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Li-Fi Based Underwater Audio and Data Transmission System

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Abstract

Visible light communication, or Li-Fi (light fidelity), is a wireless optical networking technique used for communication. Due to radio frequency communication's drawbacks, such as water absorption and scattering, Li-Fi has the potential to completely transform underwater communication. This project suggests utilizing two Arduinos, a solar panel, a speaker, a display, an amplifier, a laser, a battery, and other components to create a Li-Fi-based underwater audio and data transmission system. Using a laser, the transmitter Arduino converts the data and audio inputs into pulses of light. The Arduino receiver receives the light pulses broadcast via the water. The original audio and data signals are recovered from the light pulses by the Arduino receiver. After being amplified, the audio stream is played through the speaker. On the display, the data signal is visible. This article explains Li-Fi, a novel short-range wireless technology that offers connectivity in a confined network setting. With the use of this technology, data may be sent via THz (terahertz) visible light communication, which flashes light at rates that are invisible to human vision.

Keywords: Underwater optical wireless communication, optical wireless communication (OWC), light-emitting diode (LED), optical beam propagation, visible light, radio frequency, acoustic communication, modulation, coding

INTRODUCTION

Using two Arduinos, a solar panel, speaker, display, amplifier, laser, battery, and other components, this project offers an easy-to-use and reasonably priced Li-Fi-based underwater audio and data transfer system. A transmitter and a receiver are the two primary parts of the system. An Arduino is attached to the transmitter, and it uses this connection to encode the data and audio signals before modulating the laser light. An Arduino board is also linked to the receiver; it demodulates the laser light before decoding the data and audio streams. The battery powers the receiver, while the solar panel powers the transmitter [1]. The audio signal is output through the speaker, and the received data is shown on the display. The amplifier amplifies the audio stream. The binary data in on-off keying (OOK) is represented by turning the laser light on and off. The receiver receives the modified laser light after it has passed through the water. Using a photodetector, the receiver demodulates the laser light in order to function. The light signal is transformed into an electrical signal by the photodetector. The Arduino is then used to decode and amplify the electrical signal. Following that, the decoded data signal is shown on the display and the decoded audio signal is sent to the speaker. Users are familiar with Wi-Fi (wireless fidelity), which offers wireless internet access in homes, workplaces, schools, and even public spaces using 2.4 to 5-GHz radio frequency (RF). It is limited, though, as are most technologies. Wi-Fi is capable of covering a whole space, but its speed is limited to 50–100 megabits per second

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(Mbps) [2]. Wi-Fi has a decent speed, but not fast enough to transfer massive files like video games, high-definition (HD) movies, and music libraries. More bandwidth and speed will be required if all of the files—including music, movies, images, and games—are stored on cloud servers or media servers. Wi-Fi and other RF -based technologies are therefore not the best option.

OBJECTIVES

The possibility of Li-Fi for underwater communication is explored in this study. It builds a transmitter and receiver pair utilizing Arduinos and a laser as part of a prototype system to transfer data and sounds. Light signals are captured by a solar panel, and information is painstakingly converted into light pulses and back again by software. The system's functionality is evaluated by sending different kinds of data over a range of water conditions and distances. Finally, a real-world example shows how to communicate with submerged equipment, demonstrating Li-Fi's suitability for underwater communication. This opens the door for creative fixes and developments in this fascinating field of technology.

LITERATURE REVIEW

Four underwater optical wireless communication (UWOC) parameters have been explored from a theoretical and mathematical perspective by Vijayakumari and Sumathi [3]. These are the following: (1) bit error rate (BER), (2) bandwidth, (3) field of view (FOV), and (4) channel capacity of UWOC inter-symbol interference (ISI). The parameters are computed by straightforward, closed-form expression methods, such as Monte Carlo simulations, employing diverse link ranges in distinct water types. This offers a comprehensive and user-friendly method for computing system performance metrics like bandwidth and BER using this signal response model. The advanced modeling function-based equalizer has been implemented in the high-speed UWOC system [3].

For those purposes, Wen et al. [4] have developed a type of high-speed underwater optical communication and networks. The transmitter module and the receiver module are combined to form a half-duplex communication system. The transmitter module transmits messages using low-power blue-green light-emitting diodes (LEDs) that are powered by a MOSFET (metal-oxide-semiconductor field-effect transistor) driver circuit. To receive signals, the receiver module makes use of a photodiode and a signal processing circuit. The experimental results confirmed that the suggested system can travel a distance of 10 m underwater at a maximum speed of 115.2 kbps, offering a new and promising technique for underwater network applications [4].

By using a solar panel as a photodetector, Shinde and Jadhav [5] presented a totally new design paradigm for an optical wireless communications receiver. Their technology allows for both simultaneous energy collecting and data transfer. With a solar panel, an electrical signal that is modulated can be produced without the need for external power. The energy generated by the user can be used by the system or to extend its operating duration [5]. They concentrated on the elements that are thought to be crucial for the system's design that applies solar panels for both energy collection and simultaneous communication. They discussed how orthogonal frequency division multiplexing (OFDM) is actually used in practice. With an optical signal received, the system described can create a communication link with a data rate of 11.84 Mbps.

Png et al. [6] have successfully constructed and tested three versions of audio transmitters and receivers based on visible light communication (VLC) technology. These circuits can be mass produced for use on passenger airplanes due to their simplicity and sparse component count. On headphones, the receiver circuits can be used. LED reading lights above passenger seats can be included into the transmitter circuits. The circuits displayed here exhibit varying performance attributes and audio quality, contingent upon the kind of audio integrated circuits employed [6].

Sui et al. [7] investigated a number of modulation technologies for use in underwater environments. The benefits and drawbacks of different modulation configurations were explored through modeling and simulation. It also showed that phase shift keying (PSK) produces the best results in terms of bandwidth and error performance with low power efficiency, while pulse position modulation (PPM) is more appropriate for low powered underwater systems [7].

Khalighi and Uysal [8] concentrated on near-infrared (near-IR) outdoor terrestrial OWC linkages. In the literature, these are commonly referred to as free space optical (FSO) communication. High-speed communication over long distances—up to several kilometers—is facilitated by FSO systems. FSO lines offer a relatively high accessible optical bandwidth compared to their RF equivalents, which allows for substantially faster data speeds. Applications including fiber back-up, backhaul for wireless technology mobile networks, recovery from disasters, HD TV and healthcare image/video transmission, wireless video surveillance/monitoring, and the distribution of quantum keys are just a few of the many uses for which they are attractive [8].

There is a growing body of literature on Li-Fi based underwater audio transmission. Bao et al. [9] described a Li-Fi based underwater audio transmission system using a high-flickering LED or laser as a source. The system was able to transmit audio signals at a distance of up to 1 m in clear water.

Singh [10] described a Li-Fi-based underwater audio transmission system using a laser diode as a source and a photodiode as a receiver. The system was able to transmit audio signals at up to 5 m in clear water.

METHODOLOGY

The underwater phenomenon caused by the interaction of propagating light beams in ocean water limits optical wireless communication [5]. Oceanography's difficult task of measuring and analyzing the optical characteristics of ocean waters has persisted. Oceanographers have struggled to comprehend ocean optical qualities for possibly two centuries, just as they did with measurements of temperature, salinity, density, and chlorophyll. Numerous physical, biological, and chemical processes have an impact on optical characteristics. These mechanisms may give rise to substantial optical variability sources. The composition of clean water and suspended particles in saltwater are the causes of seawater scattering formation. The general sea depth and temperature have an impact on the scattering from clean water.

SYSTEM DESIGN

A photodetector and a light emitter are located on opposite corners of the system. The photodetector captures binary 1 when the LED is on and binary 0 when it is off. If we flash the LED several times and arrange them in a variety of colors, a message is created and data speeds in the range of 100 Mbps are obtained. When the optical data is received, it is converted into an electrical signal by a photodetector at the receiving end. Following signal conditioning, which entails the amplification, processing, and retrieval of binary data, data is injected into a speech signal.

Transmitter

The Arduino Uno, laser driver, solar panel with amplifier, and power supply block are the main components of the transmitter module. The brains behind the operation are an Arduino board that receives data and audio inputs and uses techniques like pulse width modulation and on-off keying to carefully encode them. This effectively converts light into a data carrier by converting information into changes in the laser's intensity or pulse duration. The laser then faithfully fires these encoded data through the embrace of the water, powered either by an external power source or, in less advanced systems, by harvesting the sun's energy. Sometimes an amplifier provides a hand, enhancing the signal's intensity for a greater range. Transmission flow is presented in Figure 1. The transmitter block's base is made up of this complex interaction between light and electronics that whispers secrets across.

Receiver

In the receiver section, sunlight or an external power source fuels a solar panel, powering the intricate process. The incoming laser beam, now carrying encoded information, dances onto a photodetector, essentially an electronic eye. This detector meticulously translates the light's variations back into electrical signals, mirroring the hidden data. Optical signal receiver flowchart is shown in Figure 2 Like a skilled decoder, another Arduino board equipped with the same modulation schemes used by the transmitter deciphers these signals, extracting the hidden data trapped within the light's subtle changes. Finally, depending on the desired output, the information blossoms into sound through a speaker or visualizes on a display, completing the communication loop and transforming Li-Fi's whispers into meaningful dialogue beneath the waves.

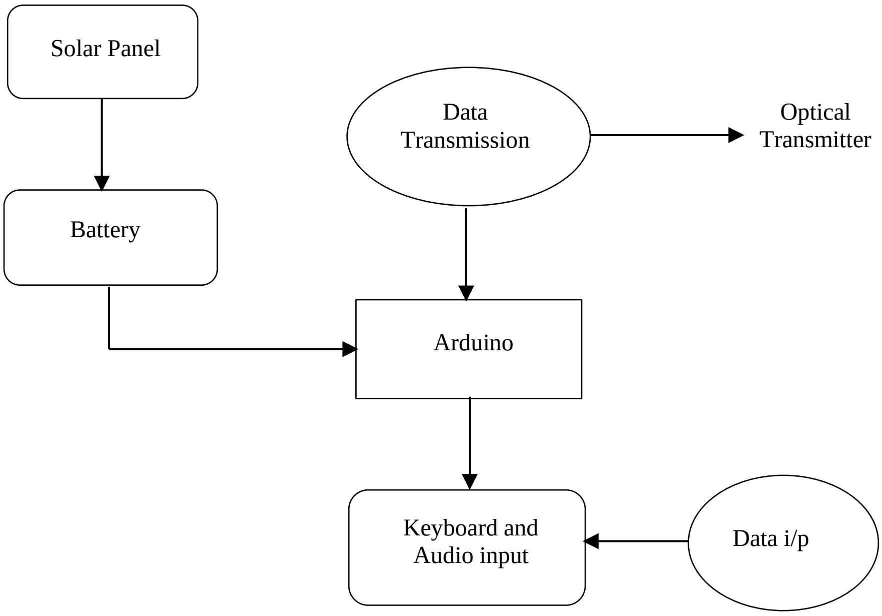

Figure 1. Data transmission algorithm.

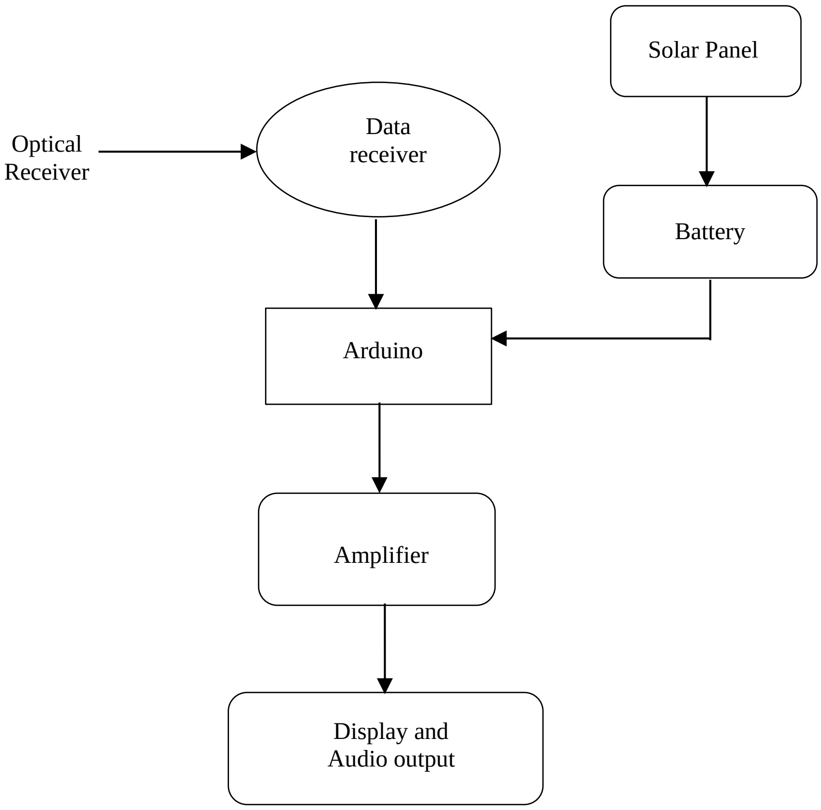

Figure 2. Optical receiver flowchart.

HARDWARE

Arduino uno

Despite lacking an inbuilt solid-state drive (SSD), the Arduino Uno R3, a microcontroller industry mainstay, is a potent tool for electronics control. Rather, its primary concentration is on using its digital and analog pins to interpret and manipulate signals, which makes it an expert at communicating with different electronic components. Its storage capacity is constrained, although it does have a tiny amount of EEPROM (electrically erasable programmable read-only memory) for storing fundamental setup settings or programs. There is no cause for worry if the project requires more extensive data storage! To increase capabilities, a USB drive or external SD card can be attached.

Laser Diode

A diode that emits light when directly pumped with electrical current can produce lasing conditions at the junction of the diode; this type of diode is known as a laser diode. The doped p–n transition, when driven by voltage, permits the recombination of an electron with a hole. Radiation, in the form of an emitted photon, is produced when an electron drops from a higher energy level to a lower one. This is an emission that occurs naturally. When the process is carried out again and produces light with the same phase, coherence, and wavelength, stimulated emission can be created. The wavelength of the output beam in modern laser diodes ranges from the infrared to the ultraviolet (UV) spectrum, depending on the semiconductor material selected.

Liquid Crystal Display

An electronically modified optical device that uses polarizers and liquid crystals' light-modulating capabilities is called a liquid crystal display (LCD). Instead of emitting light directly, liquid crystals [3] create color or monochrome pictures by reflecting light off of a backlight. LCDs can show fixed images with little information that can be shown or hidden, or they can display random images, like those used in general-purpose computer displays. Examples of devices with these types of displays include digital clocks, preset words, and digit displays. While other displays have larger parts, arbitrary images are created from a matrix of small pixels using the same basic technology. LCDs can be turned off (negative) or normally on (positive).

Algorithms

Modulation

The laser intensity can be adjusted using the OOK modulation system. Using the OOK system, turning on the laser corresponds to a binary "1" and turning it off to a binary "0".

Demodulation

The laser intensity can be modulated using the OOK demodulation algorithm. The photodetector output is sampled quickly and compared to a threshold voltage in OOK demodulation. A binary "1" is decoded if the photodetector output is higher than the threshold voltage. A binary "0" is decoded if the photodetector output is below the threshold voltage.

Error Correction

The forward error correction (FEC) technique can be employed to increase the transmission's dependability. The transmitted data is enhanced by FEC techniques with redundant bits. Algorithms involved in the process of the system flow is shown in Figure 3.

FUTURE SCOPE

There are several potential underwater applications for this device, including submarines, divers, and other underwater vehicles using underwater communication.

The following areas could be the focus of future study to enhance the system's performance and reliability: creating Li-Fi transmitter and receiver modules with increased efficiency, creating methods to lessen the impact that water attenuation has on the Li-Fi signal [2], creating methods to account for the transmitter's and receiver's movements. The system might also be expanded to accommodate high-speed data and video transmission, among other kinds of data.

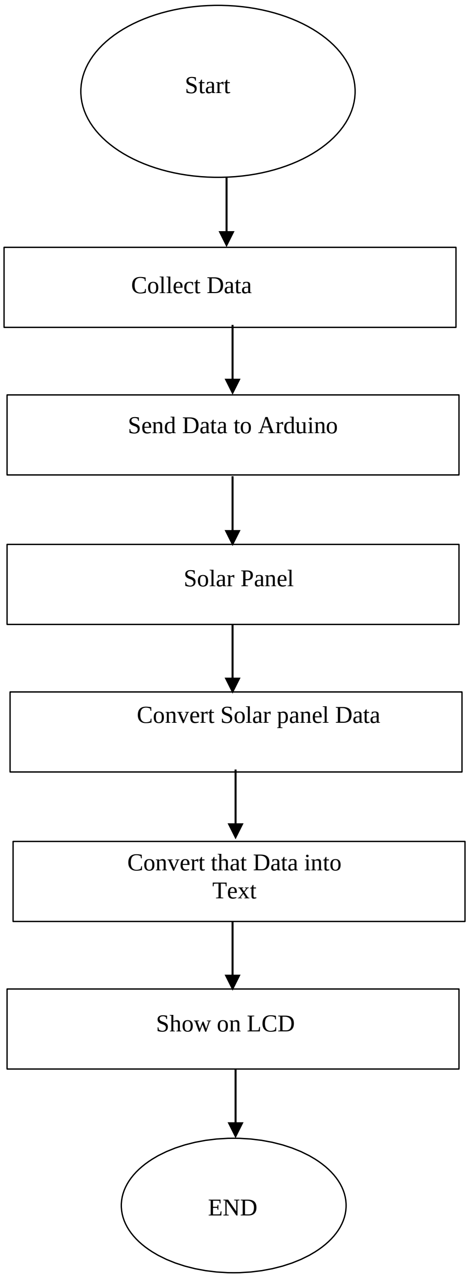

Figure 3. System working steps.

CONCLUSION

Underwater communication could be completely transformed by the proposed Li-Fi-based underwater audio and data transmission system, which is a very promising new technology. The system is perfect for a variety of applications since it is secure, fast, and self-sufficient.

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We are extremely modest in our expression of thanks. To sum up the priceless assistance and encouragement we received from several people, in a few sentences would be unfair. However, words are the only means by which one can communicate their emotions, and our thankfulness goes well beyond words. We would be proud to use this chance to express our gratitude. First of all, we would like to express our gratitude to our dear mentor Prof. S.B. Pawar for her invaluable advice, tolerance, and encouragement. She was constantly there to push us a little bit further so that we could finish the task correctly and on schedule. She has always allowed us to work independently on projects and with her supervision. We also want to thank Prof. C. R. Kuwar from the bottom of our hearts.

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