Visible Light Communication Using the Flash Light LED of the Smart Phone as a Light Source and Its Application in the Access Control System

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***Abstract* — Visible light communication (VLC) is one of the most popular research points of the short range wireless communication. Due to the high efficiency, long lifetime, and fast switching characteristics of LEDs, LEDs are ideal light source for the VLC. In this paper, the flash light LED of the smart phone has been studied and used as the light source for the VLC. The encoding and decoding methods appropriate for the flash light have been proposed and demonstrated. This VLC technique has been applied in the access control system, which is simple, reliable, convenient, and low cost, and can be a supplement to the conventional access control system.**

***Index Terms* — Visible light communication (VLC), wireless optical communication, short range wireless communication, LED, identity certification, access control system.**

I. Introduction

White illumination LEDs, with their long lifetimes and energy efficiencies at least 10 times greater than incandescent bulbs, are being massively deployed in illumination applications[1]. By utilizing the advantage of fast switching characteristic of the LED compared with the conventional lightings, the LED can be used as a communication source in VLC. The VLC has been researched since 1999[2]. With more than ten years researching and development, the transmission bit rate with 3.4 Gb/s has been reported in the lab[3], and it can be applied in the internet accessing[4], indoor positioning system[5], traffic information system[6], biomedical sensing data transmission[7], wireless audio or video transmission[8], wearable devices[9], and so on.

Although VLC has been researched and developed a lot, the related equipments and devices are relatively large, expensive and difficult to be used, and there have been few commercial products. The flash light LED, which is used for illumination smooth when taking photos, is a normal device in the smart phone. VLC system can be connected to smart phones with the help of the flash light LED as a light source and camera as a light sensor[10]. The smart phone can carry out the algorithm to modulate signals to the flash light LED and process signals received from the camera[11]. In this paper, a VLC system using the flash light LED of the smart phone as a light source is proposed, and its application in the access control system is demonstrated. This system is simple, reliable, convenient, and low cost.

II. System Architecture

The system architecture of the access control system based on VLC using the flash light LED of the smart phone as a light source is shown in Fig. 1. The smart phone encrypts and encodes the ID which is originally obtained from the server, and then transmits the ID as optical signals through the flash light LED. The optical receiver receives the optical signals and transforms them to electrical signals, and then decodes and decrypts the signals to the ID. The controller identifies if the ID received from the optical receiver is authorized or not, and send related signals to the electric lock and the optical receiver, uploads data to the server through the switch.

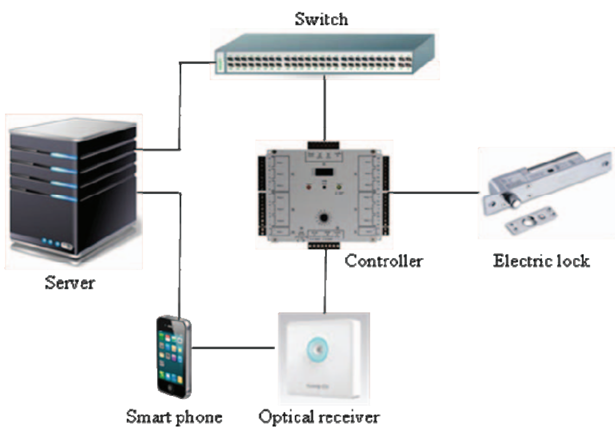

Fig. 1. System architecture of the access control system.

III. MODULATION CHARACTERISTICS OF THE FLASH LIGHT LED OF THE SMART PHONE

The on or off state of the flash light LED can be controlled through the smart phone, and the time duration of the on or off state can also be tuned. The flash light LED of a smart phone was tested. The LED was turned on and shut down for 100 times respectively, with the time duration set to zero. A photodiode and an oscilloscope were used to detect the optical signals, as shown in Fig. 2. It's found that the waveform of the signals was not uniform, and the time durations of the on an off state varied. The distribution diagram of the time durations is shown in Fig. 3. It's found that about 80% of the time durations were in the region of 0 ~ 4 ms, and the probability of time durations appearing in bigger time region became lower. When the time duration was set to 10 ms, most of the time durations were in the region of 10 ~15 ms. According to the testing results, most of the smart phones appear similar phenomena. So the clock signals cannot be recovered from the optical signals, and conventional encoding methods cannot be used, such as NRZ, PPM, PWM.

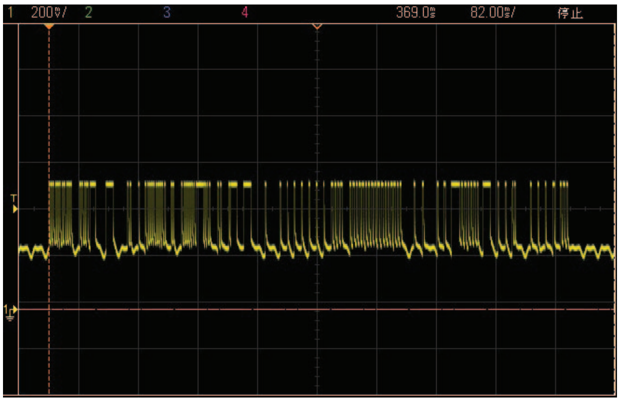

Fig. 2. Waveform of the optical signal output from the flash light LED of a smart phone.

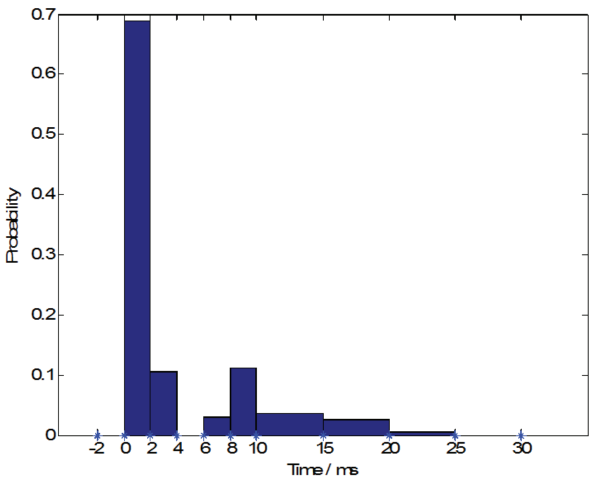

Fig. 3. Distribution diagram of the lasting time.

IV. ENCODING AND DECODING METHODS

According to this, an encoding method is proposed, where the original data are divided to many groups, and the data in each group are represented by the inversing times from 0(1) to 1(0). The time duration of on or off state between each group is set to Tout, and the time duration in each group is set to Tin, where Tout >Tin, as shown in Fig. 4. The mapping table of this encoding method is shown in Table 1.

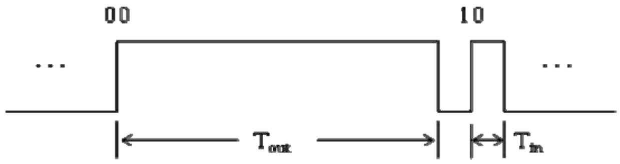

Fig. 4. Waveform of the signals after the encoding method.

TABLE I
MAPPING TABLE OF THE ENCODING METHOD

Original data	00	01	10	11
Inversing times	1	2	3	4
After encoding	1/0	10/01	101/010	1010 /0101

When signals are being received, the time durations between each inversing from 0(1) to 1(0) are recorded. All the time durations are compared with a reference time duration. If the time duration is smaller than the reference, the inversing times from 0(1) to 1(0) are recorded. If the time duration is bigger than the reference and smaller than the end time duration, it means a group of signals has been received, and the inversing times will be recounted in the next group. If the time duration is bigger than the end time duration, it means all signal is received. The reference time duration is set adaptively. For example, 54 bits data output from the smart phone are divided to 27 groups, with 2 bits data in each group. The receiver records all the time durations. The reference time duration is set between the 26th and 27th biggest time durations. Finally, the data are remapped according to Table 1.

V. IMPLEMENT AND DEMONSTRATION

The App software for the smart phone has been developed. When the software is used for the first time, an ID needs to be obtained from the server of the access control system by typing a code in the setting interface of the software. The code can be obtained in the administrating office. After the ID is obtained, optical signals can be sent out by touching the icon in the main interface of the software. Before the optical signals are sent out, the signals are encrypted and encoded by the encoding method mentioned above.

The optical receiver mainly contains PIN, amplifier, comparator, MCU, as shown in Fig. 5. The PIN transforms optical signals to electrical signals, and the resister R1 tunes the output electrical signals, which can be increased by increasing R1. Then the signals are input to the negative phase input port of the operational amplifier. A bias voltage Vbias is input to the positive phase input port to set the bias of the output voltage. The gain of the amplifier is –R3/R2, and the balance resister R4 is R2||R3. In the comparator, input signals are compared with the reference voltage Vref, and signals suitable for processing are sent out. The MCU decodes and decrypts the signals, and sends the ID to the controller.

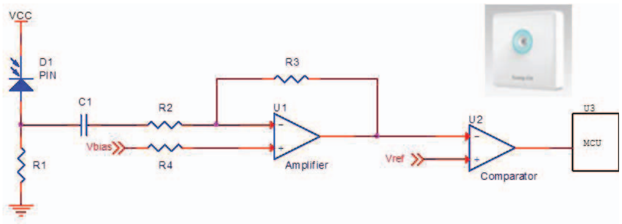

Fig. 5. Schematic diagram of the optical receiver (the inset is the real optical receiver).

An oscilloscope was used to test signals output from the comparator in the optical receiver. The testing result are shown in Fig. 6. It can be seen that the signals are divided to 27 groups, each of which is separated by a bigger time duration about 35 ms. In each group, the time durations (about 5 ms) are smaller, and there are 2 bits data. According to Table 1, the signals in Fig. 6 are 0101 0110 0010 0011 1010 0101 1000 1001 0001 0010 0000 0011 1010 00. The area, where optical signals can be received is shown in Fig. 7. The longest vertical distance is 25 cm, when iPhon4s is used.

VI. Conclusion

In this paper, the modulation characteristics of the flash light LED of the smart phone have been analysed. It's found that the light on or off state of the flash light LED can be controlled through the smart phone, and the time duration of the light on or off state can also be tuned in a region. Although the clock signals are lost in the optical signals, the times for turning on and shutting down the LED is fixed. According to these, an encoding method has been proposed and demonstrated, where original signals are divided to many groups, and data in each group are represented by the inversing times from 0(1) to 1(0). The optical receiver has also been researched and developed. This VLC system is simple, small, and low cost. An access control system based on this VLC system has been proposed and demonstrated, and it's very convenient, for most people have smart phones, which can be used as keys of the access control system.

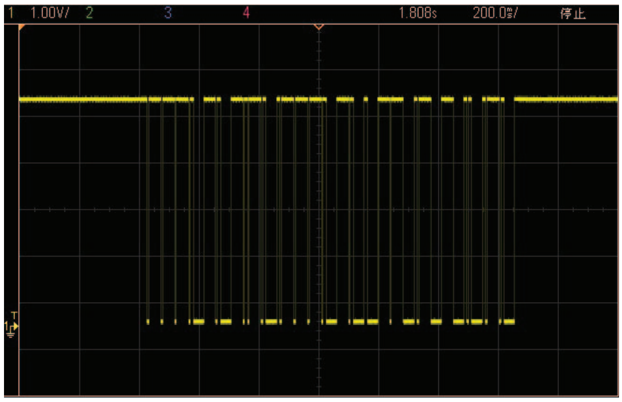

Fig. 6. Waveform of signals output from the comparator in the optical receiver.

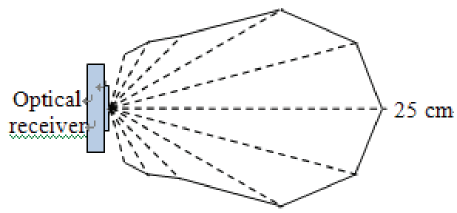

Fig. 7. Area where the optical signals can be received successfully when iPhone4s is used.

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