Prototype of Visible Light Communication Transceiver Using Array Photo Transistor for Real Time Digital Media Transfer

Inung Wijayanto¹, Sugondo Hadiyoso² and Retno Renggani¹

¹ School of Electrical Engineering, Telkom University, Bandung, Indonesia
² School of Applied Science, Telkom University, Bandung, Indonesia

Abstract. Previous research about low cost visible light communication (VLC) transceiver prototype was conducted which able to reach 98 cm, 70º and 19200 bps of transmitting distance, maximum transmission angle and transmission rate, respectively. The next prototype is built to get better performance by adding a reflector to the array phototransistor and split the power of the transceiver in order to maximize the light of the LED. This new prototype surpasses our target by reaching 134 cm of transmission distance. The system is also able to send digital multimedia files such as text, images, video in MPEG format and audio files in WAV and Mp3 format. The maximum bit rate of our prototype is 9600 bps and acceptance angle is 87º.

1. Introduction

Alternative carrier for wireless communication is highly needed to resolve the limited use of radio frequency. One of the solutions is by using a visible light that categorized as optical wireless communication. It used the light frequency where the emitting light comes into sight [1,2]. Visible Light Communication (VLC) used optical wireless communication technology that carries information by using visible light traveled in the free space environment. It transmits a signal between 380 nm to 740 nm wavelength [3]. VLC is suitable to be implemented in an indoor environment that adapted from infrared communication [4–6]. Visible Light Communication has resistance to electromagnetic interference, hard to be tapped and still undergoing a continues development. One of them is the development to reject the interference for WDM-VLC conducted resulted in 61% of reduction rate [7].

People nowadays tend to use LED as a replacement for bulb and fluorescent lamp because of its capability to saves more energy. The LED light emitted incoherently comes from the current supply of the circuit [8]. Therefore, the LED lamp has a high switching feature as the characteristic where it can switches off and on that human eyes cannot see nor follow the switching rate [9]. The characteristic influence researcher to use it as a media to transfer digital data. The “OFF” condition is representing a logic low, while the logic high represented in “ON” condition of the switching feature.

Research about VLC can be found easily with broad implementation. One of them uses VLC as a protocol for vehicle communication. The prototype built by using two toys which communicate each other informing their distance and position. The maximum transmission distance between the two toys is 1,9 meters [10]. Indoor implementation of VLC also conducted in a railway environment which has the potential to deliver data transmission system effectively [11]. This technology still faces a challenge to be built in a low-cost material. Array photodetector also used in other research to reach maximum transmission distance [7,12–14]. A 2x2 imaging MIMO OOK VLC using array photodiode can reach 150Mbps consuming 1,38 Watt and able to reach 6 m transmission distance [12]. VLC can be designed for real-time data transmission so that biomedical data such as ECG can be accessed as long as the receiver is in the room. As an application of the proposed model, a classification using machine learning used [15,16].
Previous work to build a low-cost VLC was able to send 1200 characters with a maximum distance of 15 centimeters [17]. The prototype is being optimized, and able to send data, in the form of text and images, with no error in 98 centimeters with maximum baud rate is 19200 bps [18].

The remaining section for this paper is formatted as Section II is the explanation of the method about VLC and LED. Section III describes the hardware design, followed by software design in Section IV. Section V is the experimental result, and finally in Section IV is the conclusion.

2. Method

2.1. Visible Light Communication
Visible Light Communication is one type of wireless communication that utilize the use of visible light as the transmission media. This type of communication categorized into free-space optical communication. The transmission was done by utilizing the light source flicker on and off. This flicker represents a high and low logic signal. Any light might be used to do the data transfer, but the critical parameter is how fast the light can turn on and off. The favorite choice for VLC is the use of light emitting diode because it has high-speed on-off switch[6].

2.2. Light Emitting Diode
This semiconductor device may emit visible light into an electric current. The wavelength responds from LED may vary from 700nm to 400nm which represent red to blue-violet. Some energy emits radiation (IR) 830 nm or more called an infrared emitting diode (IRED). There are two types of material in LED called as P-type and N-type semiconductors which placed in direct contact. The connection region called the P-N junction. LED has a transparent package which may pass visible light and IR energy pass through it [19]. In this research, we use super-bright white LEDs with 10W of power, and 450nm of wavelength.

3. Hardware Design
The prototype of VLC transceiver is designed to act as transceiver and receiver. It communicates in half duplex. The transceiver connected to the computer by using a DB9 connector, where the third pin of DB9 used as data output. The USB to serial converter sent -15 V to 15 V current to IC Max232. Then it converted into 5V TTL level. The output from TTL obtained through the 12th pin of max232. This output then processed in the 8th pin of IC 7414 which acts as a free-noise buffer. The 7414 connected to transistor base for high current and voltage amplifier acting as the driver of array LED. Modulation of the signal on the LED, which indicated with the switch ON and OFF of the LED, is using RS-232 serial communication protocol. The RS-232 has a higher voltage level compared to the TTL voltage level which is required by the components and IC to work. In our prototype, we choose to use phototransistor because it has a high sensitivity of light and has an internal gain. The received light generating current to the base region then increasing the current amplification thousand times from the original current [20].

We designed the transceiver of the VLC by placing the phototransistor into a 4x4 array. The array phototransistor receives the modulated light then it triggered the IC 7414 in the first pin and followed by inverting the signal to the second pin then inverted again in the third pin for the revert process. This process removed the noises and amplified the received signal. The amplified signal then forwarded to the fourth pin of IC 7414. Next, the signal forwarded to the 11th pin of IC max232. In this process, the high voltage converted to TTL level 5V out to the 14th pin connected to DB9 second pin acting as RX pin. The output of this process is now can be read by the designed software located on the computer.

![Figure 1 System model of VLC transceiver](image-url)
4. Software Design
The software has two main windows. The first window is the transmission section which has radio buttons to choose the file type to be transmitted. A file preview window and send button to start transmitting the data. In the receiver section, consists of radio buttons which must have the same selection with the transmission computer. It also has a preview window to display the received file.

5. Result and Discussion
VLC in this work is an improvement of previous research [17,18] where the primary objective is to improve performance both in distance and acceptance angle. We transferred the multimedia file (text, music, image, and video) serially. The device performances measured by calculating the data transfer rate, distance, and acceptance angle of the test parameter. Furthermore, this research also analyzed the correlation between transfer rate and distance toward error rate. We also analyzed the effect of the phototransistor switching rate toward the maximum transfer rate that can be reached.

5.1. Transfer Rate Parameter
Transfer rate test aims to determine the data rate performance of data transmission. From the test results that shown in Table 1 can be determined the maximum rate that can be achieved by this VLC system. Can be seen on the table, the maximum transfer rate is 9600bps. With 9600bps, the system can work very well with no mistakes. When the data rate set over 9600bps, an error occurred causing data corrupt during the transmission process. The transfer rate limit caused by the switching time of the phototransistor. Phototransistor cannot be switch on-off instantaneously because of the presence of internal capacitances that cause the delay.
5.2. Distance Parameter
Distance range testing aims to determine the maximum distance range between transmitter and receiver without causing an error. This performance is also the primary goal to be achieved for improvements to the previous VLC designs [18]. From the test results that can be seen in Table 2, the maximum distance that can be achieved was 134 cm. With the addition of reflector and boot the power source on this proposed system it is proven to extend the distance between the transmitter and receiver.

5.3. Acceptance Angle
One of the main parameters of VLC performance is the radiation area. The radiation area can represent the radius that can be reached by VLC so that many users can access it at the same time. From the test results shown in Table 3 the maximum acceptance angle achieved is 87°. This result is better when compared with previous work. The use of reflector affects expanding the radius to make better performance.

| File Type     | Bitrate (bps) | Transmission Status |
|---------------|---------------|---------------------|
| Image (38KB)  | 2400          | Success             |
|               | 4800          | Success             |
|               | 9600          | Success             |
|               | 19200         | Failed              |
| Music (1564 KB)| 2400          | Success             |
|               | 4800          | Success             |
|               | 9600          | Success             |
|               | 19200         | Failed              |
| Video (5669 KB)| 2400          | Success             |
|               | 4800          | Success             |
|               | 9600          | Success             |
|               | 19200         | Failed              |
| Text (1KB)    | 2400          | Success             |
|               | 4800          | Success             |
|               | 9600          | Failed              |
|               | 19200         | Failed              |

| TX-RX Distance | Transmission Status |
|----------------|---------------------|
| 20             | Success             |
| 40             | Success             |
| 60             | Success             |
| 80             | Success             |
| 100            | Success             |
| 120            | Success             |
| >134           | N/A                 |

Table 1 Transfer Rate Result

Table 2 Transmission Distance
### Table 3 Transmission Angle

| Angle | Transmission Status |
|-------|---------------------|
| 0°    | Success             |
| 10°   | Success             |
| 30°   | Success             |
| 50°   | Success             |
| 70°   | Success             |
| >87°  | N/A                 |

### Table 4 Correlation Between Transfer Rate and Distance

| File Type       | Bitrate (bps) | Distance (cm) | Transmission Status |
|-----------------|---------------|---------------|---------------------|
| Music (1564 KB) | 9600          | 40            | Success             |
|                 | 9600          | 60            | N/A                 |
| Image (38 KB)   | 9600          | 40            | Success             |
|                 | 9600          | 80            | N/A                 |
| Video (5669 KB) | 4800          | 100           | Success             |
|                 | 4800          | 120           | N/A                 |

### Table 5 Comparison with previous research

| Measurement Parameter | Yudhabrama et al. [17] | Yudhabrama et al [18] | This Research |
|-----------------------|-------------------------|-----------------------|---------------|
| Max distance          | 12 cm                   | 98 cm                 | 134 cm        |
| Bit Rate              | 19200                   | 19200                 | 9600          |
| Max Angle             | 70°                     | 70°                   | 87°           |
| File Type             | text                    | text, image           | text, image, audio, video |

5.4. Correlation Between Transfer Rate and Distance Error Rate

Further analysis is to determine the correlation between transfer rate and distance toward error rate. After the observation, the higher data transfer rate made the transmission distance shorter. This condition could happen due to the sensitivity limitations of the phototransistor then causing error data representation. Test results are shown in Table 4.

5.5. Comparison with Previous Research

Compared to previous research, this research produces a better result. We obtain further transmission distance, previous research can transmit 12 cm and 98 cm, while our prototype can reach 134 cm. The prototype can transfer multimedia data using 9600 bps because of the limitation of the phototransistor. The maximum angle for the transmission reaches 87° which better than previous work.

6. Conclusion

In this research, a prototype VLC system has successfully designed and implemented. Based on testing performed, VLC transceiver can be used for multimedia file transfer. This proposed system is a development of previous research by adding a reflector and gain the power source. The VLC
The transceiver prototype can work properly up to 134 cm of distance, the acceptance angle is 87°, and maximum baud rate is 9600 bps. Based on system testing, switching time and sensitivity of phototransistor affect the limitation of data transfer rate. For future research, it needs a better-performing phototransistor to work on higher data rates.

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