International Journal of Engineering & Technology, 7 (2.20) (2018) 170-173

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Analysis of visible light communication (VLC)for biomedical application

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Abstract

In the visible light communication (VLC), light emitting diodes (LEDs) are used as transmitters; the air is the transmission medium and the photodiodes are used for receivers. This is often referred to as light fidelity (Li-Fi). In this method, provide the methodology to evaluate the performance of VLC hotspot networks in the context of data downloading on the move scenarios by using throughput-distance relationship models. In this context, firstly, study the different properties of optical transceiver elements, noise sources, characterization interference, and different link topologies and then introduce the throughput-distance relationship model. Secondly, the analytically based throughput-distance relationship has been developed for evaluating the performance of VLC hotspot networks in indoor environment in both day and night conditions. Simulation results reveal that background noise has a significant impact on the performance of VLC hotspots. As expected, in both indoor and outdoor environments VLC hotspot performs better at night than during the day. The performance of VLC hotspot networks is also quantified in terms of received file size at different bit error rate requirements and velocities of the mobile user.

Keywords: *Visible Light Communication (VLC); Light Emitting Diodes(LED) ; Line of Sight (LOS); Semi Angle; Throughput Distance; Bit Error Rate(BER) And Spectrum Signals.*

1. Introduction

In VLC, the visible part of the spectrum is used for communication purposes. The visible light spectrum is unlimited and 10,000 times larger than the range of radio frequencies between 0 Hz to 30 GHz as shown in Figure.1 VLC provide access several hundred terahertz (THz) of unlicensed spectrum. One of the key merits of optical wireless systems is the relatively low transceiver complexity and low energy consumption of LEDs. As a result, VLC may facilitate the low energy-per-bit required for data transmission in comparison to RF systems. The visible light spectrum extends from 380 nm to 780 nm in wavelength. The VLC spectrum creates no electromagnetic interference to RF systems and vice versa In practice, many of the design parameters such as FOV of the receiver, divergence angle of LED, the degree of directionality between transmitter and receiver as well as ambient noise were considered in VLC link designing. It described these four basic link topologies. These four link characteristics were classified as directed-LOS, non-directed-LOS, non-directed-NLOS and tracked [2]. The coverage and data rate of such link designs were also provided in Many other advanced link topologies such as multi-spot diffuse link, DSD was also discussed In this thesis, non-directed LOS with tracking link topology was assumed to exist between transmitter and receiver and investigated the first scenario (data download on the move in VLC coverage). In this respect, firstly the study introduced the data download on the moving scenario with related concepts such as moving-in, moving-out, travelling angle in the mathematical framework to calculate the average throughput and file size were also introduced.

2. Data rate improvement in VLC test bed

Numerous papers have been published on increasing the data rate in VLC systems, especially for point-to-point link configuration. In most of these works, hardware demonstrations were carried out utilizing different modulation schemes, blue filtering as well as pre and post equalizers to improve the data rates. For example, in an experimental demonstration had been conducted building technology-independent MAC layer and PLC for services and connectivity to any number of devices in any room of a house and apartment. The architecture of the VLC system is illustrated in the Figure.1.

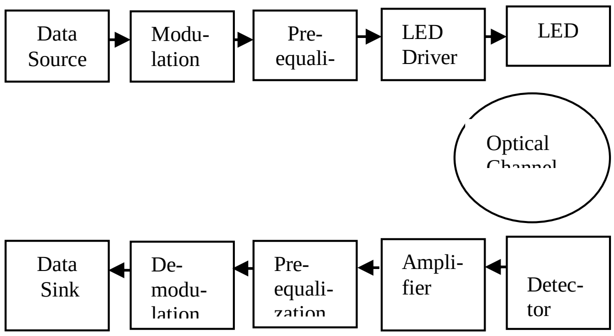

Fig .1: Block Diagram of VLC Transmitter and Receiver.

This work was part of the European Union (EU) funded home gigabit access (OMEGA) project to investigate optical-wireless communications. Data rate were achieved up to 73 Mbps in their demonstration using VLC. The prototype consists of two parts: digital signal processing and an analogue part. In their experimental setup, digital signal processing was implemented on a Vertex-5 field programming gate array (FPGA) board where serial input was mapped to a 16-quadrature amplitude modulation (16-QAM) symbol stream. On the analogue front end, the transmitter consisted of driving circuit, trans-conductance amplifier, and commercial Osram (OSTAR E3B) high-power LEDs. On the receiver side, imaging optics, a colour filter, a photodiode, a two-stage trans-impedance amplifier, and band-pass filter were used.

3. Link characterization in VLC

In VLC, link topologies can be configured in many ways. However, they are typically classified into four different basic links. Classification of these topologies is done mainly according to the degree of directionality and the presence of uninterrupted LOS between the transmitter and receiver. The basic characteristics of these link topologies are described in detail. Different types of diffuse links such as multi-spot diffuse links, dynamic multi-spot diffuse links are also discussed along with four basic link topologies. Link design of LOS and NLOS are also derived and discussed in this chapter. Finally, measurement-based link design and their performance are discussed [8].

3.1. Basics link types of VLC

Four different basic link characteristics in an indoor environment are shown in Figure.2 These four link characteristics are classified as directed-LOS, non-directed-LOS, non directed-NLOS and tracked. There are mainly two criteria used to classify these link topologies. The first is the degree of directionality and the other is the presence of uninterrupted LOS between transmitter and receiver. In directed directionality, both transmitter and receiver have narrow FOV. On the other hand, in non-directed directionality, both transmitter and receiver have wide FOV. If the LOS path is present in directed directionality, then this link topology is defined as directed-LOS, otherwise, link topologies can be classified as directed-NLOS and non- directed-NLOS. Non-directed-NLOS is also known as a diffuse link. Directed LOS is typically used in point-to-point communication links in indoor and outdoor environments as shown in Figure.2 this type of link topology experiences lower path loss and less impact of ambient light noise. As a result, hundreds of Mbps data rates can be achieved in directed LOS indoor as well as outdoor OW links 8].

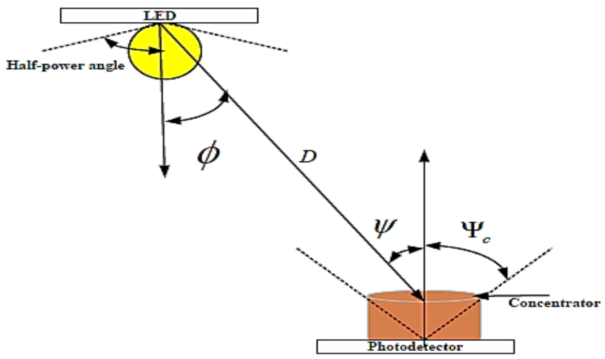

Fig .2: Link Configurations in LOS Case.

However, since this link topology requires strict alignment for LOS between transmitter and receiver, mobility is an issue to work with this link topology. In non-directed-LOS, a wide beam transmitter and wide FOV receivers are used to achieve a broader coverage area. Non-directed-LOS can be used in point-multipoint communications [2]. In this type of link topology, in addition to the LOS link, there are also other multiple signal reflections from the walls and objects of the room. The link without LOS reflections from the walls and ceiling is known as a non-directed-NLOS or diffuse link. Diffuse links are relatively immune to blockage and pointing errors and permit a great degree of mobility for the receivers in an indoor environment. However, the received signal is corrupted by multipath dispersion. As a result, a large number of collected reflections received at the receiver limit to achieve a high data rate due to inter-symbol interference. Multi-beam transmitters together with a multiple element narrow FOV angle diversity receiver are also suggested. This type of link configuration is also known as a quasi multi-spot beam. In this link architecture, a combination of point-to-point links with the mobility is achieved through diffuse links. In this case, each diffusing spot would be considered as a source of LOS link to a narrow FOV of the receiver .Although diffuse and multi-spot diffuse links depend on the reflections but there is a noticeable difference between these two link configurations. In the diffuse link, light emits over a large divergence angle, on the other hand, in the multi-spot diffuse link a series of narrow divergence beams directed to the ceiling which results into far smaller path loss in multi-spot diffuse systems than in diffuse systems [5].

3.2. VLC hotspot design parameters and their relationships

Prior to deploying any wireless networks, a number of scenarios and the relationship of key design parameters are targeted to evaluate performance in terms of capacity and reliability. Some examples of these relationships are SNR vs. throughput, SNR vs. distance, BER vs. data rate and so on. These relationships are used as tools in analytical models for analyzing as well as designing wireless networks before being deployed in practice [7].

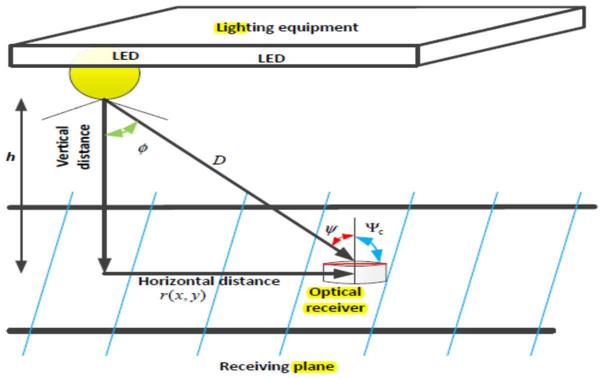

Fig. 3: VLC Hotspot Coverage.

Figure.3 shows the FOV changes due to the horizontal separation between transmitter and receiver with step changes of 0:1m. As mentioned earlier in the case of worst-case alignment, the irradiance and reception angle will be the same. It is seen in Figure.3 that as the step value increases the alignment between irradiance and reception angle increases. In this particular case, the half-power at semi-angle is chosen as 85o and FOV of the receiver is chosen as 60o. Figure.3 shows the variation of received power with Lambertian order m. It is also seen that for a fixed lam.

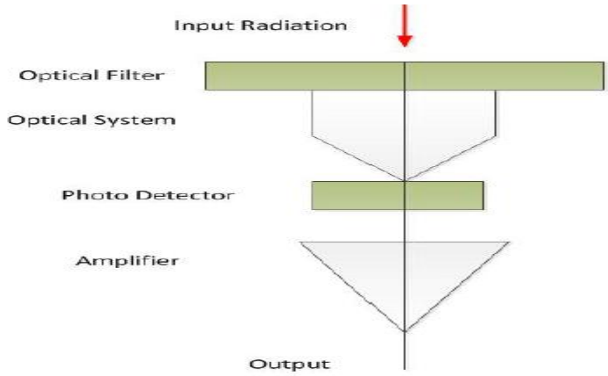

Fig. 4: Flow Diagram of VLC Communication.

Bertian order the narrow semi-angle at half power provides the order Lambertian order [3]. The flow diagram of the VLC system is clearly shown in the above Figure.4. For achieving a higher transmission Figure.4 Flow Diagram of VLC Communication Bandwidth the half-power semi-angle of the LED can be tuned to its optimal value. The optimal Lambertian and transmitter semi-angle at half-power is calculated.

4. Noise sources in wireless optical communications

There are various noise sources present in the wireless optical links. Sources of this noise are in the channel as well as generated locally in the receiver. The noise generated in VLC is shot noise, optical excess noise, photo detector dark current noise, photo detector excess noise and thermal noise. However, in this work only consider shot noise produced by natural and artificial noise sources such as the sun, fluorescent and incandescent light sources. The basic definitions of shot and thermal noise are given below:

4.1. Shot noise

Shot noise is considered to be the dominant noise sources in wireless optical communications. The origin of shot noise is due to the presence of both ambient light and transmitted signal. Shot noise is modeled as a Poisson distribution with a white power spectral density due to the discrete random nature of energy and charge in the photodiode. Mathematically, it can be expressed as

$$\sigma_{shot}^2 = 2qRrPn; \quad (1)$$

Where q is the electron charge. RR and Pn are the photodiode responsivity and the average power of ambient light respectively.

4.2. Thermal noise

In conducting materials, noise is generated due to the random motion of electrons in resistive and active devices. This random motion of electrons, which gives rise to noise voltage, is called thermal noise. A large number of free electrons and ions are responsible for generating this noise, which is bounded by molecular forces in the conductor. Hence, there is a continuous transfer of energy between the ions and electrons. This is the source of resistance in the conductor. Thermal noise is also a function of temperature. Thermal noise is generated independently of the received signal and can be modeled as the first term represents thermal noise generated in feedback resistor. KB and Tk are the Boltzmann's constant and absolute temperature respectively. RF is the feedback resistance. The second term describes the thermal noise from the field-effect transistor (FET) channel resistance where Γ is the FET channel noise factor, gm is the FET Tran inductance, and Cd is the capacitance of a detector. Cg is the FET gate capacitance, andI3 = 0:0868.Sum of contributions from the shot and the thermal noises can be written as, experimental setup of the VLC prototype is shown in Figure.5GNU radio software is used to interact between two N210 software radio peripherals (USRP2). Two types of LEDs, such as phosphor coated LED and trichromatic LEDs (RGB) are used as transmitters in VLC link measurement. Commercial RGB LEDs (LED ENGIN, 03MC00, 40 W, 81 mm footprint) LEDs and a blue-phosphor LED (LUXEON) were used in this test. On the other hand, a photo-detector (PDA36A) is used as a receiver. This particular photodiode has a built-in Trans-impedance amplifier that is set to the default value of 10 dB.

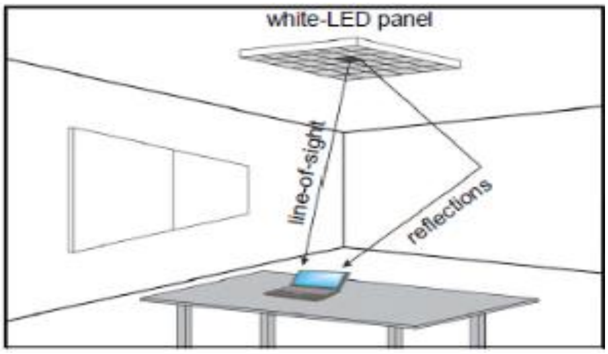

Fig. 5: Implementation of Visible Light Communication System.

Data rate and light intensity. The signal spectrum of the noise error signal is illustrated in the Figure.6.

5. Sigview output

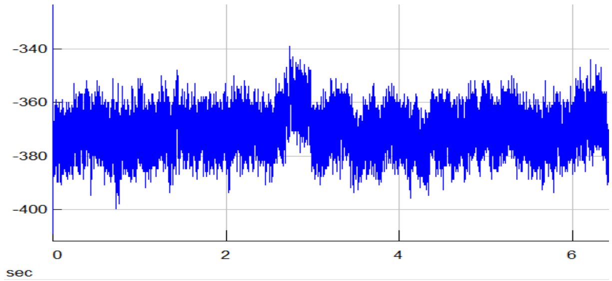

Fig. 6: (A) 2V Noise.

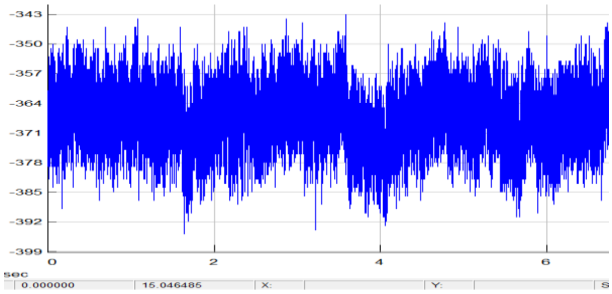

Fig .6: (B) 3.5v Noise.

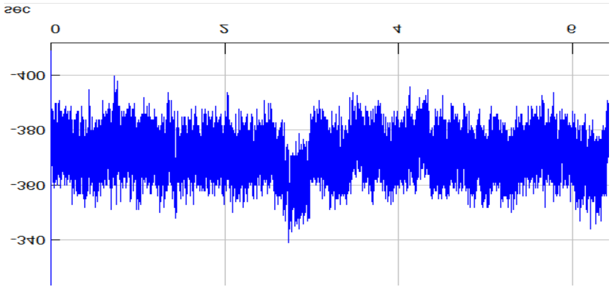

Fig .6: (C) 5V Noise.

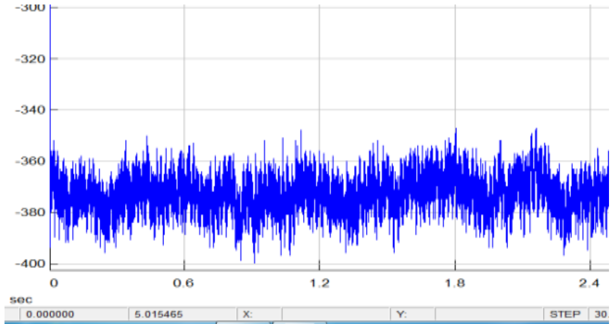

Fig .6: (D) Normal Noise.

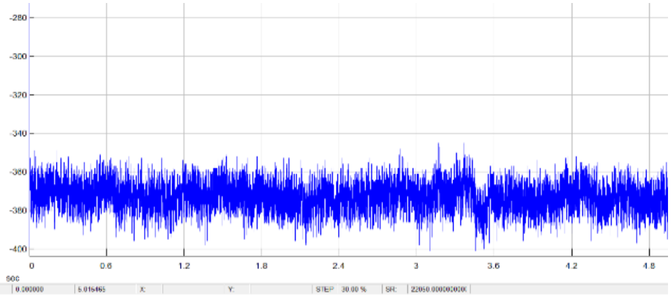

Fig .6: (E) Noise 1.

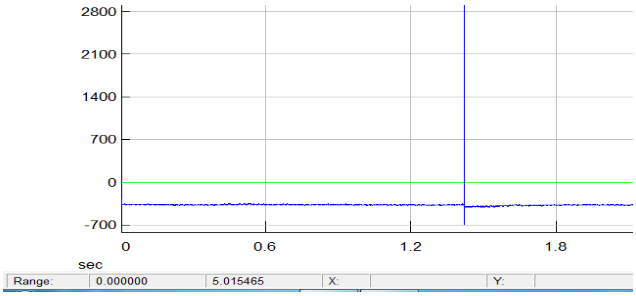

Fig .6: (F) Noise 2.

Figure. 6 Visible Light Communication Signal Spectrum of Noise-Error Signal

In Figure.7 shows Bit Error Rate (BER) analysis of the proposed system. In general lower value of bit error rate in the signal has higher quality. To maintain the output signal as lower bit error rate value. The designed VLC model has low bit error rate value; it has been taken from MATLAB simulator.

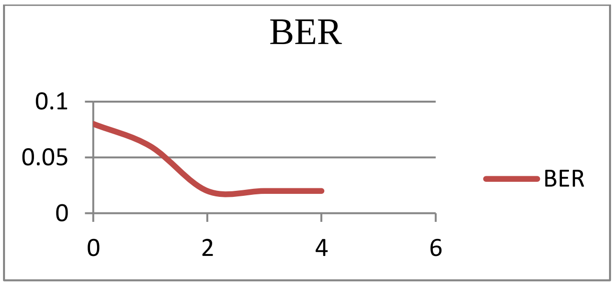

Fig. 7: Bit-Error- Rate of Propose System.

6. Conclusions

Theoretical and polynomial-based throughput-distance relationship models were also developed for the day and night conditions. Transformation of straight inclined travelling paths to equivalent horizontal travelling paths using rotational technique was used in this chapter. It was showed that this rotation (inclined path to horizontal path) simplifies the calculation of average throughput. The measurement-based shot noise was also included in the mathematical framework. Analytical solutions for calculating average throughput and file size for the single-user case were provided. Simulations were also performed to evaluate the performance of such hotspot network in the context of data download on move scenario. The simulation results revealed that there was a large impact of background noise on the performance of VLC hotspots. As expected, in both indoor and outdoor environments, VLC hotspot performed better at night than during the day.

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