Progress of Visible Light Communication

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Abstract: This article introduces "visible light communication" using visible light sources as transmitters and discusses its applications and standardization activities.

1. Introduction

Visible light communication by using visible light LED, especially white-light LED, was first proposed by our group [1] in 2000, and recently many research projects have been underway in the world. The reason for the rapid spread of research and development of visible light communication [2] [3] [4] [5] is due to the growth of LED illumination market in the world. White LEDs have recently been used as efficient light sources replacing incandescent light bulbs and fluorescent lamps. The rapid spread of white LEDs is due to the improvement of illumination efficiency known as “luminous efficacy” in units of lumen per watt. The luminous efficacy of incandescent light bulbs is about 10 lumen/watt and that of fluorescent lamps is about 100 lumen/watt. On the other hand, the luminous efficacy of white LED is about 100 lumen/watt now, and is expected to reach 200 lumen/watt in ten years as shown in Figure 1.

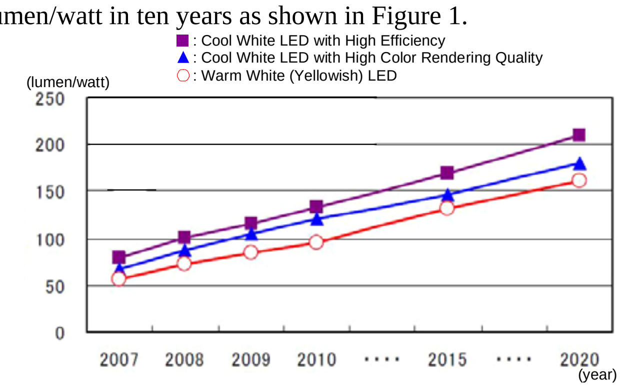

Figure 1: Prediction of LED Illumination Efficiency (Source: JLEDS Technical Report Vol.2)

Visible light LED world market is predicted to grow at the rate of 15 percent per year for the next several years, and the applications of visible light LED include not only lighting but also backlights of LCD, automotive lights, electric signs, etc.

2. Visible Light Communication

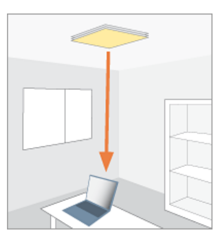

Figure 2: Visible Light Communication using Illumination Lights

Figure 2 shows a representative use of visible light communication, where an LED lamp is used as a data transmitter. The visible light communication using LEDs is expected as a means for ubiquitous communication method, because illumination lights are needed in almost all the indoor spaces such as rooms of offices, homes, or shops, and outdoor spaces where street lights or traffic lights are used.

3. Applications of Visible Light Communication

The communication distance using visible light communication is typically on the order of tens of meters to hundreds of meters, much shorter than radio-wave communication, due to the fact that visible light is obstructed by objects between a transmitter and a receiver. Because of this property of short distance communication, visible light communication is suitable for the applications of location-based services, where users need to know the information tied to the location where it is used.

Figure 3: Indoor Location Detection using Cellular Phones and Visible Light LEDs [6]

Typical applications of such location-based services are shown in Figure 3, where a user uses a cellular phone with a visible light sensor, which detects signals from an LED light. This application is especially useful indoors because GPS receivers do not work well indoors even though they work well outdoors.

4. Devices used for Visible Light Communication

Typical devices used for transmitter of visible light communication are visible light LEDs.
Intensity-modulated light from typical white LEDs using fluorescent (typically yellow) material has frequency characteristics of several MHz at 3dB attenuation, thus the data rate using white LED is on the order of several mega bits per second.
Typical devices used for receiver of visible light communication are PIN photo diodes or avalanche photo diodes, both of which are able to receive data at the rate of giga bits per second, thus fast enough to receive data from visible light LEDs.

5. Communication using Image Sensors

Another interesting device for receiver of visible light communication is an image sensor. An image sensor is able to do simultaneous image acquisition and data reception.

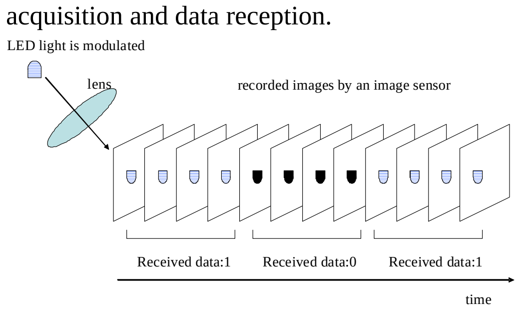

Figure 3: Concept of Visible Light Communication using Image Sensors as Receivers.

Figure 3 shows the concept of visible light communication using image sensors as receivers. An image sensor continuously takes images of a scene with an LED light whose light intensity is modulated and a receiver detects the optical intensity at a pixel where the LED light is focused on. Image sensors used for digital cameras or video cameras usually have frame rate of tens of frames per second. If a visible light signal from a visible light LED is received at a pixel of such an image sensor, the data rate is on the order of only several bits per second. However, using a high-speed image sensor whose frame rate is thousands of frames per second, it is possible to achieve data rate on the order of kilo bits per second. Application-specific image sensor for communication is able to receive data at the data rate of mega bits per second.

Figure 4: Application Example of Visible Light Communication using Image Sensors as Receivers [7]

A representative example of visible light communication using image sensors is shown in Figure 4. Data is sent from LED transmitters installed at different buildings, and image sensor detects not only its location of a source in an image, but also its received data contents. The monitor displays its contents at a location in an image where the data is sent from.

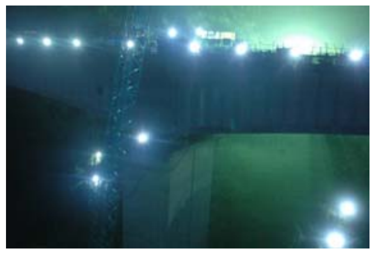

Figure 5: Another Example of Visible Light Communication using Image Sensors as Receivers [8]

Another example of visible light communication using image sensors is accurate position detection as shown in Figure 5. In this example, a photogrammetric method is used to detect the locations of LEDs installed at a bridge under construction. The accuracy of position using photogrammetric method and visible light communication was less than one centimeter at a distance of about 100 meters away from an image sensor. This accuracy of position is comparable to that of a typical surveying device called a total station with a transit and a laser electronic distance meter (EDM).

6. Standardization of Visible Light Communication [5]

We founded Visible Light Communications Consortium (VLCC) [9] in 2003 on order to do activities of market research, promotion, and standardization of visible light communication. In 2007, VLCC proposed to JEITA “Visible Light ID System” standard (CP-1222) which can be used as a location beacon using visible light sources such as illumination LED lights. And in 2008, VLCC started working with IrDA (Infrared Data Association) and the two groups made Version 1.0 of Visible Light Communication Physical Layer Specification in 2009. Its data rate is 4 Mbps and its modulation schemes are Inverted 4PPM and Manchester Code Data Modulation, both of which are designed not to cause flickering for human eyes. IEEE also has been working on standardization of visible light communication in the IEEE802.15 Task Group 7, Visible Light Communication since 2008.

7**. References**

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