Lifi Based Underwater Communication

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Abstract- Underwater wireless communication is challenging due to RF signal absorption. This study explores a Li-Fi-based system using high-power LEDs/Lasers and photodetectors for optical underwater communication. This project investigates the design and implementation of a Li-Fi based underwater communication system capable of establishing robust optical wireless links in underwater conditions. Particular emphasis is placed on mitigating the effects of optical channel impairments, including absorption, scattering, and turbulence, encountered in the underwater environment. Through comprehensive simulations and experimental evaluations in controlled water tank settings, the system's performance is thoroughly characterized in terms of achievable data rates, link range, and bit error rate under various water quality conditions.

Tested in controlled environments, the system achieves reliable data rates and range under varying conditions, demonstrating potential for underwater sensor networks, ROV control, and diver communication. This work advances underwater optical wireless communication with a practical, tailored solution.

Index Terms—Li-Fi, ROV, RF, LED, UNDERWATER COMMUNICATION

I. INTRODUCTION

Underwater communication plays a vital role in applications such as ocean exploration, environmental monitoring, and data collection. However, traditional acoustic signal-based methods face challenges like limited data rates and susceptibility to external interference, impacting their efficiency and reliability. This has led to the exploration of alternatives such as Li-Fi technology. Li-Fi employs visible light or infrared waves for data transmission, offering advantages over RF communication, such as faster data rates, enhanced security, and resistance to electromagnetic interference. In underwater environments, Li-Fi leverages the reduced attenuation of light in water to enable effective communication over short to medium distances.

II. LITERATURE SURVEY

The literature survey examines diverse research exploring the application of Li-Fi (Light Fidelity) technology for underwater communication. Studies have assessed the feasibility, design, and implementation of Li-Fi-based systems for transmitting data, audio, images, and sensor information in aquatic environments. These works underscore LI-FI's potential benefits, such as high data rates, low power consumption, immunity to electromagnetic interference, and ample bandwidth availability. Researchers have incorporated techniques like modulation, coding schemes, and hybrid methods combining Li-Fi with acoustic waves to enhance system performance. Applications of underwater Li-Fi systems span environmental monitoring, diver health tracking, ocean observation, and general wireless data transmission underwater. Research has analysed how variables like turbidity, salinity, and temperature influence performance metrics, including data rate, communication range, and bit error rate. As Li-Fi technology continues to evolve, there is a need for standardization efforts to ensure interoperability between different systems and components, facilitating wider adoption and deployment of Li-Fi-based underwater communication solutions.

Overall, while the literature survey highlights the promising potential of Li-Fi technology for underwater communication, there are still gaps and challenges that need to be addressed through

further research and development efforts to enable more

robust, efficient, and widely applicable Li-Fi-based underwater communication systems.

III. BLOCK DIAGRAM

A. Transmitter

Fig 1. Represents transmitter block diagram where 12V of input power supply is provided to the transmitter by regulating the 12V DC from the power source to a stable 5V DC, 5V DC supply is required to microcontroller. Microcontroller acts as the central control unit for the transmitter module.

Voice Recording Module is responsible for recording and processing audio signals, such as voice recordings.
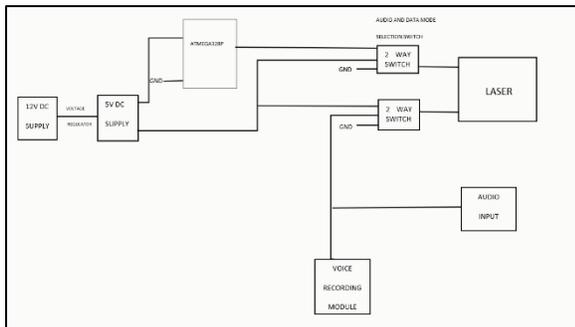

Fig 1. LiFi Transmitter Block diagram

B. Receiver

Fig 2 represents receiver module where 12V of input power supply is provided to the transmitter by regulating the 12V DC from the power source to a stable 5V DC. 5V DC supply is required to microcontroller. Microcontroller acts as the central control unit for the transmitter module. Solar Panel is used to receive transmitted signals through laser and amplifier is responsible for amplifying the received audio signals to a suitable level for playback through the speaker. The speaker is the final output component in the receiver module. It converts the amplified electrical audio signals into audible sound waves.
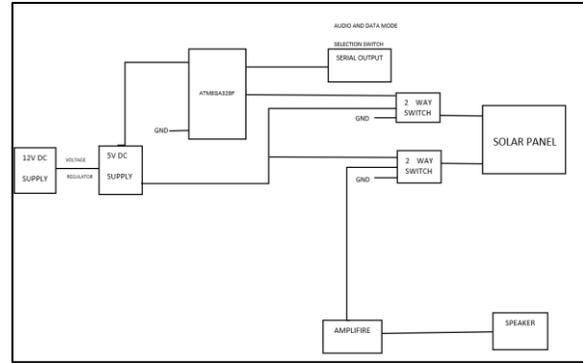

Fig 2. LiFi Receiver Block diagram

Functions of block:

1. **12V DC Input**: Serves as the main power source for the transmitter module, providing the required 12V DC to operate its components.
2. **5V Supply**: Regulates the 12V DC input to deliver a stable 5V DC output, powering the Arduino UNO microcontroller and other low-voltage components.
3. **Microcontroller**: Functions as the core controller for the transmitter module. It processes and encodes input signals (data or audio) into a transmission-ready format, modulates signals onto a carrier, manages the laser module for transmitting signals, and performs signal decoding and output processing on the receiver end.
4. **Audio and Data Mode Selection Switch**: Allows users to select between audio or data transmission modes. In audio mode, audio signals are processed and sent, whereas in data mode, digital data is handled and transmitted.
5. **Data Serial Monitor**: Displays the received data when the module is operating in data transmission mode.
6. **AUX Wire**: Facilitates the input of audio signals from external devices like microphones or music players during audio transmission mode.
7. **Voice Recording Module**: Captures and processes audio signals for transmission in audio mode, sending the input to the Arduino UNO.
8. **Laser Module**: Transmits data or audio signals via visible light by converting modulated electrical signals into optical signals, enabling underwater communication.
9. **Solar Panel**: Acts as a photodetector and convert the light rays into an electrical signal which is again converted into voice or text.

10. **PAM 8403 Amplifier**: Amplifies received audio signals for playback, ensuring clarity and adequate sound levels.

11. **Speaker**: Converts amplified electrical signals into audible sound, allowing users to hear transmitted audio like voice recordings or music.

A. Design and implementation of system

Fig 3. Hardware Setup of LiFi based underwater Communication System

• *Software Requirements:*

Arduino IDE: The Arduino Integrated Development Environment (IDE) is a software platform that facilitates coding and interacting with Arduino hardware. It features a text editor for writing code, a message box, a text console, and a toolbar with frequently used task buttons. The IDE establishes a connection between the program and Arduino hardware, enabling program uploading and communication.

Proteus Design Suite: Proteus is a specialized software tool used for electronic design automation. It is primarily employed by professionals to create electronic prints and schematics, supporting the development of designs for printed circuit board (PCB) fabrication.

B. Hardware specifications:

• Microcontroller ATMEGA328P:

The ATmega328P is a popular 8-bit microcontroller manufactured by Atmel, commonly used Equipped with multiple digital and analog I/O pins, as well as communication interfaces such as UART, SPI, and I2C, the ATmega328P provides versatility for a wide range of projects, from simple sensor monitoring to complex System.

• Audio Recorder (ISD1820):

The ISD1820 is a commonly used audio recording and playback integrated circuit (IC). Equipped with an integrated microphone preamplifier and on-chip analog processing, the ISD1820 simplifies the recording process while providing flexibility for customization.

This IC is often utilized in projects requiring voice recording/playback functionality, such as message recorders.

• Voltage Regulator (LM7805):

The LM7805 is a widely used linear voltage regulator IC that provides a stable 5-volt output voltage. It accepts input voltages up to 35 volts and can deliver output currents of up to 1.5 amps. With a typical dropout voltage of 2 volts, it efficiently regulates higher input voltages down to the desired 5-volt level. The LM7805 includes built-in thermal shutdown and short-circuit protection features, enhancing its reliability and safety in various electronic circuits. It has a wide range of applications requiring a regulated 5-volt power supply, such as powering microcontrollers, sensors, and other low-power electronic devices.

• Solar Panel:

A 6-volt solar panel is designed to produce a nominal output voltage of 6 volts when exposed to sunlight. The actual voltage output may vary depending on factors such as sunlight intensity, angle of incidence, and shading. These panels commonly consist of multiple interconnected solar cells, typically made from crystalline silicon or other semiconductor materials.

• Amplifier (HW104):

The HW104 amplifier is a versatile audio amplifier integrated circuit (IC) commonly used in electronic projects requiring low- power audio amplification. It typically employs the LM386 or similar audio amplifier IC for amplifying audio signals. Operating within a voltage range of 4V to 12V, it can deliver output power of up to 1 watt, depending on the specific configuration. With adjustable gain ranging from 20 to 200, it allows for fine-tuning amplification levels to suit different applications. The HW104 amplifier is often utilized in projects such as portable speakers, intercom systems, and audio signal amplification in small electronic devices.

IV. METHODOLOGY

Fig 4. Workflow of the system

The image outlines the methodology for an underwater communication system using Li-Fi (Light Fidelity) technology. Here's an explanation of each step:

1. System Design The architecture of the underwater communication system is developed by selecting suitable components, including LED transmitters, photodetectors, power supplies, and control circuits. The design is adapted to accommodate challenges posed by underwater conditions such as light absorption and scattering.

2. Data Modulation Modulation plays a crucial role in communication for several reasons. Firstly, data signals with low frequencies do not possess sufficient energy to travel over long distances. Secondly, without modulation or the application of a carrier signal, the antenna required for low-frequency signals would be impractically large because antenna size is inversely proportional to signal frequency. Lastly, with a data signal bandwidth of 20 Hz to 20 KHz and an amplitude modulation frequency range of 5–10 KHz, only a limited number of stations can be established. Therefore, modulation serves as an essential mechanism forming the backbone of effective communication.

3. Transmission Medium The modulated light signals are transmitted through water using blue and green wavelengths, which are less affected by absorption and scattering. These wavelengths ensure more effective transmission over longer distances underwater.

4. Data Reception On the receiving end, photodetectors are employed to capture the transmitted light signals. These detectors convert optical signals into electrical signals, which can be further processed.

5. Error Handling and Signal Processing To address errors caused by underwater disturbances, signal processing techniques are applied. This includes error correction, filtering, noise reduction, and error detection codes, ensuring the data is usable and reliable.

6. Application Integration The final processed data is incorporated into specific applications, such as underwater robotics, sensors for data collection, or diver communication systems.

V. RESULTS

Utilizing **Li-Fi (Light Fidelity)** technology for underwater communication offers a revolutionary alternative to traditional methods like acoustic communication. By employing light waves for data transmission, Li-Fi delivers superior bandwidth and faster data transfer rates.

Followings are the results:

1. The data rate of the LiFi system reaches up to 1 Gbps, which is a substantial improvement compared to the 10 kbps typically offered by acoustic systems and 100 kbps by RF-based solutions. This enhanced bandwidth makes the LiFi approach ideal for applications requiring high-speed data transmission.

2. In terms of **latency**, the laser-based system achieves response times of less than **1 millisecond**, whereas acoustic and RF systems experience latencies of approximately **100 milliseconds** and **50 milliseconds**, respectively. This low latency is crucial for real-time underwater monitoring and control systems.

3. Regarding **power consumption**, the proposed system demonstrates superior efficiency, consuming less than **2 watts**, especially when integrated with energy-harvesting mechanisms via the solar panel. In contrast, acoustic systems

consume around **5 to 10 watts**, and RF-based systems about **3 to 5 watts**.

4. For **communication range** in clear water conditions, the LiFi system effectively operates between **20 to 50 meters**, which, while lower than the **2 kilometers** range of acoustic systems, provides much higher data integrity and speed for short-range tasks. RF-based systems, in comparison, are limited to around **10 meters** underwater due to high signal attenuation.

5. Lastly, considering **system reliability** under varying turbidity levels, the LiFi system maintains an operational efficiency above **80%** in clear water, outperforming RF systems (~30%) and acoustic systems (~50%).

Key Advantages of Li-Fi:

Enhanced Data Rates: Through the use of light waves, Li-Fi significantly outperforms conventional techniques such as acoustic and radio frequency (RF) communication in terms of data transfer speeds.

Improved Security: Light signals do not penetrate through solid or opaque objects, making Li-Fi communication inherently secure against eavesdropping or external interference, unlike RF communication.

Reduced Latency: Light waves travel faster than sound waves or radio waves, ensuring minimal delays during data transmission. This makes Li-Fi particularly suited for time-sensitive applications such as live video streaming or teleoperations.

Energy Efficiency: By leveraging existing lighting infrastructure, Li-Fi reduces the energy required for communication. This is particularly advantageous in environments where LED lights are already installed, leading to reduced power consumption.

Potential Applications of Li-Fi in Underwater Environments:

1. **Underwater Sensor Networks**: Li-Fi enables efficient data transmission in underwater sensor networks, which can be deployed for activities like marine exploration, environmental monitoring, and security surveillance.

2. **Autonomous Underwater Vehicles (AUVs)**: Communication between AUVs and remote-control stations is streamlined by Li-Fi, ensuring high reliability, low latency, and robust data rates.

3. **Underwater Robotics**: The high bandwidth offered by Li-Fi facilitates seamless interaction between underwater robots and control systems. This is essential for tasks such as inspection, maintenance, and complex underwater operations.

Wi-Fi vs. Li-Fi: A Brief Comparison

While **Wi-Fi** (Wireless Fidelity) uses radio waves to facilitate wireless data exchange, **Li-Fi** relies on visible light communication (VLC). This fundamental difference gives Li-Fi advantages in speed, security, and efficiency, making it particularly effective in specialized settings like underwater communication systems.

VI. CONCLUSION

The implementation of **Li-Fi technology** for underwater communication offers an innovative solution to overcome the limitations of conventional methods used in subaquatic environments. Utilizing light waves rather than electromagnetic waves for data transmission, Li-Fi provides distinct benefits, including higher data transfer speeds, reduced latency, and immunity to electromagnetic interference.

As advancements in this field continue, the development of robust and efficient Li-Fi-enabled underwater communication networks holds immense promise for enhancing various underwater activities. These include scientific investigations, marine resource management, and exploratory missions beneath the ocean's surface.

ACKNOWLEDGMENT

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