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Visible Light Communication using White LEDs for Indoor Wireless Data Transmission

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Abstract: Optical wireless communication through visible light has been appreciably explored with the development and widespread use of white light emitting diodes (LED's). This paper, demonstrates a downlink wireless system via visible light communication (VLC) technology using pulse width modulation (PWM) technique. The prototype demonstrates a transmission baud rate of 9600 without data loss at a distance of about 30cm for peer to peer communication system and a transmission baud rate of 9600 without data loss at a distance of about 10 cm for broadcast communication system. Bit error ratio (BER) of 10^{-6} and 10^{-3} is achieved respectively.

Keywords: Optical wireless communication, light emitting diode (LED), visible light communication (VLC), pulse width modulation (PWM).

I. INTRODUCTION

This White LEDs have replaced incandescent and fluorescent lamps, thus becoming the next generation light sources. Compared to conventional light sources, white LEDs have the advantages of long life, high lighting efficiency, easy maintenance, and environmental friendliness. Besides being only the source of illumination the white LEDs can also be modulated at a fairly high rate which makes it suitable as a data transmission source. Thus LED's can be used to perform two concurrent functions, illumination and communication. This twin function of LED, illumination and communication, paves way to many novel and attractive applications. The function is based on the fast switching of LEDs and the modulation of the visible-light waves for free-space communications [1].

This new communication technology, in union with illumination, has the following advantages: Firstly, visible light communication (VLC) systems can achieve high power transmission with little shadowing due to the required illumination level and distributed lighting fixtures. Secondly, the communication component can be easily integrated with the white LED significantly reducing the total cost. As a result of these advantages, many researchers have begun related study in this field [1], [2]. Field experiments and demonstrations for the visible light communications system such as a sound communication system (analog and digital system), visible light ID system (digital system) and High-speed data transmission system (digital system) are proposed in [3]
Elementary theoretical analysis of an indoor visible light communication system has been provided in [1] proving its viability. In order to construct a practical communication system in union with lighting, many system design issues have to be taken into consideration, including three basic parts: transmitter, channel, and receiver. Indoor VLC links may be classified as line-of-sight (LOS) and non-line-of-sight (NLOS), a way similar to infrared links. Key issues in practical LOS visible light communication system design are discussed in [4] covering devices, channel path loss, and system noise sources.

The method of integrating Visible Light Communication technology with present infrastructure, without having to make major changes to that infrastructure is demonstrated in [5]. Various modulation methods available in IEEE 802.15.7 and their benefits for flicker mitigation and dimming are discussed in [6]. An indoor simplex broadcast VLC system using off-the-shelf LED lamps for the transmitter module and the PIN detectors for the receiver module is designed and demonstrated in [7]. Serial data is transmitted over RS-485 protocol.

In this paper, we design and demonstrate an indoor simplex VLC system for peer to peer and broadcast communication using off-the-shelf LED lamp for the transmitter module and the phototransistor for the receiver module. Serial data is transmitted over RS-232 protocol. The performance of the system is evaluated and some experimental results obtained during the transmission of text messages are also verified.

The paper is organized as follows. In Section II, the proposed system is given in brief. In Section III, the system design and implementation are discussed. In

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section IV, outlines the experimental setup and result analysis. The conclusions and future work are drawn in Section V.

II. PROPOSED SYSTEM

A VLC system is proposed to demonstrate simplex peer to peer and broadcast communication through the visible light channel. The system consists of a transmitter module, receiver module and an optical channel. The proposed system block diagram is outlined in Fig.1.

The hardware components mainly consist of the Led lamp and the driver circuit for transmitter and a phototransistor and an amplifier for the receiver. The software component consists of the program running on the microcontroller.

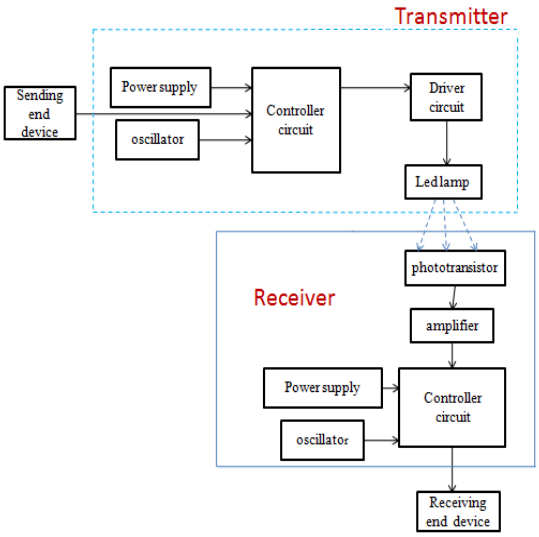

Fig.1 The system block diagram

A. Peer to peer and broadcast communication system

In general, a VLC system primarily contains two parts, one is the transmitter module, and the other is the receiver module that is peer to peer system. Our proposed system along with peer to peer (point to point) system as shown in Fig. 2(a) also demonstrates broadcast (point to multi-points) system as shown in Fig. 2(b) which permits data transmission in one direction only.

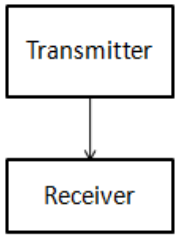

Fig.2(a) Peer to Peer

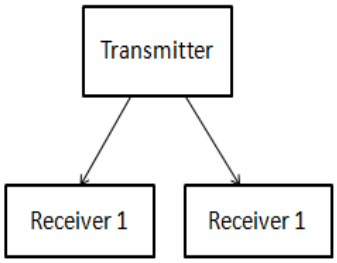

Fig.2(b) Broadcast system

III. DESIGN AND IMPLEMENTATION

The following section gives the design and implementation of the proposed system

A. Transmitter module

The transmitter module consists of a sending end device, a microcontroller powered by a power supply, and analog circuitry incorporating the driver device and LED lamp. The input to the transmitter is the text data fed from a sending end device, the computer. The data is fed to the microcontroller (PIC16F877A) in its ASCII equivalent form from the computer through a RS232 module using UART protocol.

The microcontroller will then modulate the data using pulse width modulation (PWM) scheme for logic 1s and 0s. The driver circuit consists of a power mosfet (IRFZ44N) with high switching frequency. The mosfet then drives the LED lamp which is a reading lamp with 31 surface mount devices (SMD), Low Power LED with total power output of 2.5W. The transmitter along with RS232 module is shown in Fig. 3.

The LED lamp remains on all the time but when data is being transmitted it starts flickering which is not very prominent to human eye but recognized by the phototransistor.

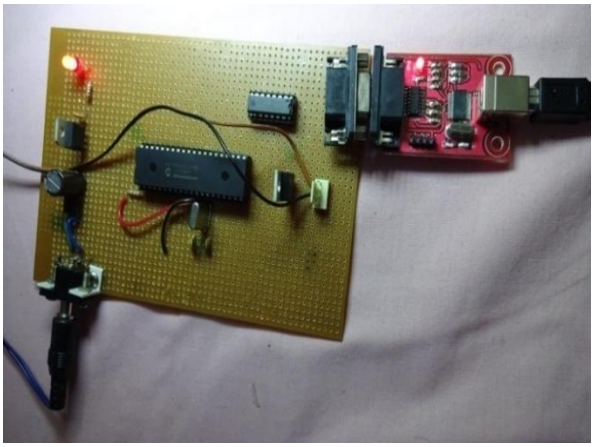

Fig.3 Transmitter module along with RS232 module

B. Receiver module

The receiver module consists of analog circuitry incorporating phototransistor, a microcontroller and a device capable of receiving and interpreting the output. The weak current signal received by phototransistor (L14G1) passes through custom amplifier (Darlington pair) for further amplification. The output is then fed to the microcontroller (PIC16F877A) circuit which decodes the data and sends it to the receiving end device for displaying it. The receiving end device used here is a liquid crystal display (LCD). The receiver module is shown in Fig. 4.

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Fig. 4 Receiver module

C. Optical channel

Visible light is used as the medium for data transmission between the transmitter and receiver. Visible light communication has few advantages over other standard wireless transmissions. The frequency spectrum bandwidth of visible light ranges from 430 THz to 750 THz which is much larger than the radio frequency bandwidth, which ranges from 3 kHz to 300 GHz. With a larger bandwidth it is feasible to accommodate more users and potentially achieve higher transfer rates because each user can be given a larger portion of the bandwidth to transfer information. The next major advantage that visible light systems have over other communication systems is its abundance. Light sources are everywhere, and can be more efficiently used by increasing its simultaneous functionality by transmitting data in addition to lighting an area [8]. The transmitter and receiver are vertically aligned for the sake of system stability in the line of sight (LOS) channel model.

D. Coding design

The visible light communication (VLC) system is based on the illumination by LED lamps. The serial data received from the computer has to be modulated using a specific modulation scheme before transmission through the LED because the data bits must be transmitted with the dimming control signal. The PWM signal plays a role for dimming the LED lamps. Thus pulse width modulation (PWM) scheme is used for the dimming control signal for LED illumination. On the transmitter side the data from the computer is fed serially to the microcontroller through UART protocol as shown in Fig.5. The microcontroller then performs PWM as depicted in the flowchart in Fig.6.

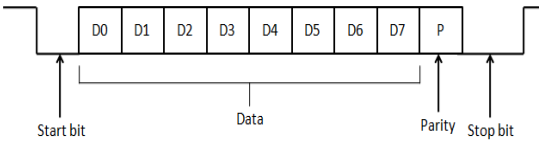

Fig. 5 Data frame format for UART protocol

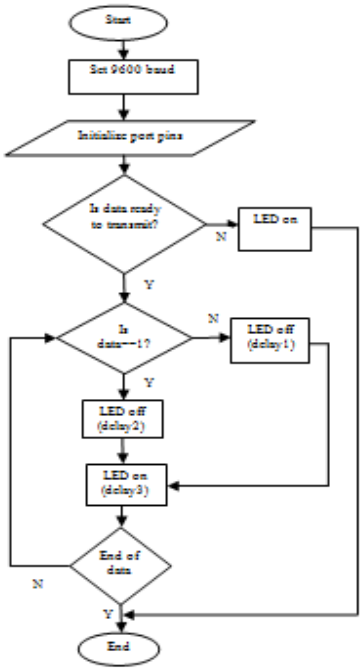

Fig. 6 Transmitter code flowchart

On the receiver side the output from the amplifier is fed to the microcontroller which decodes the data bits and sends the output to the LCD. The flowchart for receiver program is shown in Fig.7.

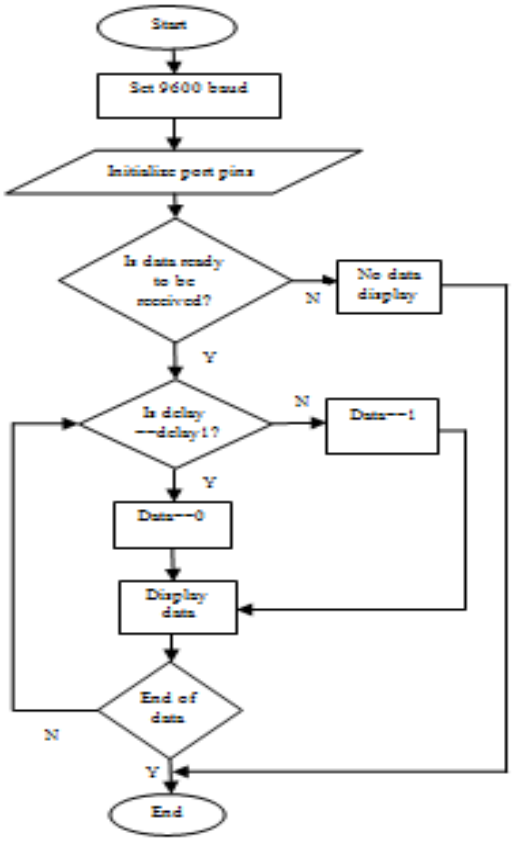

Fig.7 Receiver code flowchart

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Table 1 lists up the parameters related to the experiment. The LED parameters are provided at the forward current of 30 mA.

TABLE 1 EXPERIMENTAL PARAMETERS

LED lamp (reading lamp with 31 SMD LEDs)	Peak wavelength	450nm
	Spectral response	400-800nm
	Viewing angle	120^o(typical)
Phototransistor (L14G1)	Peak wavelength	940nm
	Spectral response	500-1100nm
	Viewing angle	10^o
	Rise/fall time	300us(approximate)
PWM	700us for logic 1	
	900us for logic0	
Distance	30cm (peer to peer)	
	10cm (broadcast)	

IV. EXPERIMENTAL SETUP AND RESULT ANALYSIS

The experimental setup for peer to peer communication system is shown in Fig.8. The receiver is vertically aligned under the LED lamp. Data transmission at a baud rate of 9600 without data loss is obtained over a distance of 30cm, with a BER of 10^{-6}. When the baud rate was increased to 19200 data was corrupted but if the distance was reduced to about 10cm then a BER of 10^{-3} was achieved.

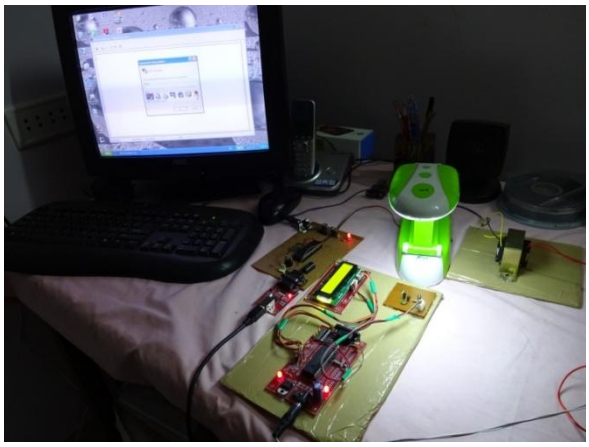

Fig.8 Peer to Peer communication system

The experimental setup for broadcast communication system is shown in Fig.9. The receivers are vertically aligned side by side (to be still in LOS) under the LED lamp. Data transmission at a baud rate of 9600 without data loss is obtained over a distance of 10cm with BER of 10^{-3}. When the baud rate was increased to 19200 data was corrupted but if the distance was reduced to about 5cm then a valid output was obtained.

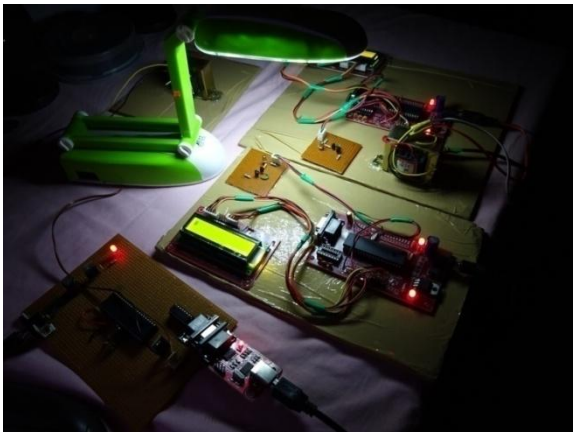

Fig.9 Broadcast communication system

V. CONCLUSION AND FUTURE WORK

The paper develops a basic VLC simplex peer to peer and broadcast communication system. The proposed system allows a 9600 data transmission rate between two end devices without data loss at a distance of 30cm for peer to peer communication system and at a distance of 10cm for broadcast communication system.

In future, a high sensitive phototransistor with wide viewing angle will be used to increase the data transmission rate and the transmission distance. The system could be upgraded to support full duplex communication mode of operation.

REFERENCES

[1] T. Komine and M. Nakagawa, "Fundamental analysis for visible light communication system using LED lights," IEEE Trans. on Consumer Electronics, vol. 50, pp. 100-107, 2004.

[2] D. O'Brien, H. L. Minh, L. Zeng, G. Faulkner, K.Lee, D. Jung, Y. Oh, and E. T. Won, "Indoor visible light communications: challenges and prospects," Proc. of SPIE, vol. 7091, 709106, 2008.

[3] VLCC: Visible Light Communication Consortium. [Online]. http://www.vlcc.net., 2008.

[4] K. Cui, G. Chen, Z. Y. Xu, and R. D. Roberts. "Line-of-sight visible light communication system design and demonstration," 7th International Symposium on Communication Systems Networks and Digital Signal Processing (CSNDSP), 21-23 July 2010, pp.621-625.

[5] DurgeshGujjari, "Visible Light Communication," Master', Thesis, Dalhousie University, 2012.

[6] Sridhar Rajagopal, Richard D. Roberts, Sang-Kyu Lim, "IEEE 802.15.7 Visible Light Communication: Modulation Schemes and Dimming Support," IEEE Communications Magazine, 72 0163-680, March 2012.

[7] Yu Yang, Xiongbin Chen, Lin Zhu, Bo Liu, Hongda Chen, "Design of Indoor Wireless Communication System Using LEDs," SPIE-OSA-IEEE, Vol. 7632 76321L-7, 2009.

[8] Casey Barney, Alexander Dich, Dennis Koufos "VISIBLE LIGHT COMMUNICATION SYSTEMS," Project Report-Degree of Bachelor of Science, 2014.