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Using a Smartphone Transmitter for the Visible Light Communication System to Provide Secured Light Fidelity

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Abstract: This paper presents an approach to utilizing smartphone transmitters in Visible Light Communication (VLC) systems to achieve secured light fidelity, often referred to as "Li-Fi." by harnessing the capabilities of modern smartphones. A cost-effective and innovative solution is explored for secure short-range wireless communication. In the transmitting side the smartphone transmitter transmits data by using the screen or LED flash as a light source. Short-distance data transmission can be done quickly and securely by varying the intensity of the light emitted. This method is economical since it makes use of the hardware already present in smartphones. On the other hand, in the receiver side a photodiode or LDR sensor module that can recognize transmitted visible light signals makes up the receiver. We take into consideration a symbol rate range of 6 kHz to 10 kHz, which is an appropriate transmission rate for receivers that make use of the rolling shutter effect. The experimental setup was proven successful and the distance between the transmitter and receiver is 80 cm to realize a successful transmission line of sight is permanently desired and the transmission distance between them can be increased to 1.5 meters. Based on experimental results and basic factors in our wireless optical communication such as the distance between both transmitter and receiver and used modulation technique are simulated in MATLAB software depending on the BER of the communication medium.

Keywords: Visible Light Communication, Smartphone, Transmitter, Data transmission, Optical wireless communication.

1. Introduction

Radio-Frequency (RF) alone won't be able to handle the high data rate issue in the coming days .As the number of users grows, so does the amount of network traffic .A good way to support a large number of indoor users is using visible light communication (VLC) .Over RF communication, VLC has a high data rate. VLC works on the top layer of the electromagnetic spectrum, which utilizes the visible wavelength range from 380 to 780 nm and is identical to a frequency spectrum between 430 THz to 790 THz [1], [2]. Nowadays, the interest in visible light communication has grown, which is more secure as a result of walls blocking the light signal and more efficient for energy consumption than RF.

Visible Light Communication (VLC) systems have become a viable substitute for conventional radio frequency (RF) techniques in short-range wireless communication [3]-[5]. Due to smartphones' widespread use and visible light signal emission and reception capabilities, the use of smartphone transmitters in VLC systems has become increasingly popular. The purpose of this study of the literature is to give a thorough overview of the possible advantages, difficulties, and current research projects related to the use of smartphone transmitters in VLC systems. In-text citations will be used throughout the study to assist the investigation of this developing topic and cite pertinent studies.

Utilizing smartphone transmitters in VLC systems has several benefits, one of which is the utilization of the hardware already in place—more especially, the LED flash or screen—as a light source for data transmission. VLC system using a smartphone camera and LED flash to accomplish high-speed data transfer across short distances [6]. Their device exhibited fast and secure data transmission that was similar to conventional radio frequency communication techniques by varying the intensity of the LED flash. This creative application of widely accessible smartphone components creates new opportunities for broad acceptance and a range of useful uses.

The combination of smartphone transmitters and VLC systems' adaptability opens up a world of fascinating possibilities. For example, investigated the possibilities for indoor navigation and positioning with cellphones that support VLC [7]. Their research demonstrated the possibilities for location-based services and augmented reality by achieving precise placement within buildings through the transfer of data via visible light signals. In addition to giving developers and consumers new tools and opportunities, this work highlights how smartphone transmitters can improve the functionality and applicability of VLC systems.

Nevertheless, there are challenges when using smartphone transmitters with VLC systems. The shorter transmission range than RF waves is one major problem. In order to solve this issue, it is proposed a hybrid VLC-RF system in which the smartphone transmitter transmits data using both RF waves and visible light [8]. Their technique increases the overall transmission range by adaptively switching between the two modes based on the communication scenario. The possibilities for hybrid systems to get around the drawbacks of pure VLC configurations are demonstrated by this study.

The effect of ambient light interference on VLC systems' dependability is another challenge. So it is suggested a unique coding scheme for smartphone transmitters with VLC capability [9]. It is achieved greater data rates and increased reliability by utilizing a channel coding technique to increase the robustness of data transmission against ambient light noise. Also, it emphasizes how crucial signal processing methods are to addressing the difficulties presented by the optical wireless medium.

The VLC system includes different modulation techniques as shown in Fig. 1. The fact that amplitude and phase cannot be combined to encrypt the signal in VLC is a significant distinction between RF and VLC technologies [2]. The LEDs can be switched using modulation signals at the required frequencies that include the data to be transmitted. Using direct detection demodulation, it is possible to modulate and demodulate the intensity of the light. Table 1 presents a summary comparison of some of the proposed modulation types.

This paper offers a recommendation for using smartphone transmitters in VLC systems to produce secure light fidelity. This is apparently due to its simplicity and low implementation costs.

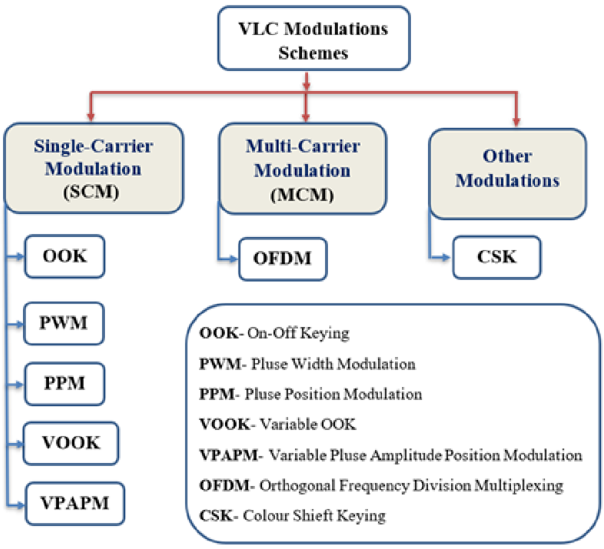

FIGURE 1. VLC Modulation Types.

TABLE 1. Comparison of Proposed Modulation Techniques

Modulation	Spectral Efficiency	Power Efficiency	System Complexity
OOK	High	Low	Low
PPM	Low	High	medium
PAM	medium	Low	Low
OFDM	High	medium	High
GSK	medium	Low	High

2. PROPOSED SYSTEM BLOCK DIGRAM

Figure 2 shows the proposed system diagram; in the transmitting side the smartphone transmitter transmits data by using the screen or LED flash as a light source. Short-distance data transmission can be done quickly and securely by varying the intensity of the light emitted. This method is economical since it makes use of the hardware already present in smartphones. On the other hand, in the receiver side a photodiode or LDR sensor module that can recognize transmitted visible light signals makes up the receiver. This part facilitates the extraction and processing of data by converting the incoming light signals back into electrical signals. Then, advanced signal processing techniques play a crucial role in enhancing the security and reliability of the system. This includes channel coding techniques, such as error correction and detection, to ensure data integrity during transmission. Additionally, encryption and decryption method can be employed to secure sensitive information transmitted through the VLC system.

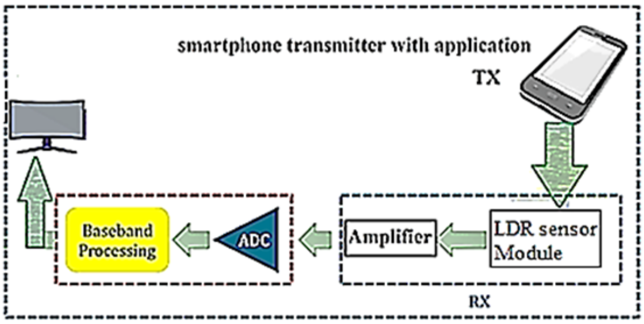

FIGURE 2. Proposed system block diagram.

3. VLC SYSTEM RECEVIER CIRCUIT

Figure 3 shows the main components of receiving circuit which consist of LDR sensor module, Arduino and LCD display 2x16. The LDR sensor module is used to measure light intensity, as the most common method for detecting ambient brightness and light intensity is to employ a photosensitive resistor module, which is very sensitive to environmental light intensity. It is connected to the board's AO and DO labels, which stand for analog and digital output pins, respectively. When there is light, the LDR's resistance will decrease in proportion to the light's intensity. The LDR's resistance decreases as light intensity increases. The potentiometer knob on the sensor allows you to modify the LDR's sensitivity to light. It is use DC input voltage from 3.3V to 5V. Then, An Arduino board can be utilized for research and study purposes. An Arduino board can be a useful tool for creating rapid sensor-based projects. Programming and learning Arduino are simple tasks. Arduino is programmed using the Arduino IDE. An application to build programs for Arduino boards is the Arduino IDE. The Arduino IDE is free software that is available for download and installation on computers. Many ready-to-use libraries are available in the Arduino IDE. Arduino developers will save lots of time by using these libraries.

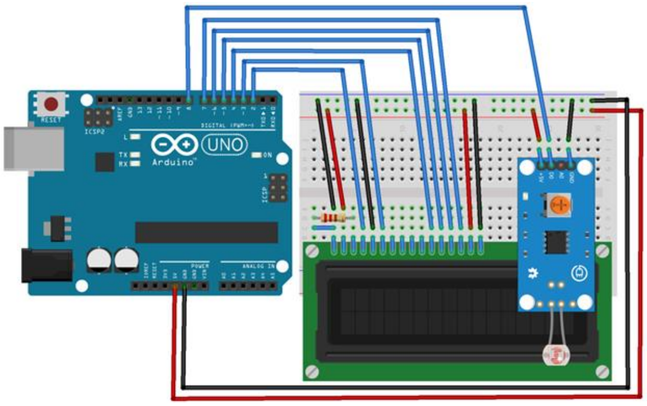

FIGURE 3.VLC system receiver circuit.

For displaying the transmitted data on the receiver side we have used and LCD with stands doe liquid crystal display , this particular type module is used in in a wide range, including televisions, computers, calculators, cell phones, and more . on the other hand Seven-segment and multi-segment light-emitting diodes are the main applications of these displays but we have used LCD in our receiver side due to its low cost, ease of programming, animation, and unlimited display options for unique characters, special effects, and animations, among other things.

3.1 Data Transfer Methodology

The flowchart shown in Fig. 4 provides a summary of the framework and the proposed VLC system's working principle. The major principle of the VLC system is - if the camera flash is switched ON, binary one will be transferred and if the camera flash is switched OFF, binary zero will be transferred.

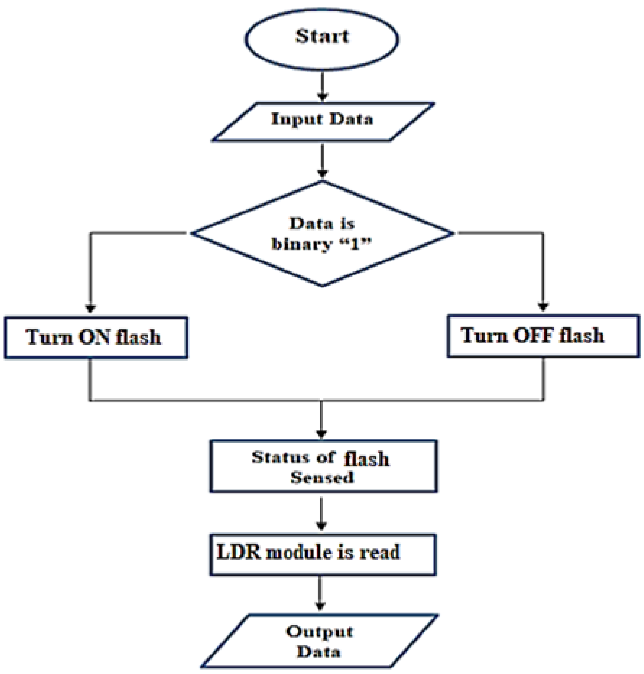

FIGURE 4. Flowchart of System Working Principle.

The main units of the system are the smartphone flash brightness and LDR sensor module detector circuit. Flash lights flicker because large and small current changes, so information is transferred at a very high speed. The LDR sensor module detection circuit at the receiver detects the high-speed flicker, transmits the received data, reconstructs the received data, and gets the primarily transmitted data.

3.2 Li Fi Security

Each channel in a meeting room setting has an access area that is the breadth of the light pool and is available to numerous users. Higher data speeds are possible for each user than for an equivalent Wi-Fi channel. With Wi-Fi, each user or group of users competes directly for bandwidth access. This means that everyone's download speeds decrease with the number of connections. But in the case of Li-Fi, each light pool provides full channel data rates with a few concurrent users due to the vast number of accessible access points. Once more, each user receives the advantage at a speed that is up to 1000 times faster. Moreover, light does not go through barriers, in contrast to radio waves. Therefore, security is significantly better than with Wi-Fi and requires less effort to prevent leaks from windows, etc.[10].

4. MATHEMATICAL MODELING OF VLC TRANSMISSION

One of the most important aspects of comprehending and creating high-performance VLC systems is mathematical modeling of the technology.

4.1 Channel Model

Taking light propagation characteristics into account, the VLC channel can be described as a line-of-sight (LOS) communication link as shown in Fig. 5 [5]. Equation 1 can be used to determine the channel gain, or *h*, which is a crucial parameter [6].

$$h = \frac{A.cos^m(\emptyset)}{d^2}.cos(\theta).T(\psi).g(\psi) \qquad (1)$$

where *A* is the physical area of the photo-detector, capturing the incident light, $\emptyset$ is the angle of incidence to the receiver, *m* is the Lambertian emission order is given by

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

and *d* is the distance between transmitter and receiver, θ is the angle of irradiance, $T(\psi)$ are the gains of the optical filter and concentrator respectively.

Both the sent signal and noise have an impact on the received signal, *r(t)* as given in Eq. 2.

$$r(t) = R.s(t) + n(t) \qquad (2)$$

where *R* is the photo-detector responsively, converting intensity of the light into electrical current, s(t) is the transmitting signal and n(t) is AWGN noise which is a common model noise in communication systems.

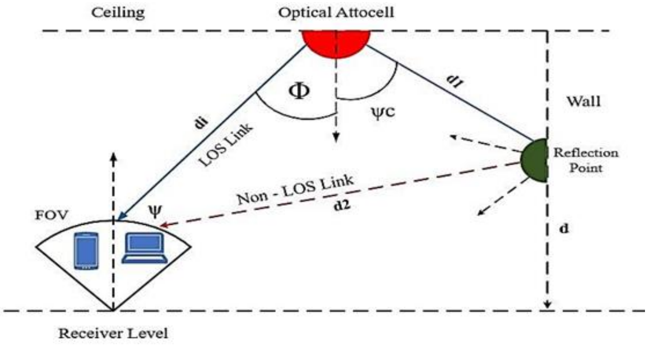

FIGURE 5. VLC system model of LOS link [5].

5. EXPERIMENTAL SETUP

It is possible to use a smartphone's flashlight to send data by developing an android application to send data through its flashlight. The process involves using Samsung Galaxy A34 5G flashlight to transmit the data through VLC system. And the other side receives the transmitted signal from smartphone by using a LDR sensor module for detection. It detects the ON/OFF switching of smartphone flash as intensity varies a LDR sensor Module produces current, which is a very weak signal. And then amplify it before further use using Arduino programming circuit. We take into consideration a symbol rate range of 6 kHz to 10 kHz, which is an appropriate transmission rate for receivers that make use of the rolling shutter effect. The experimental setup was proven successful and the distance between the transmitter and receiver is 80 cm to realize a successful transmission line of sight is permanently desired and the transmission distance between them can be increased to 1.5 meters. An experimental setup for the VLC system is shown in Fig.6. This distance can be approved experimentally by using a smartphone with high lighting power flash and by using solar cell instead of LDR to increase the receiving efficiency.

6. RESULTS AND DISCUSSION

After the overall design, the system was tested by observing the output data signal in a digital oscilloscope. The received data signal of the LDR detector is taken from the receiver module, which is then amplified. The utilization of the VLC system has been tested at different distances from a short distance of up to 80 cm between the transmitter and receiver. Table 2 listed V_{pp} at the receiver side as the output of LDR detector using a digital storage oscilloscope (DSO). While amplitude reduces as the distance between smartphone transmitter and the LDR detector increases as shown in Fig.7.

TABLE 2. Peak to Peak voltage at Receiver using DSO

S.N	Distance (cm)	White LEDs (Vpp)
1	30	2.65
2	40	1.98
3	50	1.4
4	60	1
5	70	0.82
6	80	0.76

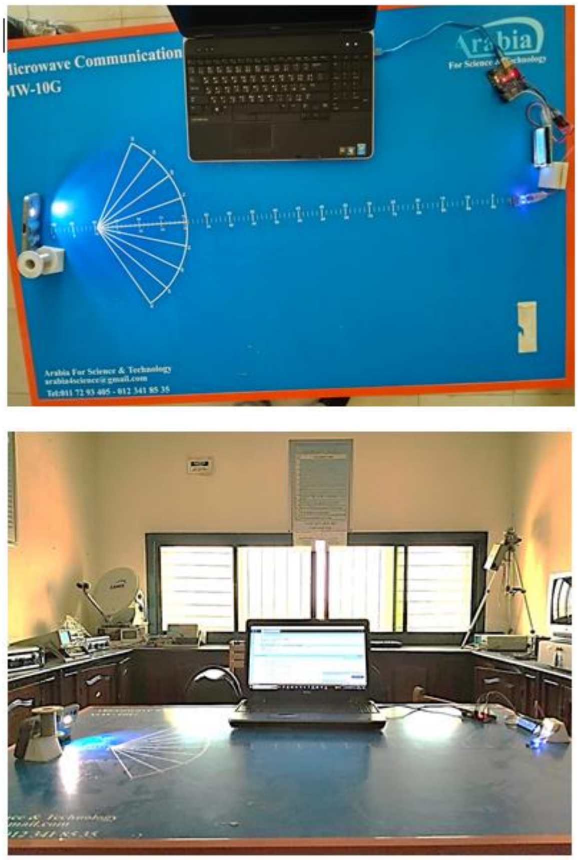

FIGURE 6. Experimental setup for VLC system.

OOK is commonly used in visible light communication systems to test system performance. Bit error rate (BER) is a good indicator of data link performance. The BER is immediately converted to the number of errors that happen in a given series of numbers of bits [10]-[12]. The bit error rate can be defined using Eq. 3. Although the OOK-BER error probability can be determined using the following Eq. 4. Fig. 8 shows the theoretical OOK-BER error probability simulated using the MATLAB code.

$$BER_{OOK} = \text{Number of errors / Total bits sent} \quad (3)$$

$$P_{error-OOK} = \left(Q\sqrt{\frac{E_b}{N_o}} \right) \quad (4)$$

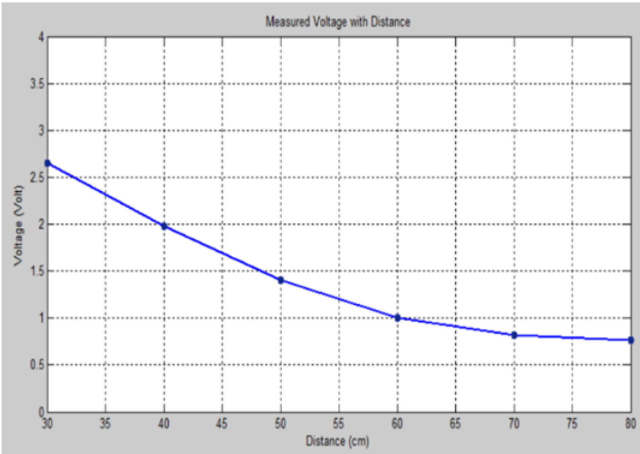

FIGURE 7. Measured Voltage Variance with Distance.

Where $P_{error-OOK}$ is OOK BER error probability and E_b / N_o is the signal-to-noise power ratio and the Q function is linked to the error function (erf).

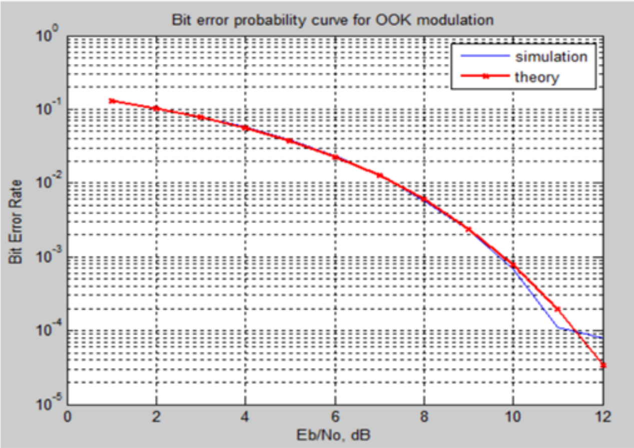

FIGURE 8. OOK BER error probability.

7. CONCLUSION

Visible Light Communication has a significant deal of potential to replace conventional communication methods in RF-limited zones in special. The VLC system is proposed to transmit data taken from a smartphone transmitter and transmit them via its camera flash. The results display the significance of the purpose and the distance between both receiver and transmitter in system performance. Through experimental results, and with the increase of the distance between the transmitter and the receiver, the value of the measured voltage decreases drops non-linearly due to the decrease in the optical power which leads to a lower signal-to-noise ratio and Bit Error Rate (BER) increase that proves the mathematical equation simulated through MATLAB software.

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