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COLOR PHASE MODULATION FOR LI-FI COMMUNICATION

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ABSTRACT

The need of radio spectrum in wireless communication has crossed with the requirements of the current society. There are few solutions to the radio spectrum insufficiency. One of the alternative solutions is the communication with visible light spectrum, such as Light Fidelity. The paper has a new method for visible light communication called Color Phase Modulation (CPM). The proposed modulation method is simulated and presented the results.

INTRODUCTION

In the current society, the radio mobile devices are used exponentially day to day and the radio spectrum is finished due to these devices. Many solutions are proposed for effective use of radio spectrum, such as cognitive radio networks. The optical wireless communication (OWC) is another alternative for replacing the radio based wireless communication. Since the optical wireless communication supports higher capacity, which is important for various broadband applications such as HD Televisions, steaming videos, mobile video phones, cloud services, and high-speed internet access, its demand is increased. At present, three types of communication spectrum are used for OWC applications: visible light, infrared rays (IR), and ultraviolent (UV) light. The optical wireless communication, which uses the visible light band as medium, is generally called as visible light communication (VLC)[13,15]. The VLC uses light emitting diode (LED) and photo detector (PD) for communication. The applications of VLC include indoor wireless communications, precisely the

personal area network (PAN), vehicular networks, and local area networks. Furthermore, a new technology has emerged that uses LEDs to transmit. This new technology is called light fidelity (Li-Fi) [4,9] and it uses VLC for communication. It is similar to Wi-Fi, but Li-Fi uses visible light of electromagnetic spectrum from 400THz to 790THz, see Figure 1. The idea is first introduced by Harald Haas [1,4]. The objective of Li-Fi is to transfer the data with light as medium for accessing the internet, stream videos, receive emails, and data stores. Hence, the required task is to modulate data into some or an array of LEDs. These modulation techniques need to improve the communication between the transmitter's LED and the receiver's PD. The modulation methods are enhanced by incorporating the homogeneous sequence of LEDs for simultaneous data transmission, or using mixtures of RGB light emitting diodes to change the frequency of light. Here, RGB-LED contains an LED with three-color frequencies.

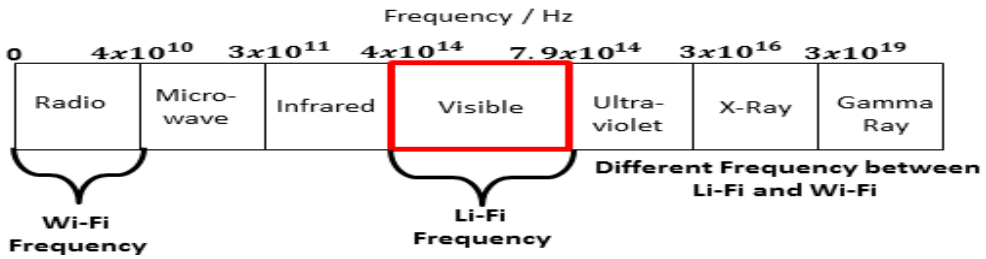

Figure 1 Spectrum usage

The papers focus on modulation techniques for the light fidelity and propose a new method, named as Color Phase Modulation (CPM). The related work and discussion of some existing modulation methods are presented in section II. The section III discusses the new modulation technique CPM. The section VI is presented the simulation, whereas, the section V conclusion the paper.

RELATED WORK

The visible light communications normally use optical light for communication. With an advantage of this, the visible light communication has been now is an alternative to wireless radio communication [2]. In other words, it transmits and receives data by using visible light as the medium. The VLC has three components: transmitter, receiver, and channel, see the Figure 2.

Figure 2 VLC block diagram

However, any lights can be used to transmit data in visible light communication. Some lights have better characteristics, such as high brightness or capacity to transmit data. The significant characteristic is speed of communication. The more useful characteristics for communication can be found in LED. For that

reason, the VLC used light emitting diodes (LED) to transmitted data. LEDs are made of semiconductor technology, which allows it to transmit data. Some researchers proved that LED speeds of over 10Gbps for a single LED lamp [3].

Many applications have spread over VLC such as light fidelity (Li-Fi). It allows transmitting the data in very faster intensities than the human eye would recognize it. In addition, Li-Fi is better than Wi-Fi in capacity, bandwidth, data rate, and cost. One of the significant advantages of Li-Fi is the saving of energy by transmitting data with LED. In addition, the VLC cannot be penetrating through walls, which mean the Li-Fi signal is more secure than WiFi while transmitting data see Figure 3.

Figure 3 Li-Fi limited.

The idea for Li-Fi is to modulate data through electromagnetic waves using the visible light spectrum to communicate between devices. Hence, the LEDs in Li-Fi uses intensity modulation (IM) and direct detection (DD). However, the modulation is needed for many purposes such as to reduce the bandwidth, interference less transmissions, and protection of signals from intersecting paths, and communication with short antennas. Each modulation varies from one to another depending on the methods. During the selection of modulation method for transmitting the data, it is important to analyze the advantages and disadvantages of the modulation methods. For analog transmissions, the amplitude modulation (AM) and frequency modulation (FM) are widely used, whereas for the digital data transmissions the phase shift and quadrature amplitude modulations are often used. The survey on various modulation techniques for Li-Fi is presented in [1]. The analysis of various modulation techniques for radio based communication is give in [14]. It has been described the importance of diversity technique in radio spectrum based communication to avoid the interference and enhance the system performance in fading channels [16]. It is important to study the same impairment for visible light spectrum based communication too.

The two modulation methods, pulse duration modulation (PDM) and pulse width modulation (PWM) vary the pulses proportionally to the analog signal amplitude and the position of the pulses fixed [5]. The way to drop the combined power provided by an electrical signal is to modify the pulse width, which is done by cutting the pulses into distinct components. Here, the duty cycle is the period of the signal during operation [6].

In VLC, one of the simplified and well-known modulation method is On-Off keying (OOK) [7]. In this method, there is a tradeoff between performance and complexity. However, the connection may change at low intensity levels of the light, see Figure 4.

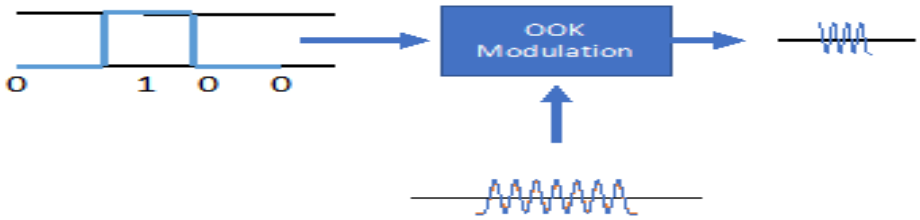

Figure 4 OOK modulations.

In Amplitude Phase Modulation, the amplitude shift keying (ASK) refers to digital data as a change in carrier capacity. Two different carrier frequency amplitudes are required to represent zero and one, respectively. This can call it OOK. The amplitude may drop depending on the signal levels. In ASK, the phase and the frequency are fixed [8].

In frequency shift keying (FSK), the digital data is transmitted by the distinct frequency differences of the carrier signal. The modulation method permits changes in the carrier signal frequency, whenever the digital data is transmitted. It has two binary states and it needs to be two distinct frequencies before transmitting two distinct values (0 and 1) [8]. A modulation method aiming to avoid the interference for LTE based system is proposed [14]. The method performance is analyzed and shown the better BER results. This method can be used for hybrid LiFi systems. There are few well known simulators for simulating the modulation methods [16].

CONTRIBUTION

The light fidelity is a new communication paradigm using visible light spectrum, which has some specific advantages than Wi-Fi. In addition, the security in the Li-Fi is good for indoor system. In LiFi system, it happens some conflux and noise in the signals will effect inefficient of the system. Hence the modulation importance to enhance the communication.

The proposed model has an array of LEDs with each LED has RGB colors. In LED, the semiconductor materials are used to emit the light when the current flows in it. Compared to a normal lamp, the LED is consuming less electricity [9]. Earlier days, the LED was emitting only one weak light and recently the industries developing LED with three basic colors RGB (Red, Green, and Blue) [10]. The same technology is used in displays, TVs, radios, telephones, calculators, and watches.

RGB-LED is mix of three LEDs (Red-LED, Green-LED, Blue-LED) in one component and it can extract various colors by joining the RGB colors through different intensity of each LED. For instance, to produce pure green light, fix the

green LED to the maximum intensity and the blue & red LEDs to the minimum intensity. A pulse width modulation signal can be used to modify the intensity of each LED. RGB LEDs have two type: common cathode LED and common anode LED [11].

The Li-Fi communication is very useful for indoor wireless communications and it can be adapted to many communication systems in the near future, as radio bands are consumed to end due to the heavy use of mobile devices. The visible light spectrum is available abundantly and unlicensed for Li-Fi communication. The modulation techniques need to be improved as the technology is new to the current environments. An example of some problems in modulation techniques in sub-carrier Inverse PPM (SCIPPM), the challenge is an uneven bit periods for various incoming symbols and it could disturb the light illumination performance. In FSK, it needs two different frequencies in the variable pulse position modulation (VPPM) and High-efficiency LED driver for Color Shift Keying modulation (CSK).

Color phase modulation (CPM) is new modulation we propose for Li-Fi that transmits input data to three bit at a time. Each color carries one bit and it is represented in a different fixed phase, see Figure 5.

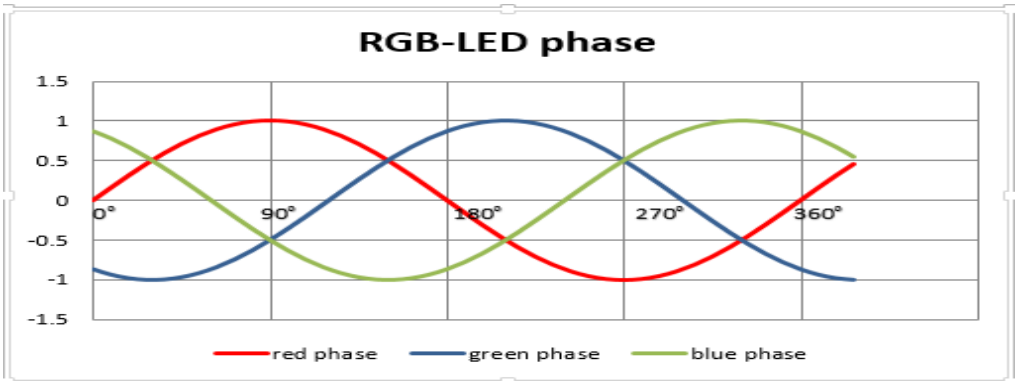

Figure 5 The phase for LED colors (RGB).

The signals with fixed red phase start from 0°, fixed green phase start from120°, and the fixed blue phase start from 240° see Figure 6.

The new modulation method CPM improves the data transfer rate and decreases the interference between LED rays. In LiFi, the light system uses RGB-LED in color modulation, which has only three colors red, green and blue. These three colors have different phases, see Figure 7.

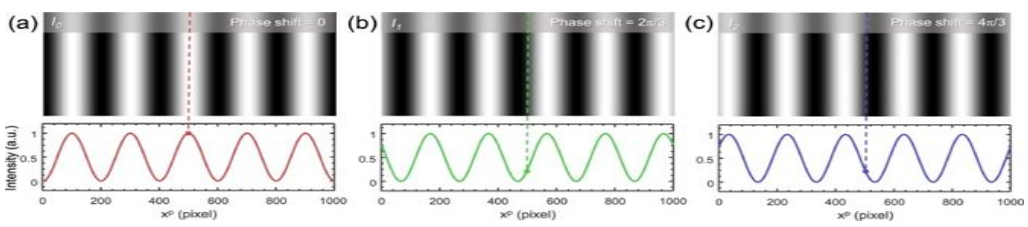

Figure 6 Color shift phase.

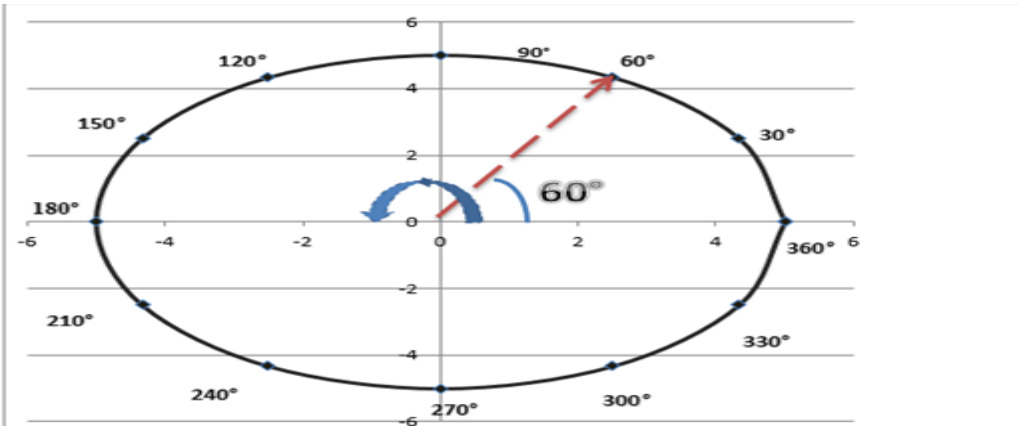

Figure 7 Different phase

Table 1 RGB phase modulation

RGB	RGB phase
000	0°, 120°, 240°
001	0°, 120°, 60°
010	0° , 300°, 240°
011	0°, 300°, 60°
100	180°, 120°, 240°
101	180°, 120° , 60°
110	180°,300°, 240°
111	180°, 300°, 60°

The binary data is transmitted through visible light LEDs. The CPM modulation can transmit three bits simultaneously with three different colors. If it wants to send zero bits, it needs to add 0° to the existing fixed phases. In other words, there is no change with the fixed phases. If it wants to send one bit, it needs to add 180° to the existing fixed phases. The Table 1 shows various phases of RGB LED for its respective bit patterns.

SIMULATION

Simulating the Color Phase Modulation for the Li-Fi is done by used MATLAB software. The Table 2 shows the simulation parameters. In the simulation, we have considered the indoor room with the size 6x6x6 m3. We have assumed that some of the parameters are ignored. These parameters include the photo diode refractive index, the reflectivity of wall, and the gain of the optical filter. The fixed phases for the RGB LED colors are 0°, 120°, and 240°, respectively for the red, green, and blue. We run the simulation and calculating the receiving power for individual colors. The following equation is used to calculate the signal receiving power [12].

$$Pr = Pt \cdot \frac{(m+1)}{2\pi dxd} COS^{mi}(\Phi).T_s(\psi)g(\psi).COS(\psi),\ 0 \leq \psi \leq \psi_{con} \quad (1)$$

We have varied the distance between LED and the photo diode and plotted the graph for the signal receiving power; see the Figure 8, Figure 9, and Figure 10, for the colors blue, green, and red, respectively.

Table 2 Simulation parameters

Parameter Name	Values
Room Dimension	6 x 6 x 6 m^3
Transmitter point	Center (5,5,10)
Reflectivity of wall	Ignored
Refractive Index	Ignored
Max Distance d	6 m
Optical Power LED	50 mw
Active area (AR)	1 cm^2
Half angle FOV	60

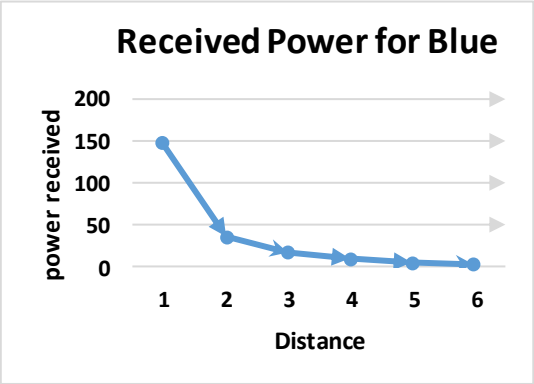

Figure 8: Received Signal Power

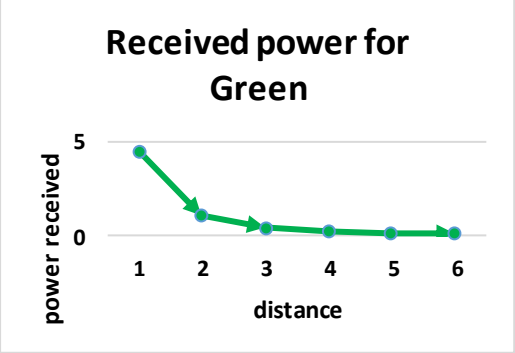

Figure 9: Received Signal Power

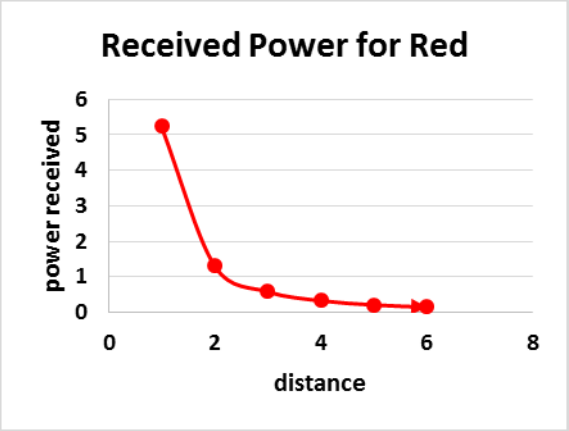

Figure 10: Received Signal Power

CONCLUSION

The radio spectrum is not sufficient for the requirements of the current and future world because of the large number mobile devices and applications. The wireless communication using visible light band is one of the best alternatives to the radio based wireless communication. The visible light spectrum is used in Li-Fi technology. This new technology Li-Fi provides a solution to the insufficient radio bands. However, LiFi needs lot of study and development, as it is recently developed. This paper has proposed a new modulation scheme for indoor communication using visible light spectrum. The simulation is done for the proposed modulation technique CPM.

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