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DESIGN AND IMPLEMENTATION OF VISIBLE LIGHT COMMUNICATION SYSTEM IN INDOOR ENVIRONMENT

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ABSTRACT

Visible Light communication (VLC) using White Light Emitting Diode (LED) is a promising technology for next generation communication for short range, high speed wireless data transmission. In this paper inexpensive transmitter and receiver of VLC system is designed and its performance is evaluated. The effect of natural and artificial ambient light noise sources is also considered. Experimental results show that the data transmission distance achieved upto 0.45m.Performance analysis is done with respect to optical power, photo sensitivity of photodiode at the receiver and the increase in distance between the transmitter and receiver.

Keywords: visible light communication, light emitting diode, on off keying, optical power, ambient light noise.

1. INTRODUCTION

Recent advancements in solid state electronic devices such as light emitting diode (LED) has triggered the possibility of illumination along with communication which is popularly known as Visible Light Communication system (VLC). In the future, home and office environments will be replaced by White LEDs instead of conventional fluorescent lamps due to the advantages, like longer life time, low energy consumption and less health hazards. VLC, due to its properties, it dominates, even in RF prohibited areas like hospitals and airplanes. Some of the applications of VLC include underwater communications, road to vehicular communications, patient monitoring in hospitals, flight entertainment and location based communications.

VLC is standardized by the Institute of Electrical and Electronics Engineers (IEEE) [1]. Visible Light Communications Consortium, Japan carried out an initial research on visible light communication [2]. Now Asia, Europe, Wireless World Research Forum are also working in VLC research [3].

In this paper, transmitter and receiver circuit is designed for the proposed VLC system under the influence of ambient light noise source such as fluorescent lamp inside the indoor room and indirect sunlight from the window placed near to the system.

This paper is organized as the following sections. In Section II, System design of proposed Indoor Visible Light communication system is described; Section III defines the basic experimentation and its results. Section IV concludes about the performance measures, its challenges and scope for future extension.

2. SYSTEM DESIGN OF PROPOSED INDOOR VISIBLE LIGHT COMMUNICATION SYSTEM

VLC is a short range optical wireless communication technology which is used for both illumination and data communication. It uses the spectrum of visible light from 380 nm to 780 nm. VLC system consists of transmitter which uses white LEDs as an optical source, free space (air) as the transmission medium and Photodetector at the receiver.

VLC communication acts as a supplement to the present RF communication as it has the advantages of bandwidth, low power consumption, visibility, free from Electro Magnetic Interference and radiation hazards. Figure-1 shows the block diagram of the proposed VLC system.

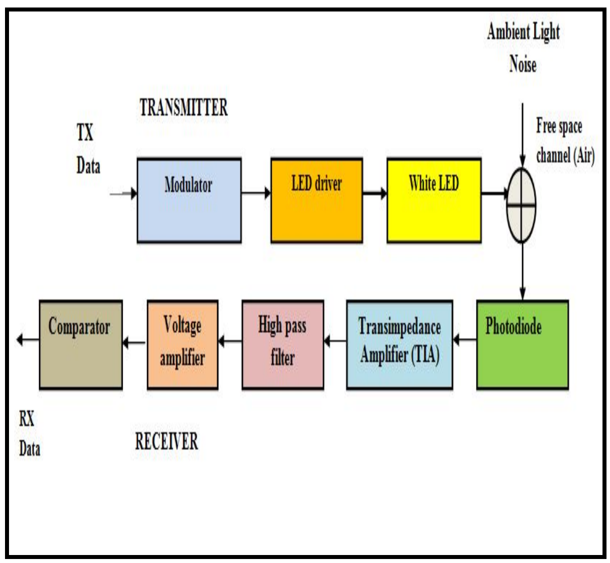

Figure-1. Block diagram of our proposed of VLC system.

A. VLC transmitter

In this work, On-off keying is used, a form of amplitude-shift keying (ASK), is the simplest modulation technique where the presence of the digital data is represented as binary one and absence of the digital data with zero [10]. The advantage of OOK modulation is the reduced power consumption, compared to other modulation techniques such as phase shift keying (PSK),

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binary phase shift keying (BPSK) and quadrature phase shift-keying (QPSK). The input frequency of 1 kHz is given using function generator. The input signal is converted as square wave using 555 timers, in astable mode. Light emitting source is of phosphor based White LED of 1 Watt with the viewing angle as 90^0, forward current of 0.35A/3.2W, power dissipation of 1.6 W. It will give about 80 lumens of light intensity. When compared to RGB LEDs it is of less cost and not complex. The LED driver consisting of resistor prevents the current flowing through the LED. To prevent the LED from flickering requires constant illumination. LM555 timer is used to produce carrier wave at 4.8 kHz. Figure-2 shows the schematic circuits design of the proposed VLC Transmitter.

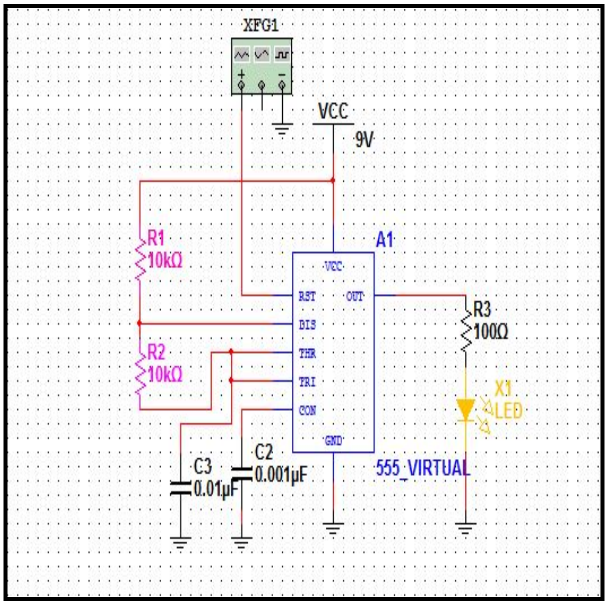

Figure-2. Schematic design of proposed VLC transmitter.

B. Channel modeling

Natural and artificial Ambient light noise sources such as sunlight, incandescent lamps, and fluorescent lamps, electronics noises degrades the performance of the VLC communication system [8, 9]. Thus visible light communication channel is modeled as a linear optical additive white Gaussian noise (AWGN) channel and the noise model should also be included with the channel model; the model follows the mathematical form as given by equation (1)

$$I(t) = \eta p_i(t) \otimes h(t) + N(t) \quad (1)$$

Where I(t) is the photo detector current, η is the photosensitivity of the Photo detector, the instantaneous input power, the symbol, $\otimes$ denotes the convolution, h(t) denotes the impulse response and N (t) denotes the AWGN noise. VLC is two different scenarios which are Line Of Sight (LOS) and Non Line Of Sight (NLOS) links [4-5].

Line Of Sight (LOS) is the unobstructed path of communication between the transmitter and the receiver. The transmitter directs the light beam in the direction of the receiver. In the LOS case the received power is given by the equation (2)

$$P_r{}^{LOS} = H_{LOS}(0)\, P_t \quad (2)$$

In the NLOS case, the light reflected by walls or any other obstacles is taken under consideration. The received power is generally given by the channel DC gain on LOS and reflected path $H_{ref}(0)$ is given by equation (3)

$$P_r = H_{LOS}(0)\, P_t + H_{NLOS}(0)\, P_t \quad (3)$$

$$= H_{LOS}(0)\, P_t + \sum_{ref} H_{ref}(0)\, P_t \quad (4)$$

In this work, the noise considered are indirect sunlight, ambient light noise such as fluorescent lamp driven by conventional ballast present in the indoor lab environment and electronics noise and line of sight (LOS) model between the transmitter and receiver to achieve better data rate.

C. VLC receiver

The proposed, VLC Receiver consists of photodiode as a Photodetector because of its advantages over APDs [6, 7]. VLC receiver also includes transimpedance amplifier (TIA), and electrical high pass filter, voltage amplifier and comparator to recover back the original data. Figure-3 shows the schematic of the proposed VLC Receiver.

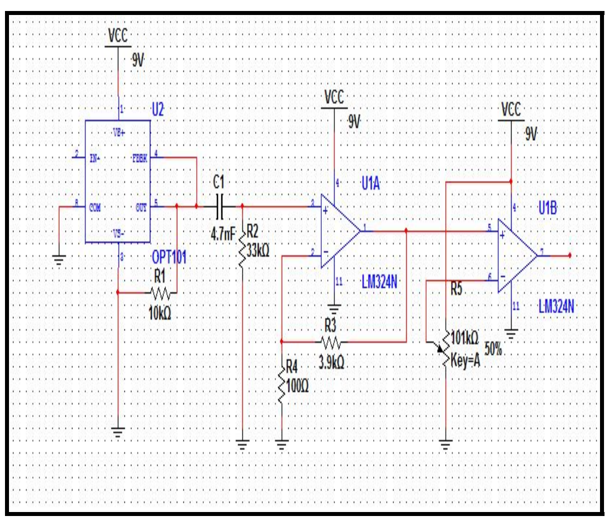

Figure-3. Schematic design of proposed VLC receiver.

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A monolithic photodiode and single supply Transimpedance amplifier (OPT101) of 0.09x0.09 inch cell is operated in the photoconductive mode for excellent linearity and low dark current with maximum responsivity at 650nm.

The excitation power supply ranges from +2.7V to +36V is used. It has got wavelength detection range from 200-1100 nm. The wide range of detectable wavelength helps to detect the modulated signal in the form of visible light and electric current is generated depending on the intensity of light. TIA present on the same chip converts the electrical current into voltage. The signal is passed through the high pass filter (HPF) to optimize the external noise and light from other ambient light sources.

The signal received through photo detector is very weak and it is in the mV range, so it needs to be amplified. Hence voltage amplifier circuit is designed to amplify the detected voltage. LM324 Quadruple operational amplifier of open loop offers differential voltage with the amplification factor as 100V/mv and the required supply voltage ranges between 3V to 32V. The voltage comparator is used at the final stage to convert the data signal into digital format. Thus the transmitted signal is recovered back at the receiver side. The operation and installation cost is less in Visible light communication system compared with other RF communication systems. This system can be implemented in any indoor environment such as office room or at home to transfer any data signal.

3. EXPERIMENTS AND RESULTS

The basic experimental set up of a proposed VLC system is shown in Figures 4 and 5. It includes the hardware to generate intensity modulated light emission from white LED as an optical source, free space (air) as the transmission medium and Photo detector at the receiver. The experimentation was performed inside the electronics laboratory of B.S Abdur Rahman University as an indoor VLC system. The test was performed with various conditional constraints. Further it was performed for the various communication distances, to extend the length of VLC. The analyses of observations are discussed in the succeeding section. Figures 4 and 5 shows the transmitter and receiver hardware schematic of the proposed VLC system.

Figure-6 shows the complete experimental test bench of the proposed VLC system. This proposed VLC system transmits OOK modulated signal via white LED, where the electrical signal is converted into intensity modulated optical signal. The optical signal is transmitted via air as the channel medium and the optical signal is detected by the photodiode and converted into an electrical voltage at the trans impedance amplifier stage. The high pass filter is used to reduce the noise due to other sources and ambient noise source. Thus the signal received is very weak so amplified using voltage amplifier and converted back to digital signal using comparator. Figure-7 Shows the transmitted signal is recovered back at the receiver.

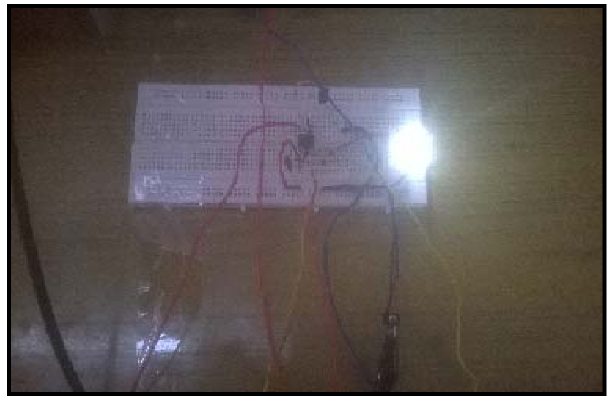

Figure-4. VLC transmitter circuit hardware prototype.

Figure-5. VLC receiver circuit hardware prototype.

Figure-6. Experimental test bench of the proposed VLC system.

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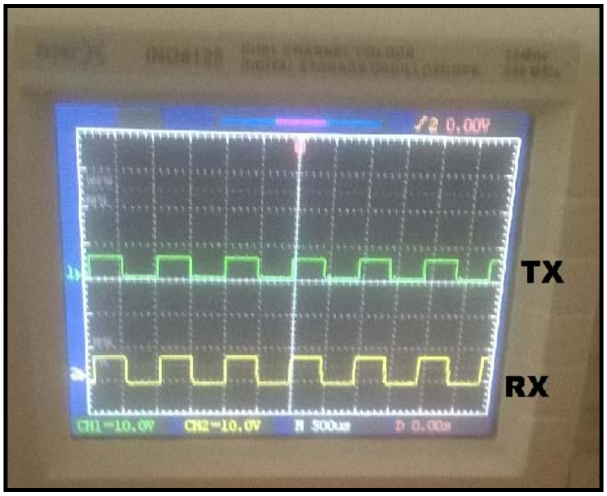

Figure-7. Captured transmitter and receiver waveform in Digital Storage Oscilloscope.

Above 0.20mA, the light intensity seems to have measured maximum level, increasing the current over this saturation point will have no effect on the light intensity. The maximum output optical power of this LED is 6mW. Figure-8 shows the graph of the current vs light power characteristics

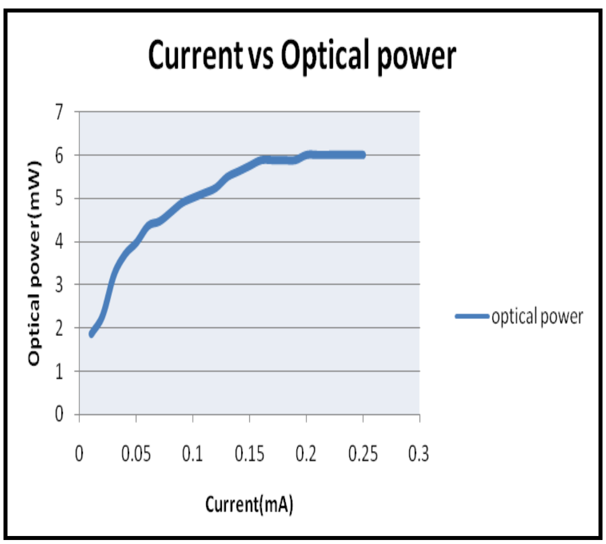

Figure-8. The graph of current vs light power characteristics.

It is observed that the output voltage decreases with the increase in vertical distance between the transmitter and receiver. The received output voltage is directly proportional to the intensity of light falling on the photodiode. The maximum achievable distance between the transmitter and receiver is 45cm after that the received signal is not properly recovered back at the receiver side. Figure-9. Shows the graph of vertical distance between the transmitter and receiver and the output voltage

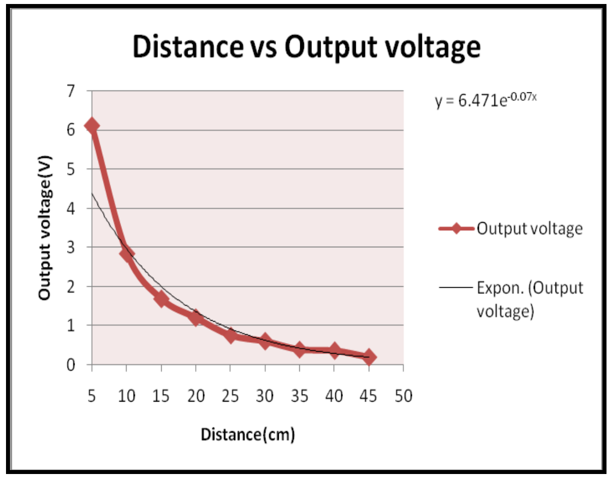

Figure-9. The graph of the vertical distance between the transmitter and receiver and the output voltage.

The circuit constructed is tested by measuring the optical power using Benchmark optical power meter when the ambient light is present in the room where the experiment is carried on while varying the vertical distance and the results are analyzed. Figure-10 shows the power graph of the vertical distance between the transmitter and receiver.

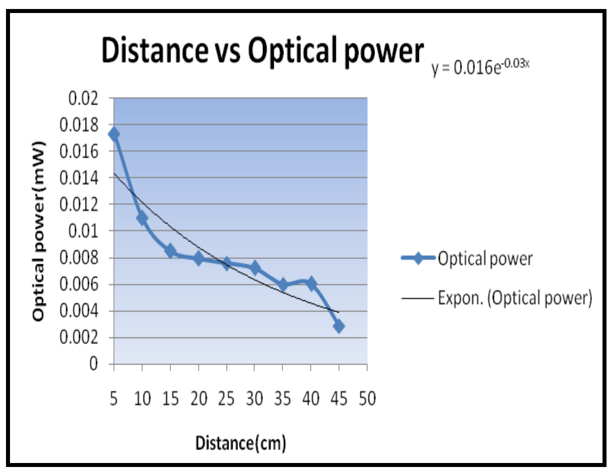

Figure-10. The graph of the vertical distance between the transmitter and receiver and the optical power.

4. CONCLUSIONS

In this paper, VLC system for indoor environment is implemented. This proposed work reports the transmitted data signal is received back at the receiver with reduced noise interference using the proposed transmitter and receiver circuit design. It is observed that, the output voltage and optical power decreases with respect to the increased transmission distance between the transmitter and receiver. Thus in future VLC system will be promised to play a main role in everyone's life by

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replacing the white LEDs with the incandescent and fluorescent light

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