VLC FOR SIGNAL TRANSMISSION AND RECEPTION: A NOBEL APPROACH

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Abstract- Visible Light communication (VLC) using White Light Emitting Diode (LED) is a promising technology for short range, high speed wireless data transmission. In biomedical or healthcare application, the implementation of RF technologies is frequently flustered by the electromagnetic wave radiations and interference which are harmful to the human beings. 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. The transmission of low power (10 to 100μv) signals with high degree of accuracy and at very high transmission rate is a challenging job. Thereby, it may go for a new novel method of transmission of signals using VLC (Visible light communication) technology. 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- Communication, LED, Photodiode, Receiver, Transmitter, VLC.

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I. INTRODUCTION

Optical wireless communication (OWC) refers to the wireless transmission of electronic data via a light wave carrier [1]. Typical optical sources in OWC systems include high power solid state lasers or diode lasers. With the recent advances in the semiconductor technology, these sources can be replaced by light emitting diodes (LEDs), especially for short and medium-range applications. Systems using visible light as carriers are termed as visible light communication (VLC) systems [2]. Recent advancements in solid state electronic devices such as light emitting diode (LED)[3] has triggered the possibility of illumination along with communication which is popularly known as Visible Light Communication system (VLC). Visible light communication using white light emitting diode is a promising technology for the next generation communication for high speed data transmission. For indoor environments, VLC systems provide a low cost, high speed, power efficient, and secure solution to data transmission in addition to lighting. VLC systems may find their applications in healthcare, aviation, underwater communications, and location based services [4] etc. In the future, home, hospital 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 (patient monitoring etc.), airplanes and location based communications. In this paper, transmitter and receiver circuit is designed for the proposed VLC system. Biomedical data are the observations of physiological activities of the humans. Biomedical data can be used to detect potential problem associated with the activity. Because of their low amplitude of biomedical signal, it is more difficult to detect it with respect to other signal. The usage of RF based device in the
healthcare have a dangerous impact on the health of the patient. Taking into these considerations, in this paper we have implemented signal transmission using visible light communication system.

II. LITERATURE SURVEY

VLC is standardized by the Institute of Electrical and Electronics Engineers (IEEE) [5]. Visible Light Communications Consortium, Japan carried out an initial research on visible light communication [6]. Now Asia, Europe, Wireless World Research Forum are also working in VLC research [7]. Early in the year 1990’s countries like Germany, Japan as discovered LED’s to send information when it is switched ON and OFF. The progress in the recent research shows that the light emitting diode can be used for high data rate transmission. The photonic crystal used in LED can help to achieve high efficiency in visible light communication system [8]. The loss of information due to dimming of light can be overcome using On Off Keying (OOK) modulation scheme [9]. Line of sight (LoS) is one of the important parameters in the visible light communication, it must be maintained between transmitter and receiver to achieve high throughput [10]. The transmission rate of about gigabit is achieved [11] which enable us for the quick access to the information. LED lamps can be used as communication emitters without losing their illumination functionality. Beam width of the communication link is shrunk to have higher data rate and hence transmitted data can be tuned to point towards the target receiver [12-14]. New innovative lighting products are developed with this trending technology [15]. Data-driven approaches can be used to create models based on physically sensed data rather than found from analytical methods [16]. There is also a need for LOS channel model to fix the path loss and optical power received for optimization of the receiver under major noise source [10]. By manipulating the fast-switching characteristic of commercial white LED devices, digital signals can be transmitted wirelessly via the optical channel [17-18] using a technique known as visible light communication (VLC).

III. VLC 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 Photo-detector at the receiver. Figure-1 shows the block diagram of the proposed VLC system.

![Figure 1. Block diagram of proposed VLC system.](image-url)
3.1 Circuitry Analysis of Proposed VLC Transmitter

The transmitter part mainly consists of an IC555 timer and a driver circuit as shown in Figure 2. Table 1 represents the required component list with specification for designing of transmitter. The timer is configured as an astable multivibrator or free running oscillator and its output is square wave in nature. The outputs of multivibrator produce the modulated signal. The carrier frequency is chosen 40 KHz and modulating input signal varies from 50Hz to 2 KHz, 1 V_{pp} (one volt peak to peak). The modulating signal from function generator is fed to the triggering input (pin no 2) of the timer. The modulated output varies according to input signal. C₁ is used as a coupling capacitor. A coupling capacitor is a capacitor which is used to couple or link together only the AC signal from one circuit element to another. The capacitor blocks the DC signal from entering the second element and, thus, only passes the AC signal. The bleeder resistance R₄ (4.7K) is connected to ground; C₂ and C₃ are used as a decoupling capacitor to prevent the surge and spike or to block unwanted A.C signal.

| SL NO. | COMPONENT | DESCRIPTION | VALUE/Specification |
|--------|-----------|-------------|---------------------|
| 1      | C₁        | Coupling Capacitor | 0.047uf/50V         |
| 2      | R₁a, R₁b | Resistance     | 120KΩ               |
| 3      | R₃        | Resistance     | 270KΩ               |
| 4      | R₄        | Bleeder resistance | 4.7KΩ              |
| 5      | C₂        | Capacitor      | 0.01uf/50V          |
| 6      | C₃        | Capacitor      | 10nf/63V            |
| 7      | C₄        | Capacitor      | 0.01uf/50V          |
| 8      | C₅        | Capacitor      | 10nf/63V            |
| 9      | R₂        | Resistance     | 10KΩ                |
| 10     | D₁        | Diode (high speed switching diode)IN4001 | 0.3V,3MHz       |
| 11     | D₂        | LED            | 160° field angle,5W,12V,420mA |
| 12     | D₃        | Power LED indicator | 2V,10mA, Red     |
| 13     | R₅        | Resistance     | 10 KΩ               |

R₁a, R₁b and C₅ are used as a trunk circuit to generate the required duty cycles and frequency. D₁ is used to achieve 50% duty cycles.C₄ is used to control the A.C surge voltage and to prevent the abnormal operation of timer IC555. The modulated output (Pin 3) from the timer is fed to the base of Darlington pair transistor through the biasing resistance (R₃) to control the base current. R₂ is used to prevent false triggering. Darlington pair transistor is used to drive the 5 watt LED as the output current of IC555 timer is not sufficient. The 5W LED act as a modulating signal transmitter. The LED (D₃) is used as the indicator of the presence of the power. Figure-2 shows the schematic circuits design of the proposed VLC Transmitter.

![Figure2. Schematic diagram of proposed VLC transmitter](image)
3.2 Proposed VLC Receiver

The receiver mainly consists of an OPT101 and a voltage regulator (LM324) as shown in Figure 3. The heart of the receiver is OPT101. The OPT101 is a monolithic photodiode with on-chip transimpedance amplifier. Output voltage increases linearly with light intensity. The amplifier is designed for single or dual power-supply operation, making it ideal for battery operated equipment. The integrated combination of photodiode and transimpedance amplifier on a single chip eliminates the problems commonly encountered in discrete designs such as leakage current errors, noise pick-up, and gain peaking due to stray capacitance. It is available in clear plastic 8-pin DIP, and J-formed DIP for surface mounting. Temperature range is 0°C to +70°C. The main incoming source signal is fed to the pin no 2 which is the negative input of the Op-Amp and cathode of the photodiode. This incoming modulated signal is first arrived/reached to the photocell and according to modulated signal this converts various voltages depending on the intensity of the of the modulated light source. This voltage is amplified to drive the further stages by the amplifier which is internally built within IC OPT101. The pin no 4 is the feedback input coming from internal feedback network and it is also connected to pin no 5 (output device). The anode of the photodiode performs as the common input terminal (Pin 8) which is typically connected to the ground potential. Pin no 3 is the negative power supply connected to the ground or a negative voltage that meet the recommended operating condition. The output of OPT101 (Pin 5) is fed to the next detector circuit and filter circuit which is the combination of R1, R2 and C1. The output of this filter is feed to IC LM324 (Quad comparator) through pin no 2. The LM324 series consists of four independent, high gain, internally frequency compensated operational amplifiers designed to operate from a single power supply over a wide range of voltages. Operation from split-power supplies is also possible and the low-power supply current drain is independent of the magnitude of the power supply voltage. The selected voltage of the comparator is controlled by the variable resistor R3. The voltage across the resistance R1 will act as the threshold voltage of the comparator. 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. The final output from IC LM324 is again fed to CRO through coupling capacitor (C1). The time scale for CRO is chosen 1ms. Here, a bleeder resistor (R6) is connected in parallel with the output of the circuit for the purpose of discharging the electric charge stored in the power supply's filter capacitors when the equipment is turned off, for safety reasons. Figure 3 and Table 2 represents the schematic diagram of the proposed VLC Receiver and the required component list with specification respectively.

Table 2: Component list for the Receiver

| SL NO | COMPONENT | DESCRIPTION | VALUE |
|-------|-----------|-------------|-------|
| 1     | R1        | Resistance  | 22 KΩ |
| 2     | R2        | Resistance  | 33 KΩ |
| 3     | R3        | Resistance  | 10 KΩ |
| 4     | R4        | Resistance  | 120 Ω |
| 5     | R5        | Resistance  | 3.3 KΩ |
| 6     | R6        | Bleeder Resistance | 1M Ω |
| 7     | C1        | Capacitor   | 10uf  |
| 8     | C1        | Capacitor   | 10uf  |
IV. EXPERIMENTAL SETUP

The basic experimental set up for the transmitter and receiver hardware model of the proposed VLC system is shown in Figure 4 and Figure 5 respectively. 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 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.
Figure 6. shows the complete experimental test bench of the proposed VLC system. This proposed VLC system transmits 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 transimpedance 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.

V. METHODOLOGY

This project is designed to send information to the respective receiver with the help of a new wireless communication technique known as Visible Light Communication (VLC) based on a general Light Emitting Diode (LED). It is the combination of transmitter to transmit data and receiver to receive data and analyze the data.

In transmitting part a simple concept of a timer base modulation circuit has been used. Here IC555 is used as a timer and it is configured as astable multivibrator. Primarily, it is used to produce a 4 KHz carrier frequency and its duty cycle was 66.66%. The input Frequency of 1 KHz is given using a Function Generator. This input square wave testing signal has been varied from 50Hz to 2 KHz. The modulated output signal is fed to a 1W LED through a driver transistor whose field angle is 150°. This LED driver operation is depends on the modulating frequency. Initially, one NPN Bipolar Junction Transistor (BJT) is used to drive the LED driver, but it was unable to tolerate the high current. Next, the current and designed of a higher current driver circuit has been calculated using Darlington pair transistor. It has high power and current carrying capacity. Now we observe some atmospheric disturbance and overlapping occurred in receiving end due to using 4 KHz carrier frequency. To over come the above mentioned problem, the transmitter has been redesigned for 40 KHz carrier signal and a high speed germanium diode (D1) is used for 50% duty cycle. After this we noticed that the output transmitted data and the receiving data are identical. Using 1 W LED the transmitting distance can be covered up to 1.2 meter, which is too short. Now the data transmitting distance increases up to 3 meter by using a 5 W, 12 V LED instead of 1 W LED. The field angle of 5 W 12 V LED is around 160°. Being omnidirectional, the receiver can receive the data from anywhere within the transmitting distance but our aspiration is to make it longer one. For this we search a unidirectional LED for signal transmitter. After a long trial and error, finally a reflector LED torch
has been chosen which is only 1 W having 15° field angle for data transmitting. Now we can easily transmit data to a minimum distance of 15 meter and the transmitting data is noiseless and distortion free.

The optical signal is then detected by the VLC receiving system, composed by a photodiode and a front end amplifier. The gain of the front end amplifier is continuously adapted in order to reduce the effect of ambient and other background light sources. Here we use OPT101 as the photodiode. The output of the photodiode is passed through a high pass filter so that we can extract the main signal. This signal is finally fed to CRO through a LM324 comparator. The developed project has the following advantages:

- It is not harmful for human body.
- Energy consumption is very less.
- Increase in security.
- Patient can be continuously monitored without human interface.
- This is very effective way for transmitting information to health care staff and health care providers.
- No harmful rays that effect human life.
- Low cost.
- Time saving.

The proposed design can be applied in the following fields:

- Hospitals and institutions.
- Defence and security.
- Underwater communication.
- Services provided based on location.
- Patient is monitored in remote areas or while travelling.
- Mobile connectivity.
- Smart lighting.
- Wi-Fi spectrum relief.

VI. CONCLUSIONS AND SCOPE OF FUTURE WORKS

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 designed transmitter and receiver circuit. It is observed that, the output voltage and optical power decreases with respect to the increased transmission distance between the transmitter and receiver. The developed design is insensitive to sunlight and indoor fluorescent lights. If this technology is put into practical use then every bulb can be used to transmit wireless data and we will proceed through greener, cleaner and safer future. Thus in future VLC system will be promised to play a main role in everyone’s life by replacing the incandescent and fluorescent light with the white LEDs. We believe that VLCs will be one of the most promising technology in the future. Although the system is challenging, however it aims at an interesting area of research.

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