which can be transfer at very high speeds without notable effect on the lighting output and human eyes[1]. The duple use of LEDs for communication and illumination purposes is a sustainable and energy-efficient approach and has the potential to revolutionize in communication and use light. VLC can be used in a wide area of applications inclusive wireless local area networks, wireless personal area networks and vehicular networks among others. LEDs due to their unique characteristic of high switching rate had predominantly become the most suitable light source for VLC. With the recent pass for energy efficient light sources for residential, retailing and commercial units, LEDs are rapidly replacing traditional lighting fixtures, which make the case of using them for VLC much more stronger. Although LEDs would have to be kept on to transmit data, they could be dimmed to below human visibility while still emitting enough light to carry data[2]. There are many benefits in case we using LEDs to transfer data like :

(1) Fully avoiding the interference happened between the outdoor and indoor use .

(2) There is no interference, lower power RF base station, so ‘greener’ mobile networks.

(3) Most effective in utilization of the scarce wireless transmission resources.

(4) Reduced costs and improved user experience.

2 Theoretical background :-

Wireless optical technology provides various outdoor and indoor services such as indoor wireless (ir) communications[3], earthly links[4], wireless (uv) communications[5], and visible light communications[6]. The LED was used for data transmission and the diffuse channel is used as a media. The component of Diffuse Channel modeling for indoor optical wireless systems based on (Lambertian source model)[7]. It assumes the transmit source is a Lambertian source that is irradiating a detector surface located at an axial distance from the source. Based on the transmitter (source) half-angle (∅) or angle of radiation power, the Lambertian order is calculated as follows [7]:

$$\boldsymbol{m} = \frac{-\log(2)}{\log(\boldsymbol{cos}(\emptyset))} \text{..................} \qquad \textbf{(1)}$$

Where m is Lambert's mode number (expressing directivity of the source beam).

φ is the angle of radiated power ,when Ø = 0 is the angle of maximum radiated power

For Ø = 60°, m=1 (Lambertian transmitter).

Since $m = \frac{-\log(2)}{\log(cos(\emptyset))} = \frac{-0.3}{-0.3} = 1$. The gain of optical concentrator is calculated as follows [8]:

$$\textbf{Loss} = \left[\frac{\{(\boldsymbol{m}+1).\boldsymbol{Ad}\}}{2\pi.\boldsymbol{h}^2}\right](\boldsymbol{Gain}\ .(\cos\Theta)^{\boldsymbol{m}} \cos\emptyset\ ) \quad \textbf{......(2)}$$

Where (h) is the distance between an LED chip and a receiving point, $(A_d)$is an effected area of a photo detector, Ø is transmitter half angle and the Θ is the angle between vertical and the line between source and receiver.

In any simulation program like optisystem ver. (15),it must take into consideration the parameters that effected to the environment of the program and how change the parameter depend to this parameters and don't change it arbitrary. The optical wireless channel transfer function is defined by[9] :

$$\mathbf{H_{ow}(f) = H_{\,los} + H_{diff}} \quad \ldots\ldots\ldots\ldots\ldots \quad \mathbf{(3)}$$

Where H_{los} is the contribution due to the LOS, which is basically independent on the modulation frequency, and it depends on the distance between transmitter and receiver and on their orientation with respect to the LOS , whereas H_{diff} is almost homogeneous and isotropic in most rooms . In a directed link the power ratio between the LOS and the diffuse links can be increased by reducing the transmitter beam width and/or the receiver front of view (FOV).This can be quantified by the Rician factor (K_{rf})[10]:

$$\mathbf{K_{rf} = (\frac{H_{los}}{H_{diff}})^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathbf{(4)}$$

As in radio communications it is defined via the electrical signal powers. The radiant intensity $S(\emptyset)$ is given by[11]:

$$S(\emptyset) = Pt\,\frac{(m1+1)}{2\pi d^2} \quad cos^{m1}(\emptyset) \quad \ldots\ldots\ldots \quad (5)$$

Where ϕ is the angle of radiated power ,mentioned in eq. (1).
The received power becomes[12]:

$$\mathbf{P_{r-los=H_{los}}\,(0)P_t.} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ \mathbf{(6)}$$

Where P_t is the power transmit , P_r is power received and H_{los} is the contribution due to the LOS.

3- Simulation design and diagram :-

The figure (1) is clarify the component of the program and device used in our project.

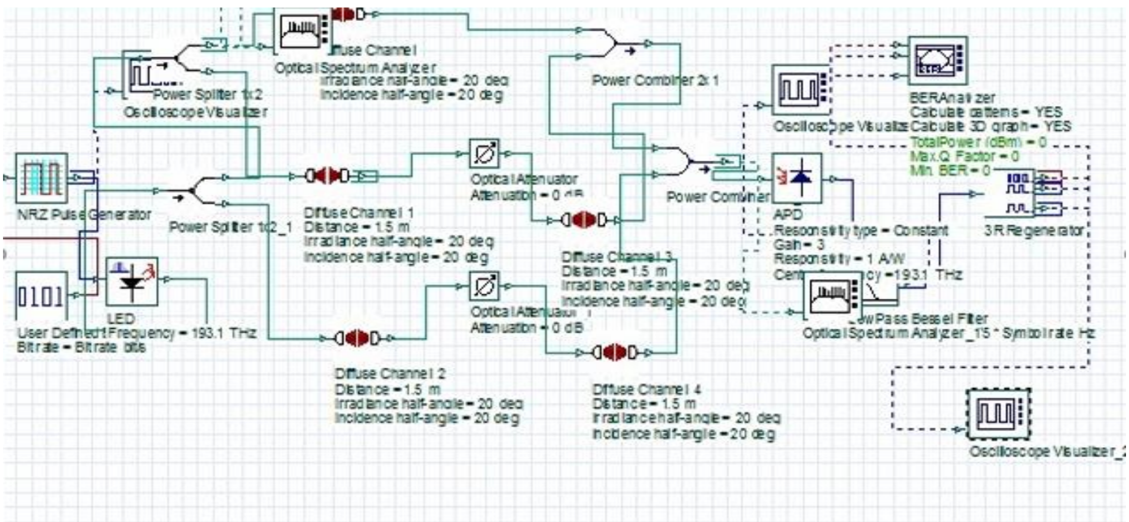

Fig (1) : Optisystem simulation model of LOS and NLOS propagation model

VLC system is designed with the help of Optisystem 15. The measured parameters are utilized in Free Space Optics (FSO)component in Optisystem to realis the channel characteristics on simulation for our Visible light communication using white LED.

In this model fig.(1) , the condition for the project was :-

- The diffuse channel was free space .
- The angle was 20^{o}.
- Data rate was 300kps.
- User defined bit sequence generator is the followed by NRZ pulse generator that supply the data signal for the white LED.
- The frequency of (LED) was 1550 nm.

The frequency caring the data in diffuse channel in tow links, (LOS) and (NLOS) respectively by using a power splitter for divided the signal to the two parts. The signal external from the splitter to the diffuse channel and collected it by the power commoner to receive it by an avalanche photo diode as a detector. The received data is filtered using Bessel filter[13] (This filtered signal is regenerated with help of 3R regenerator to analyze the Bit error rate (BER) and Q- factor in BER analyzer) to remove the optical frequency interference in PIN output.

In this optisystem simulation, there are four test to find the value of Q. factor versus of changing distance for LOS and NLOS, the first test was, the distance for (LOS) link was 3m and for the N-LOS link is 1.5 m for each diffuse channel. The Q -factor in this condition is 12.9 and (BER) was 1.09 e^{-36}.

The second test was the distance is increasing, the LOS link become 5m , and NLOS was 2.5m . It is notice that the performance of the system is decrease. In this case Q-factor was (10.9) and the (BER) was equal to 18.87e^{-27}.

The third test was the distance of 7m for (LOS) link while the NLOS is 3.5m for four NLOS link. The Q- factor and the (BER) was 6.8 and 2.8 e^{-12} respectively . When the distance is increase the quality of the system or (Q- factor) is decreases because of the relationship between the Q-factor and the distance between transition and the reception is inverse since . In this situation the distance was 9m and 4.5m for LOS and NLOS respectively. Finely it is observed that when the distance reach to 9m , the

Q- factor was 4.8 and the (BER) was 0.6 e^{-6} as is evident from fig. (2) and fig.(3).

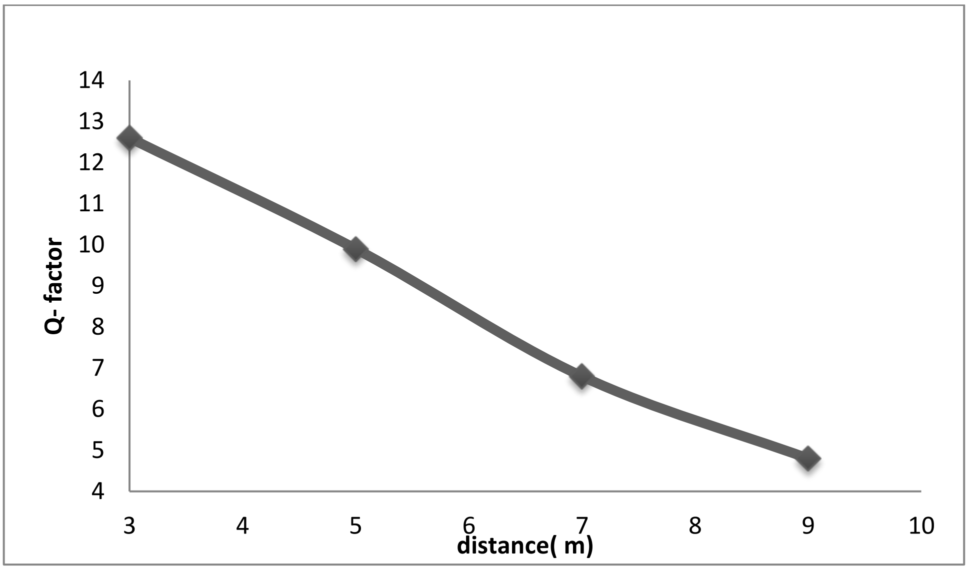

Fig (2): Q- factor versus. distance of LOS

Noticed when the distance increase the Q-factor is decrease until reach to 7m. Where Q- factor is 6.8 ,this is acceptable result while greater than 7m the Q- factor is unacceptable result .Axis of fiq.(2) does not start from the origin point because of the distance in this project start from the 3m in the first test.

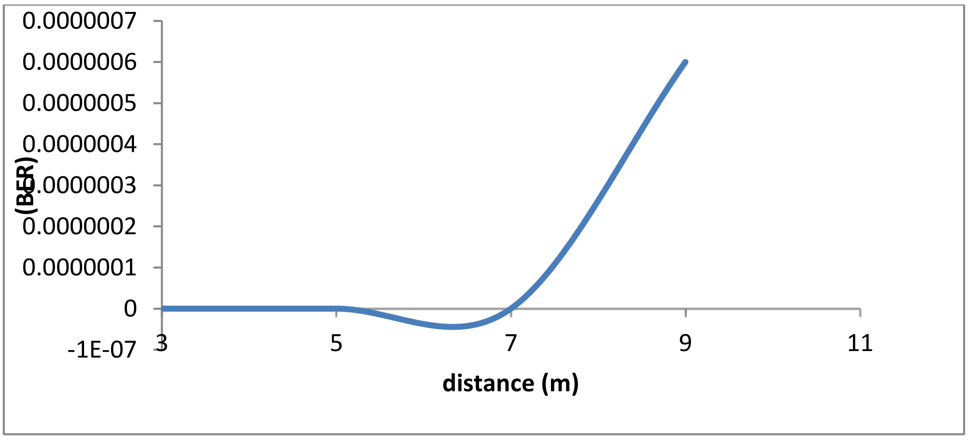

Fig. (3) BER vs distance (m) .

Fig. (4) present eye diagram for the signal under 3m and 7m .It noticed that when the LOS link applied 3m the diagram was clear and wide with a good signal as shown in fig. (4a) because of the wide circular ring that mediates the shape means that the signal received is a good signal. On the other hand when the LOS applied 7m the eye diagram was narrow and decreasing in the quality of the signal as shown in fig (4b). The diagram for 2 diminution is called eye diagram.

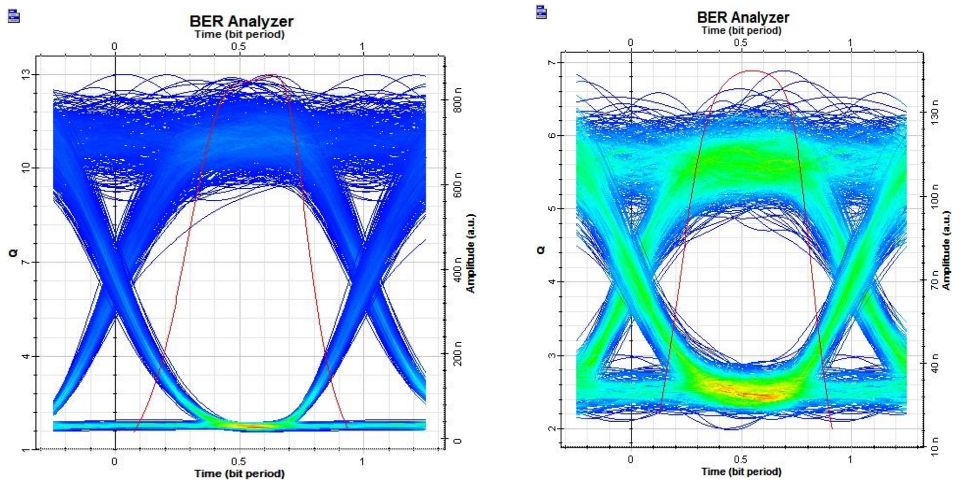

Fig (4) eye diagram of receive signal for (a)3m link distance (b)7m link distance

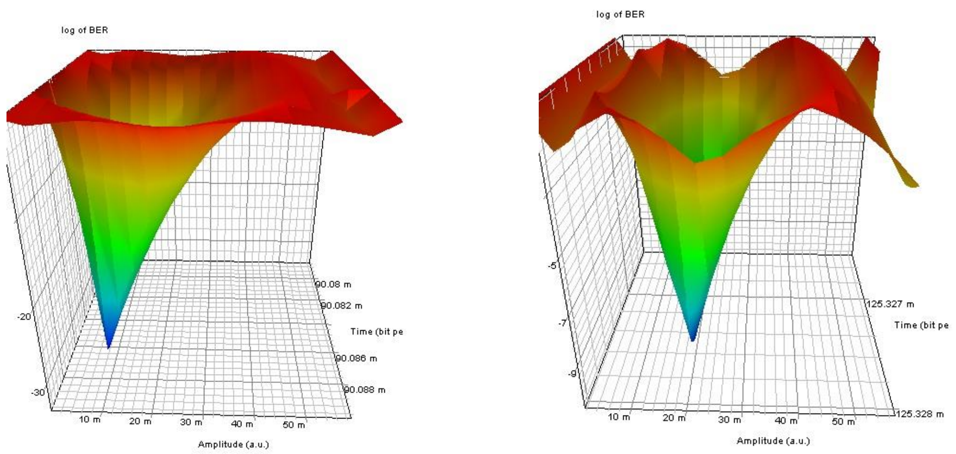

Fig. (5) a b

Fig. (5) 3D pattern for BER vs distance (m for (a)3m link distance (b)7m link distance.

Figure (5) is represent the values of 3 diminutions , in 3m and 7m link distance. Where the conical shape indicates that the value of the BER increases as the distance increases. This is evident from the opening of the large conical shape at a distance of 9 m.

It shown that the performance of an optical wireless communication system has been presented by several parameters such as by BER ,amplitude and time for 3m and 7m respectively .The min. BER for 3m was 1.09 e^{-36} ,while for 7m the min. BER was 2.8 e^{-12}. It is observed that the link have a good performance for the proposed system.

4- Conclusions :-

Most of studied in Li-Fi cannot take in account the non line of sight (NLOS) and the effect of the optical attenuator for indoor optical wireless system.The investigation of the work run out by the optiwave ver. 15 to examine the transmission of optical signal for indoor channel . The system can be work for 9m with a sufficient performance .The performance of the system can be an improvement with long distance and high data by increasing the power of the signal and used multi light source .

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