AUDIO SYSTEM USING LIGHT FIDELITY

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Abstract. *Currently, wireless communication technologies such as Wi-Fi and Bluetooth are widely used in our daily lives. Their wireless communication technology uses radio waves and uses frequencies allocated to each country. However, this method has problems such as limitations and interference with radio frequency (RF), security, and high cost. The Light-Fidelity (Li-Fi) method, which can solve these problems, has emerged as an alternative. Because the Li-Fi communication method uses visible light, its availability, bandwidth, security, and efficiency are superior to Wi-Fi.*

In this paper, the actual usability of Li-Fi was confirmed by implementing an audio system using the Li-Fi wireless communication method. The proposed system designed a modulation unit that converts the audio signal into an optical signal, and a demodulation unit that converts the optical signal back into an electrical signal and transmits it to the speaker. Additionally, an audio amplifier was added to amplify the signal. LED was used as a light source, and a solar cell, which is used in solar power, was used as a sensor to detect light signals.

As a result of implementing the system, it was confirmed that the audio signal passed through the system using the Li-Fi method and that the appropriate audio signal was output from the speaker. By using a solar cell as a sensor, it can be used for both sensor and solar energy storage. Although it is a basic audio system using Li-Fi, an independent wireless optical communication room can be configured in the future. In addition, it was confirmed that using a laser diode as a light source could be applied to a wider range of fields.

Keywords*: LED, Li-Fi communication, light receiver, solar cell, Audio Amp, Li-Fi modulator, LiFi Demodulator.*

Introduction

Li-Fi (Light Fidelity) is a type of wireless communication technology that uses light signals. The technology of transmitting data wirelessly is a means of wireless communication between two communicating devices. WiFi uses radio waves (RF) to transmit data, while Li-Fi uses visible light. Visible light can transmit data faster and more efficiently. Additionally, once optical signal conversion and demodulation devices are developed, data can be transmitted in both directions. The word Li-Fi originates from the University of Edinburgh in England, but the first person to use the method was German professor and physicist Herold.

Many scholars and engineers around the world are researching Li-Fi technology, but it has not yet been put into practical use. Before 2010, there was a lot of research mainly on the introduction, concept, and basic technology of Li-Fi [9-18], but since 2015, more and more practical research is being conducted and papers are being published [1-8].

In this study, a Li-Fi audio system was implemented by designing and manufacturing the modulator and demodulator components of the Li-Fi system. When an audio signal is received from the smartphone, which is an audio source, the optical modulator converts it into an optical signal. The light source used at this time is an LED that sends light to the light source. An optical demodulator receives optical signals, converts them into electrical signals, amplifies them, and sends them to the speaker. The light modulator used a solar cell. The signal output from the solar cell is connected to an audio amplifier using TDA2023A, and the output of the amplifier is output to a speaker.

As a result, by implementing an audio system using Li-Fi, it was confirmed that communication using visible light can be used in our daily lives. In addition, Solar Cell is used for solar energy accumulation and can perform two functions, solar energy accumulation and communication, at the same time by being used as an optical signal receiving sensor. In addition, since it is possible to build an Internet network using visible light, it is also possible to build an independent optical communication laboratory, which is advantageous for security. Communication is possible even in areas where Wi-Fi is not available, so it is effective when applied to various areas.

2. Audio system using Li-Fi

2.1 Data communication

In data communications, the method of exchanging data through wired or wireless transmission media is very important. The purpose of data transmission is not for the sender or receiver to create data, but rather to transfer already existing data and communicate securely throughout the communication process. There are three ways of physical communication between sender and receiver. Unidirectional, half duplex and full duplex.

1) Simplex: It is a one-way communication method. This method is mainly applied to radio or TV broadcasting communications.

2) Half duplex: Communication occurs in both directions, but not simultaneously. Instead, communication occurs in only one direction at a time. This method is mainly used for walkie-talkies.

3) Full duplex: This is a method in which communication occurs simultaneously in both directions. This applies to most communications used today, including the Internet and telephones. In this paper, the Simplex method was used to study the basic system configuration to confirm the practicality of Li-Fi.

2.2 Light Fidelity (Li-Fi)

Li-Fi is a next-generation mobile communication technology that uses visible light in the spectrum from infrared to ultraviolet rays such as LEDs. It is an abbreviation for Light Fidelity and is commonly called Li-Fi. Information exchange takes place through the flickering of light from the light source LED unit, which acts as a transmitter. Because the speed of flickering is one millionth of a second, it is not perceptible to the human eye. The characteristics of Li-Fi are as follows. Li-Fi is a technology that uses light, but it doesn't have to be bright all the time. If Li-Fi is needed in the middle of the night or in a dark place without light, the lighting can be lowered to a level that humans cannot see. In the case of Wi-Fi, the router must be turned on continuously, but with Li-Fi, Internet is possible even if the LED appears almost off. In this respect, Li-Fi can reduce power consumption compared to Wi-Fi. The advantage is fast speed. In theory, the speed is 100 times faster than the Internet currently used worldwide. Additionally, exposure to electromagnetic waves is reduced. Since communication and lighting are used simultaneously, a separate communication device is not needed, so the number of communication devices can be reduced by one. The 2.4 GHz Wi-Fi band, the currently used Internet frequency, is reaching saturation point. Because Li-Fi has a different frequency band, it does not overlap with Wi-Fi frequencies, which can reduce frequency interference.

However, there is a disadvantage that communication is impossible if there is an obstacle blocking the light between the receiver and the transmitter, the currently used Internet frequency, is reaching saturation point. Due to frequency interference, the Internet may be blocked in special cases such as hospitals or airplanes, but since Li-Fi does not cause interference itself, Internet connection is possible regardless of location without affecting other equipment. However, there is a disadvantage that communication is impossible if there is an obstacle blocking the light between the receiver and the transmitter.

2.3 Basic configuration of Audio System using Li-Fi

The usability of Li-Fi was confirmed and an audio system using it was implemented. The audio signal source was a smartphone. The smartphone's voice signal is converted into an optical signal through an optical signal modulator, and an LED is used as a light source. The optical signal carrying the audio signal is transmitted to the sensor (solar cell) of the optical demodulation unit, and the solar cell converts the optical signal into an electrical signal. An audio amplifier is used to amplify the converted electrical signal. The amplified audio signal goes through another amplification and is output to the speaker. To check the results, you can actually hear the smartphone's music clearly through the last speaker. However, it can be confirmed that when the light source transmitted through the light source is blocked, communication is impossible and no sound is heard.

3. Proposed Audio System using Li-Fi function and operation algorithm

3.1 Implemented system block diagram

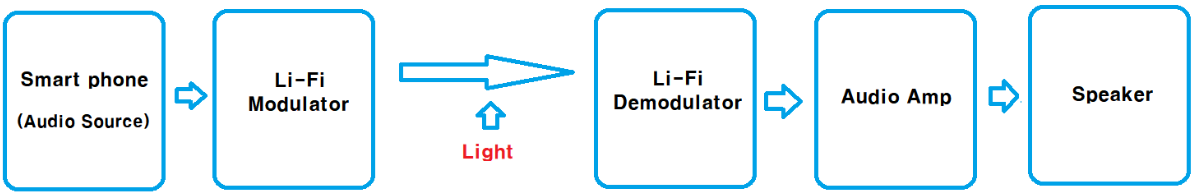

Figure 1. System block diagram

The block diagram of the implemented audio system is shown in Figure 1. The implemented system is largely divided into five parts. It can be divided into an audio signal source, an optical modulator, an optical demodulator, an audio amplifier, and a speaker. The part that transmits light transmits it into the air, creating an environment that does not block optical signals. If optical signals are forcibly blocked, communication is interrupted. Next, each part of this system is explained in detail.

3.2 Smart phone

3.2.1 Samsung Galaxy A24

Figure 2 is a photo of the smartphone used as the audio source in this study, Samsung Electronics' Galaxy A24. The Galaxy A24 is a 2023 target smartphone of the Galaxy A series released by Samsung Electronics in April 2023 and is the successor to the Galaxy A23. The rear design uses a floating camera design. Additionally, the 19.5:9 ratio display allows users to easily understand information. The specifications of the Galaxy A24 model first use MediaTek Helio G99 MT6789 as the AP. It uses the ARM Cortex-A76 quad-core CPU and ARM Cortex-A55 hexa-core CPU, as well as the DynamIQ-type HMP mode-supporting octa-core CPU and ARM Mali-G57 GPU, which apply the big. LITTLE solution. The built-in memory standard uses UFS 2.2, and the built-in memory uses 128 GB. The display supports 2340 × 1080 resolution with a 6.5-inch 19.5:9 ratio, and the panel format is Super AMOLED Infinity-U Display. Compared to Full-HD resolution, which has a 16:9 ratio, the resolution in the vertical part is expanded. The built-in battery capacity is 5,000 mAh. The rear camera is equipped with a 50-megapixel camera as standard. The terminal standard uses USB Type-C as the input/output terminal, and supports up to USB 2.0 as the transmission standard. And a 3.5mm terminal is installed for sound output. The software uses Android version 13.

Figure 2. Samsung Galaxy A24

3.2.2 Li-Fi Modulator

Figure 3. Li-Fi Modulator

Figure 3 is a photo of the optical modulation unit implemented in this study. This is the part that converts the audio signal of the smartphone into an optical signal. The audio signal goes through an electronic circuit and is converted into an optical signal. A white LED is used as a light source, and a resistor to control the current is also inserted into the circuit. The optical modulation unit uses a separate +9V power supply, and DURACELL +9V batteries are used. The batteries used are shown in Figure 4.

Figure 4. 9V DURACELL battery

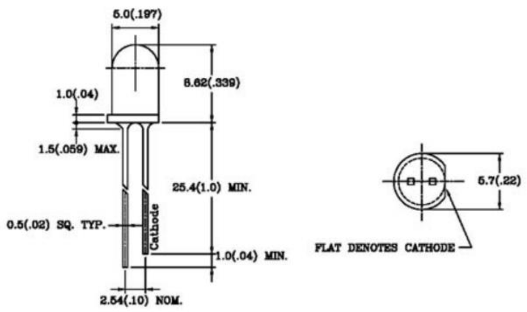

Figure 5. LED ***Figure 6. LED Dimension***

Figure 5 is a photo of the light source LED, a key component of the optical modulation unit. LED is a name derived from the initials of 'Light Emitting Diode', and is a semiconductor that has the property of emitting light when current flows. It can directly convert electrical energy into light energy, so it has excellent energy efficiency, low power consumption, and fast response speed. LEDs are made using semiconductors in a structure called a PN junction. Since the energy of electrons in a PN junction is directly converted into light energy, heat or kinetic energy is basically not required for light emission. Electrons and holes injected from the electrode into the semiconductor flow through different energy bands and then recombine across the electric field barrier near the PN junction. When recombination occurs, significant energy is released from the electric field barrier as photons or light. The size of the LED is as shown in Figure 6. The specifications of the LED are as follows: Luminous intensity (20mA): 40000mcd, Forward voltage (20mA): 3.1V, 50% output angle: 15 degrees

3.2.3 Li-Fi Demodulator

Figure 7. Li-Fi Demodulator, Sensor (Solar Cell, AK 150 X 85)

Figure 7 is a photograph of the optical demodulator implemented in this study. This is the part that accepts the optical signal generated by the optical modulation unit. A solar cell (AK 150 x 85) was used as the sensor. The solar cell used in this study is a solar panel made of polycrystalline silicon and has a size of 150 Multiple units are used for charging using small solar power or in small solar power plants. One module can produce about 150mA, the voltage is 5V, and the maximum output is 1W. Generally, solar cells are used in photovoltaic power plants, but in this study, they were used as optical sensors that receive optical signals and showed excellent performance as a sensor.

3.2.4 Audio Amp and Speaker

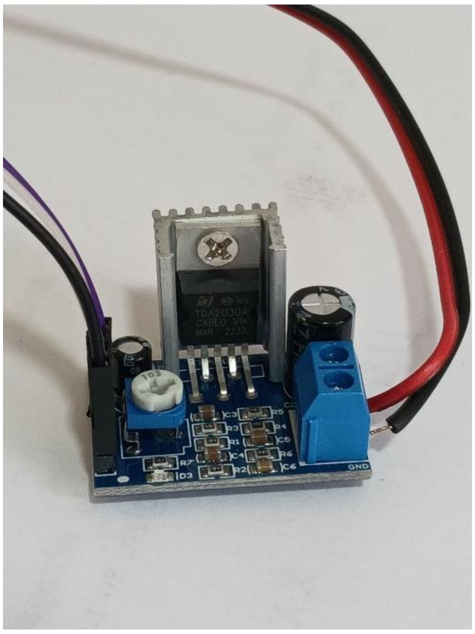

Figure 8. Audio Amp

Figure 8 is a photo of the audio amplifier used in this study. This is the part that converts optical signals into electrical signals and amplifies these signals again. The audio amplifier was constructed using a TDA 2030A type chip. The driving voltage of this amplifier is about 6~12V. It is an 18W monophonic type (with a single audio channel) that provides optimal sound quality and features a practical size and minimum number of components. It is a very economical amplifier. This module is designed to amplify small sound signals from computers, mobile phones, iPods, MP3s, MP4s, tablets, etc. so that they can be heard through large speakers. The output impedance is 4-8 ohm, and there is a variable resistor so the amplification rate can be adjusted. Because it generates heat, an internal heat sink is installed and the size is 3.2cm x 2.7cm x 2.2cm.

3.2.5 Audio Amp and Speaker

Figure 9. Speaker

Figure 9 is a photo showing the speaker, which is the final step in this research system. The speakers used are general-purpose stereo speakers commonly used at home and connected to a computer. The stereo speaker model name is S00179 and the operating voltage is 5V. The output is 2.5W, and the amplification rate can be adjusted using the volume. Through the amplifier built into the speaker, you can once again hear great music through the signal received from the audio amplifier in front of the stage.

4. Proposed Audio System using Li-Fi and Implementation

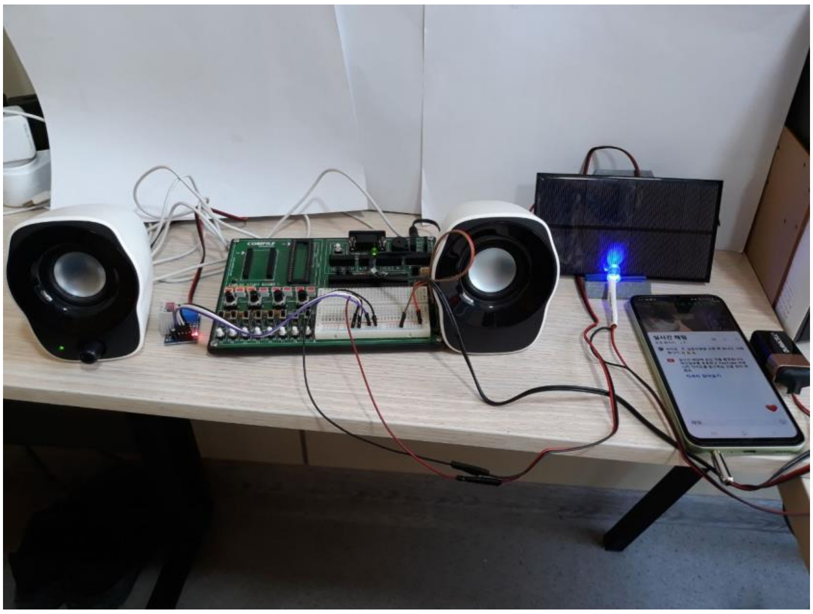

Figure10. Audio system using Li-Fi

Figure 10 is an overall picture of the research system, the Li-Fi audio system. The audio signal output from the smartphone is converted into light through an optical modulator, and this optical signal is converted into an electrical signal by an optical demodulator using solar cells and transmitted to the speaker through an amplifier. The speaker's output varies depending on the distance between the light source, LED, and the light receiving part, the solar cell. When the optical signal is blocked, no sound is heard from the speaker.

As a result of completing and implementing this system, the following results were confirmed.

1) Confirmation of commercialization possibility through actual implementation of Li-Fi using optical signals

2) Check the possibility of using solar cells as light receiving sensors

3) It was confirmed that the signal received by the solar cell is very small, so an amplifier is needed when using it.

4) Since the intensity of light emitted by LED varies depending on distance, it is expected that communication over longer distances will be possible using laser diodes.

5. CONCLUSION

In this study, an audio system was built using LI-Fi technology, which is emerging as a next-generation communication method to replace Wi-Fi. We designed and manufactured optical communication modulators and demodulators ourselves. The light source used was a commonly used LED, and the demodulator used a solar cell. Solar cells are generally used as components that receive and charge solar energy, and in this study, they were used as sensors that receive light sources. As the system grows larger, it will be able to perform two functions simultaneously:

generating solar energy and receiving signals. By completing a system using Li-Fi technology, we were able to confirm the practicality of Li-Fi. When applied to lighting that uses multiple LEDs rather than a single LED, indoor lighting and communication functions can be used together. Additionally, by using laser diodes instead of LEDs, Li-Fi technology can be used over long distances. Compared to Wi-Fi technology, because it uses visible light, there are no country-specific frequency restrictions and it is also advantageous for security. Now that we have completed the first step of utilizing Li-Fi technology, we plan to design optical transmitting and receiving units and proceed with a project that utilizes communication without Wi-Fi.

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