International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 03 | March - 2024 SJIF Rating: 8.176 ISSN: 2582-3930

Underwater Audio and Data Transmission System using Li-Fi Technology

Apoorva N*[1], Pragati R.M[2], Impana B[3], Anusha Kumari[4], Siddalingappagouda Biradar[5]
[1,2,3,4] Under Graduate Student, Department of Electronics and Communication, Dayananda Sagar Academy of Technology and Management, Bangalore, Karnataka, India
[5]Associate Professor, Department of Electronics and Communication, Dayananda Sagar Academy of Technology and Management, Bangalore, Karnataka, India
*Corresponding Author: Apoorva.aug@gmail.com

Abstract

Underwater communication system utilizing Li-Fi (Light Fidelity) technology for transmitting audio and data. The system addresses limitations of traditional methods by leveraging an Arduino Uno microcontroller for control, lasers for data transmission, and solar panels for reception. To enhance received audio signals, an amplifier circuit is employed before feeding them into a speaker for playback. Data is recovered and processed on the receiving end using the Arduino Uno. This research explores the feasibility of Li-Fi for underwater applications. The paper details the design and development of the communication system, including hardware components like lasers, solar panels, amplifier circuits, and speakers, along with the software implemented on the Arduino Uno. The results focus on the successful transmission and reception of both audio (heard through the speaker) and text data processed by the Arduino Uno. This work paves the way for further development of Li-Fi based underwater communication solutions for various applications.

Keywords- Underwater Communication, Li-Fi (Light Fidelity), Arduino Uno, Laser Diode, Solar Panel, Audio Transmission, Data Transmission, Amplifier Circuit, Speaker

I.INTRODUCTION

Underwater communication underpins various endeavors, from oceanographic research and resource exploration to underwater robotics and autonomous vehicles. Traditional methods using radio frequency (RF) waves and acoustic signals encounter significant limitations underwater. RF waves suffer from high attenuation and multipath propagation, limiting their range and reliability. Acoustic communication, while functional, is plagued by low data rates and vulnerability to background noise.

These limitations hinder our ability to effectively collect data, transmit commands, and establish real-time communication underwater. To address these challenges, researchers are exploring alternative technologies like Li-Fi (Light Fidelity). Li-Fi leverages light waves for data transmission, offering several advantages over traditional methods. Light experiences lower attenuation in water compared to RF waves, especially at specific wavelengths. Additionally, Li-Fi boasts higher data rates and inherent security due to the limited range of light underwater.

Over the past decade, significant advancements have been made in visible light communication (VLC) and Li-Fi systems, primarily utilizing light-emitting diodes (LEDs) as the light source. These systems have found applications in various environments like indoor data transmission and vehicle communication.

This underwater communication system utilizes an array of modulated lasers, a variant of VLC technology. Lasers offer several advantages over LEDs for underwater Li-Fi, including superior directionality, greater range, and higher bandwidth. We delve into the design and development of this system, focusing on the transmission of digital audio and data through the laser-based underwater Li-Fi channel and its reception and processing on the receiving end. This research paves the way for the exploration and advancement of Li-Fi based communication solutions using lasers for diverse underwater-applications.

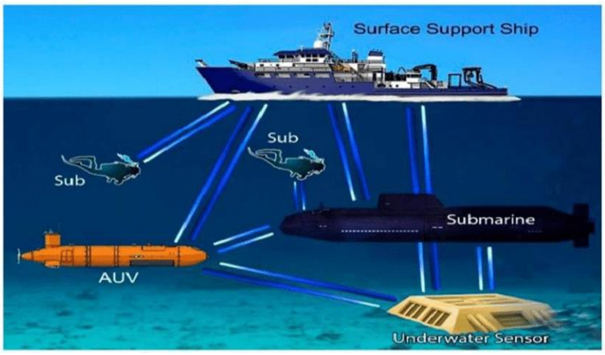

Fig.1: Li-Fi technology in underwater

II. OVERVIEW OF LI-FI TECHNOLOGY

Li-Fi (Light Fidelity) is a bidirectional, high-speed and fully networked wireless communication technology that utilizes light, similar to how Wi-Fi uses radio frequency. Visible light communication (VLC) is a data transmission variant employing visible light between 400 and 800 THz. Li-Fi technology was introduced by Harald Haas of the University of Edinburgh in 2011, demonstrating super-fast and secure wireless communication using standard, commercially available lasers. Since then, significant progress has been made, solidifying Li-Fi as a viable and efficient technology for data communication.

While Li-Fi is becoming a leading force in visible light communication, it traditionally uses light-emitting diodes (LEDs) for both illumination and data transmission. However, this paragraph proposes a variant using lasers instead. Lasers offer several advantages over LEDs for Li-Fi applications, including superior directionality, greater range, and the ability to achieve higher data rates. Here, the lasers would generate short, modulated light pulses at extremely high speeds. Photodetectors on the receiving end can detect these rapid variations in light intensity, converting the digital data back into a usable form.
Similar to LEDs, lasers offer key advantages like not interfering with radio frequencies, making them suitable for areas like hospitals and aircrafts where radio waves can disrupt sensitive equipment. Li-Fi's inherent security due to its limited range through walls and its resistance to congestion (allowing multiple users to share bandwidth) remain valid with lasers. As laser light offers superior speed and penetration compared to radio waves, it presents a compelling alternative for data communication technologies. Research in optical wireless communication is ongoing, and recent studies suggest that the usable spectrum for laser-based Li-Fi is significantly larger than the entire radio frequency spectrum. In the context of the upcoming fifth generation (5G) mobile network, Li-Fi with lasers could not only facilitate the transmission of larger amounts of data but also alleviate the pressure on the increasingly congested radio frequency spectrum.

III.CHALLENGES IN UNDERWATER COMMUNICATION

Underwater communication faces a multitude of challenges: radio waves suffer from high attenuation and multipath propagation, sound can be absorbed and distorted by water properties and background noise, bandwidth is limited compared to land, some methods require significant power, and security can be compromised. These limitations necessitate innovative solutions, and Li-Fi technology offers promise for overcoming some of these hurdles, particularly in terms of data rate and inherent security.

IV.LITERATURE SURVEY

In [1] Sivasakthi T describes the use of Visible Light Communication (VLC), which is like Wi-Fi but instead of using radio waves, they use light from LEDs. This method, known as Li-Fi, is faster and safer for underwater communication. The authors explain that radio waves, like the ones Wi-Fi uses, don't work well underwater and can harm sea creatures. Li-Fi, on the other hand, uses visible light for communication, making it more suitable for underwater tasks such as guiding divers, preventing accidents, and sending various types of data like audio, text, images, and videos. The paper also mentions that Li-Fi was invented by a smart person named Harald Haas, and it works by sending light signals from LED lights to a special detector. This technology is considered a better option for underwater communication compared to traditional methods because it's faster, more reliable, and doesn't harm marine life. In simple terms, the authors highlight that Li-Fi, using light to transmit data underwater, is a clever and efficient way to communicate in the ocean, ensuring accurate information transfer and safe underwater exploration. [2] the paper underscores the crucial role of communication in the well-being and survival of organisms, emphasizing its significance as a fundamental aspect of understanding. The evolution of communication methods from traditional Electromagnetic (EM) waves to more efficient alternatives is highlighted. In this context, the research focuses on data transmission, with particular attention to Li-Fi (Light Fidelity), an emerging technology that has garnered attention over the past decade. Unlike conventional Wi-Fi, Li-Fi enables data transmission without relying on the internet and offers wireless connectivity. However, the existing underwater communication systems utilizing Li-Fi involve high complexity circuits, presenting challenges in terms of cost-effectiveness and practical implementation. Therefore, the paper aims to address this issue by proposing an experimental model that not only enhances data transmission but also reduces the cost and complexity associated with the setup. [3] the author addresses the ongoing need for more efficient techniques in underwater communication to minimize energy consumption, transmission losses, and enhance communication speed. It introduces a simple yet high-speed communication system for underwater applications, employing Visible Light Communication (VLC), commonly known as Light Fidelity (Li-Fi). The inspiration for implementing Li-Fi in underwater wireless communication is drawn from the innovative work of Dr. Harald Haas of Germany, who initially introduced this concept to improve data transfer and information security in air applications.

The primary focus of the author is on presenting the fundamental design of a Li-Fi underwater communication system, emphasizing novel concepts aimed at reducing overall power consumption. The incorporation of Li-Fi technology in underwater communication holds the promise of addressing energy efficiency concerns and increasing data transfer rates.

The paper highlights key components such as LED (Light Emitting Diode), Frequency Modulation, Pulse Width Modulation, and Signal Recovery, which collectively contribute to the efficient functioning of the Li-Fi underwater communication system. The choice of these components is strategic, aiming to optimize communication performance while minimizing power consumption. Furthermore, the paper includes simulation results and a comparative study to provide valuable insights into the performance of this new technology. Through these analyses, the authors offer a comprehensive understanding of how Li-Fi can be applied in the underwater domain, showcasing its potential benefits in terms of energy efficiency and high-speed communication. In essence, this paper contributes to the exploration of techniques for efficient underwater communication by introducing and detailing the design of a Li-Fi-based system. [4] and [5] the paper addresses the critical need for efficient underwater wireless communication in various applications, spanning from remote control in the off-shore oil industry to pollution monitoring in environmental systems, scientific data collection at ocean-bottom stations, speech transmission between divers, and mapping the ocean floor for object detection and resource discovery. Traditionally, these applications relied on military-exclusive technologies, but the field is rapidly expanding into commercial domains. The authors propose leveraging Li-Fi technology to establish wireless underwater communications. Li-Fi, or Light Fidelity, is recognized for its potential to transmit data using light signals. This technology becomes particularly advantageous in underwater scenarios due to its ability to transmit signals over long distances without obstruction in water. The high speed of light allows for increased data rates, making Li-Fi a promising solution for underwater data communication. The adoption of Li-Fi technology in underwater communication has transformative implications. It enables the establishment of wireless connections, eliminating the need for physical tethers. This highlights Li-Fi's potential to revolutionize underwater communication by providing a means to transmit signals effectively, overcoming the challenges posed by the underwater environment. The challenges of data transmission in underwater environments, where traditional wired networks pose installation and maintenance difficulties are addressed in [6] and [7]. They advocate for the application of LI-FI technology, a wireless communication solution, in various applications like underwater communication and environmental monitoring.

[8] the author explores the potential of water electronic communication for underwater communication, acknowledging the challenges of transitioning from laboratory experiments to real water environments due to limited physical scale. The authors evaluate various agents to modify experimental water coefficients and establish criteria for assessing water communication reliability. The frequency domain characteristics of data communication through the water channel are measured and compared, revealing significant influences from agent type, particle size, and concentration on water properties. Shifting focus to underwater health monitoring during diving, the paper introduces a system utilizing Li-Fi (Light Fidelity) to transfer data related to divers' health specifications, such as heartbeat, temperature, and lung expansion. The health data is recorded in a chip for analysis, and to optimize power consumption, the system transmits information to nearby divers only during abnormal health conditions. The proposed system is designed for use at depths of up to 135 meters in the ocean, enabling data transfer to 4-5 receivers simultaneously. Overall, the research emphasizes the potential of water electronic communication and Li-Fi for enhancing underwater communication and addressing health monitoring challenges during diving.

In [9] This paper explores the integration of smart sensor technology and wireless communications to advance applications such as environmental monitoring in challenging terrains, diverse oceanographic data collection, and underwater search and rescue missions. The focus lies on the emerging field of underwater communication, emphasizing the ongoing development efforts to achieve low power consumption, compact size, and extended range. Optical waves are identified as a promising approach for secure and high-speed underwater communication.

The paper details the implementation of a Li-Fi-based module designed for underwater communication. The system operates on the transmission principle through an LED array and utilizes a solar panel for reception. Experimental observations delve into the analysis of the distance versus power relationship for transferring textual data. results indicate that the data transfer method, employing Li-Fi technology, is applicable and effective for underwater communication. Overall, the research contributes to the advancement of underwater communication systems by leveraging smart sensor integration and optical wave technology to address the challenges of power consumption, size, and communication range.

In [10] V. Muralidharan addresses the challenges of underwater communication faced by divers, who traditionally rely on white boards for communication.

The author introduces an innovative solution, Li-Fi technology, proposed by German physicist Harald Haas. Light Fidelity (Li-Fi) is described as a bidirectional, high-speed, and fully networked wireless optical communication technology.

The paper emphasizes Li-Fi's ability to overcome obstacles underwater by widening the light angle, enabling reflection or refraction even when obstructed by floating objects. This characteristic enhances its reach to the receiver, and the technology remains effective even as light sways with the current. The paper highlights the versatility of Li-Fi, noting its applications beyond underwater communication, including its use by the Navy to enhance submarine communication systems.

The author suggests that Li-Fi's potential applications extend beyond underwater scenarios to areas such as aviation and chemical plants. Overall, the research underscores the transformative capabilities of Li-Fi technology, not only in addressing the specific challenges of underwater communication but also in contributing to broader applications across various domains.

V.CONCEPTUAL FRAMEWORK

As seen in Fig.2, conceptual framework delves deeper into the components and functionalities of an underwater audio and data transmission system utilizing Li-Fi technology. Developing a practical underwater Li-Fi system requires a well-defined conceptual framework. This framework serves as a blueprint, outlining the system's core functionalities, interactions between components, and potential challenges. It facilitates:

A. Data and Audio Source: The source of the data and audio signals can vary depending on the application. It could be a submersible equipped with various sensors generating environmental data streams. Alternatively, it could be a diver's communication device transmitting voice or video data. The framework should consider the specific data formats (e.g., sensor data streams, audio/video) and their potential impact on processing requirements within the data processing unit (DPU).

B. Data Processing Unit (DPU): With appropriate programming, the Arduino Uno can handle some basic DSP tasks like analog-to-digital conversion (ADC). It can also perform simple filtering and signal conditioning. Here Orthogonal Frequency Division Multiplexing is carried out for DSP. FFT (Fast Fourier Transform) is applied for modulation and demodulation in the OFDM scheme. The digital audio signal is segmented into multiple subcarriers using OFDM. Each subcarrier is associated with a specific frequency range. Depending on the underwater channel conditions, the modulation scheme for each subcarrier may be dynamically adjusted to optimize performance.

C. Modulation Circuit: In the Li-Fi context, a longer duration of light represents one binary state (e.g., '1'), and a shorter duration represents the other binary state (e.g., '0'). The modulation is achieved by adjusting the time the light source is in the "on" state versus the "off" state. The modulated light signal, with varying pulse widths corresponding to the digital data, is transmitted through the underwater medium. The modulation pattern carries the encoded information.

D. Underwater Li-Fi Channel: This channel presents a challenging environment for light propagation due to water absorption and scattering. The framework should consider: Water-Properties: Wavelength-dependent absorption and scattering by water molecules and suspended particles will affect the transmitted signal. Operating at appropriate wavelengths can mitigate these effects. Background Light Noise: Ambient light from natural sources or bioluminescence can introduce noise that interferes with the transmitted signal.

E. Underwater Li-Fi Receiver: Solar panel captures the modulated light signal transmitted underwater. The photodetector converts the modulated light signal into an electrical current. The intensity and variations in this current reflect the encoded data. For example, in OOK modulation, high and low light intensities correspond to binary 1s and 0s, respectively. The subsequent stages of the receiver system will then process and decode this electrical signal to recover the original data transmitted.

F. Demodulation: Demodulation circuitry, comprising comparators, filters, and amplifiers, diligently compares the incoming signal to a threshold, revealing the binary data (0s and 1s. The received light signal undergoes pulse width detection. This process involves measuring the duration of light pulses and the intervals between them. A threshold is set to distinguish between different pulse widths. The receiver identifies the transitions between "on" and "off" states in the received light signal. Based on the measured pulse widths and the established threshold, the receiver extracts the digital information encoded in the light signal. Longer pulses may represent one binary state ('1'), and shorter pulses represent the other binary state ('0').

G. Signal Processing: Improves signal quality and prepares it for decoding. Within the underwater Li-Fi receiver system, the signal processing stage acts as a meticulous alchemist, transforming the raw, potentially muddled signal into a pristine format ready for decoding. Fast Fourier Transform (FFT) is applied to demodulate the OFDM subcarriers and reconstruct the digital audio data and text data.

H. User Interface/Data Storage: The user interface allows for interaction with the received data, such as visualizing sensor data streams, controlling underwater equipment, or listening to transmitted audio. Alternatively, the data might be stored for post-mission analysis or archival purposes.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 03 | March - 2024 SJIF Rating: 8.176 ISSN: 2582-3930

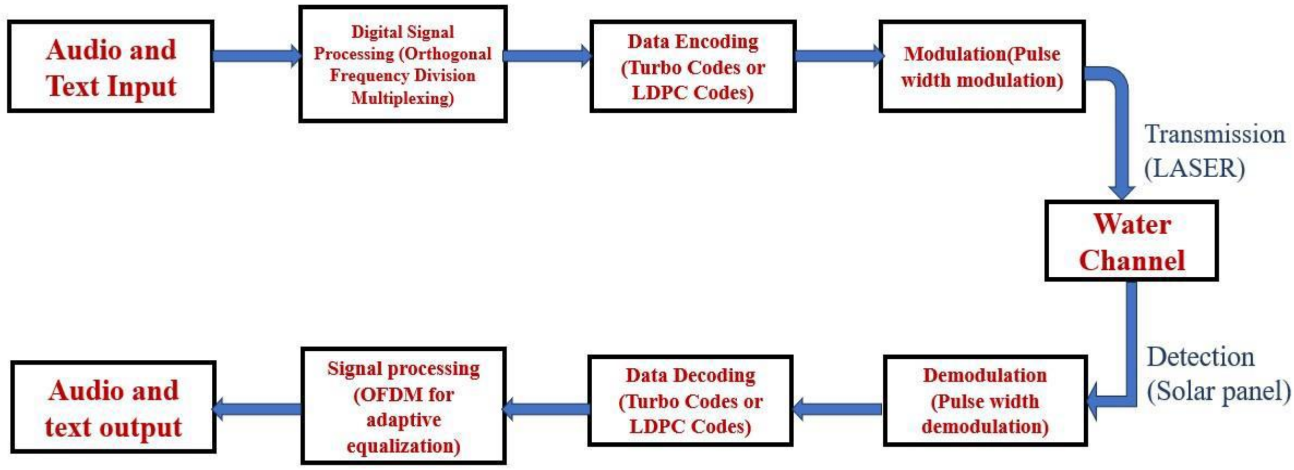

Fig.2: Conceptual framework of the proposed system

VI.DEVELOPING THE PROPOSED SYSTEM

The underwater system was developed in two parts: Hardware: The required hardware components are shown in Table I. Li-Fi technology, revolutionizing underwater communication, operates through a meticulously orchestrated series of steps (see Fig.3 and Fig.4). Initially, data undergoes preparation, transforming text or audio into electrical signals and binary codes. These binary instructions are then encoded into light pulses through modulation techniques like On-Off Keying (OOK) or Pulse Width Modulation (PWM). The magic unfolds as light flickers convey the encoded data, akin to a Morse code of underwater whispers. To overcome absorption challenges underwater, lasers, with their focused beams, replace regular LEDs for longer journeys, especially favouring blue or green lasers for improved penetration. On the receiving end, photodetectors capture the modulated light signals, acting as underwater ears attuned to the light's language. The captured light signals are demodulated, converting them back into electrical signals and recovering the original binary data sequence. Through this process, the encoded information resurfaces in its original form, completing a journey through water powered by the remarkable capabilities of Li-Fi. Despite its evolutionary nature and challenges like water turbulence and limited range, Li-Fi holds immense potential for secure, high-speed data transmission, heralding exciting possibilities in marine research and exploration.

Software: Arduino IDE provides a user-friendly interface for writing code (called sketches in Arduino), compiling it into a format the Arduino board understands, and uploading the code to the board. code is written in a simplified version of Embedded C programming language. Once code is written, it is compiled. Compiling translates the human-readable code into machine code that the Arduino board can understand and execute.

The Arduino IDE has a built-in compiler that takes the code and converts it into the appropriate format for the specific Arduino board you're using (e.g., Arduino Uno). The Arduino IDE includes a built-in serial monitor. This allows you to see the data being sent or received by your Arduino board through the serial communication protocol.

The serial monitor is used to print debugging messages from the code, visualize sensor readings, or interact with the Arduino board by sending it commands.

TABLE I

REQUIRED COMPONENTS OF THE SYSTEM

Module	Components
Sender	Arduino uno, 2-way switch, LASER, Voice recording module, 5v power supply
Receiver	Arduino uno, 2-way switch, Speaker, Solar panel, Amplifier board, serial monitor

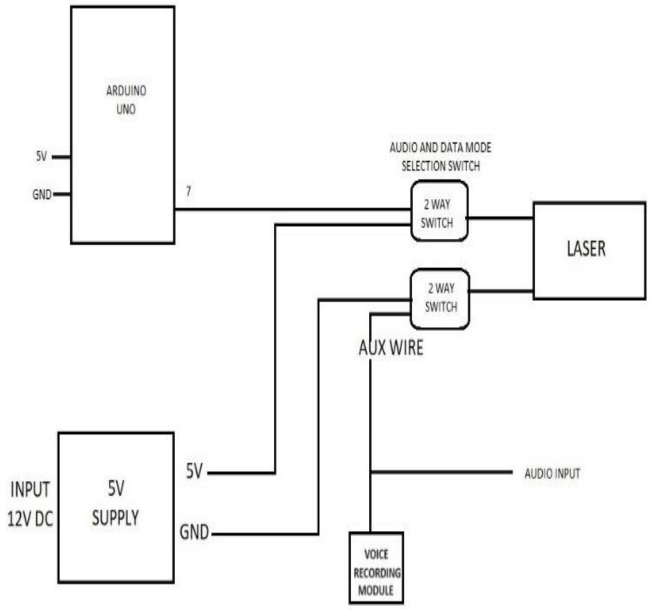

Fig.3: Transmitter block diagram

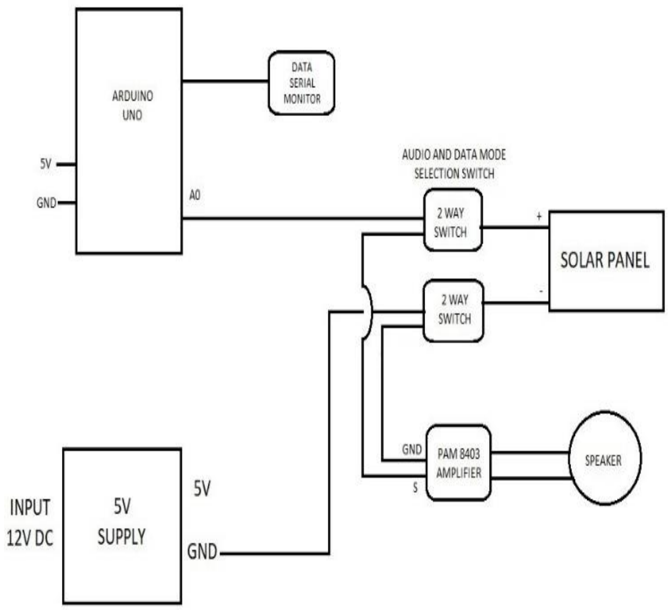

Fig.4: Receiver block diagram

.

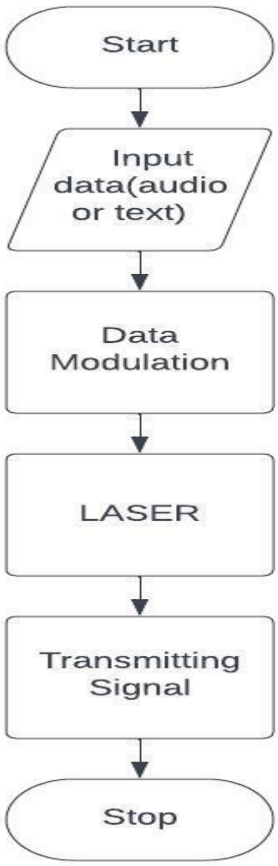

Fig.5: Sender

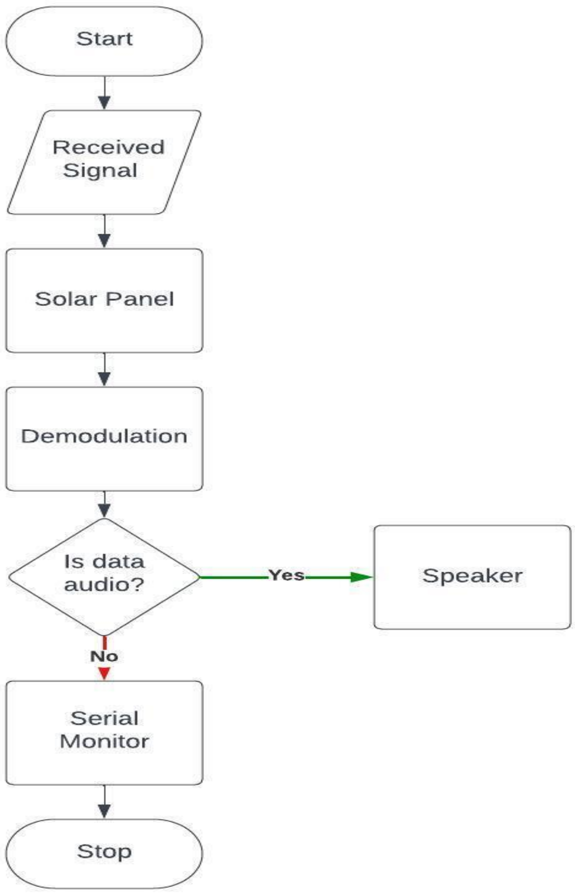

Fig.6: Receiver

VII.APPLICATIONS

This project holds promise for underwater communication and data logging applications. The red laser light and Arduino Uno could enable Li-Fi communication by encoding data onto laser pulses for transmission between submerged devices. Pre-recorded audio messages could be transmitted underwater using the ISD1820 module and speaker, though real-time audio would require a hydrophone and further processing. For data logging, the solar panel (and potentially the 5V power supply) could provide sustainable power for extended deployments. The Arduino Uno can be programmed to collect data from sensors (not included) and store it on an external memory card (not included) for later retrieval. This versatile platform could be adapted for various underwater applications depending on the configuration and additional components. Examples include deploying the system with sensors for underwater data collection, using it for basic diver communication with pre-recorded messages, or even controlling an underwater robot with further development in programming and hardware. However, for practical use, the system would require further development to address challenges like waterproofing the electronics and ensuring reliable underwater communication.

VIII.CONCLUSION

Researchers studying marine life, ocean currents, or underwater ecosystems could deploy this system to collect data from sensors placed underwater. The solar panel would enable long-term data collection, and the Li-Fi communication system could transmit the data back to a surface station for analysis. Archaeologists exploring shipwrecks or submerged ruins could utilize the system for communication between divers and for recording data on underwater discoveries. Pre-recorded messages could be used for basic communication, while data logging capabilities would allow them to document their findings. The core setup utilizes an Arduino Uno for control, a red laser for Li-Fi data transmission, and a solar panel for powering the receiving end. Pre-recorded audio messages can be transmitted using the ISD1820 module and speaker, though real-time audio communication would require a hydrophone and further processing. Data logging capabilities are achieved by programming the Arduino Uno to collect data from external sensors (not included) and store it on a memory card (not included) for later retrieval. This project highlights the potential of Li-Fi technology for underwater communication. The system's modular design allows for various configurations depending on the specific application. Imagine deploying this system with environmental sensors to gather crucial underwater data or using it for basic communication between divers with pre-recorded messages. With further development in programming and hardware, the system could even be used to control underwater robots for exploration or data collection tasks. However, for practical underwater use, the system would require further refinement to address waterproofing challenges and ensure reliable underwater communication.

IX.ACKNOWLEDGEMENT

This research was supported whole heartedly by faculty of Department of Electronics and Communications Engineering, DSATM. We would like to show our gratitude for their great support.

REFERENCES

[1] Sivasakthi T, Palani U, Roshini S, Subhashree S, Vasanthi D, Saundariya K "Underwater Communication Through Li-Fi for Data Transmission" in 2021 international Conference on System, Computation, Automation and Networking (ICSCAN) IEEE DOI: 10.1109/ICSCAN53069.2021.9526524

[2] Vismaya V, Sridhar N, Venkateswaran K "Li-Fi based Data Transmission for Underwater Communication" in 2021 6th International Conference on Communication and Electronics Systems (ICCES) IEEE DOI: 10.1109/ICCES51350.2021.9489200

[3] Muhammad Aman, Gang Qiao, Muhammad Muzzammil "Design and Analysis of Li-fi Underwater Wireless Communication System"
in 2021 OES China Ocean Acoustics (COA)
DOI: 10.1109/COA50123.2021.9519887

[4] Prof.B.R. Thawali, Deshmukh Vishvajeet, Mhaske Nawanath V, Shirgire Vitthal N "Ship to ship communication using Li-Fi technology"in International Journal of Advanced Technology in Engineering and Science Volume No.03, Issue No. 01, January 2015 ISSN (online): 2348 – 7550 137.

[5] Narmatha.M, Portia Sahayam J, Prabavathi M, Tharani, K S Hepzibhai "Optical Data Transfer in Underwater System using Li-fi" in International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Published by, www.ijert.org ICONNECT - 2017 Conference Proceedings

[6] International Journal of Innovation in Engineering Research and Technology [IJIERT] ISSN: 2394-3696 Website: ijiert.org VOLUME 8, ISSUE 7, July. -2021 DOI.10.1109/IJIERT.2021.2809435

[7] International Journal of Scientific and Research Publications, Volume 12, Issue 11, November 2022 H.

Haas, "High-speed wireless networking using visible light," SPIE Newsroom, vol. 1, no. 1, 2021 DOI: 10.1109/TNSM.2021.2842055.

[8] International Journal of Research Publication and Reviews, Vol 3, no 4, pp 966-970, May 2021 DOI: 10.1364/IJRPR.388264.

[9] IOSR Journal of Engineering (IOSRJEN) www.iosrjen.org ISSN (e): 2250-3021, ISSN (p): 2278-8719 Vol. 08, Issue 10 (October. 2021) DOI: 10.1109/IOSRJEN.2021.2869388.

[10] Divya Kiran Xalxo1, V. Muralidharan "SUBAQUATIC MESSAGE TRANSMISSION USING LIFI" International Journal of Trendy research in Engineering and Technology (IJTRET) Volume 2 Issue2 April2021DOI:10.1109/IJTRET.2021.3007871

[11] Naresh Subray HariKant, Dr.N.Sridhar, "Development of Data Transmission Model for Underwater Communication using Li-Fi Technology", IEEE, 2020

[12] Kahn JM, Barry JR. "Wireless Infrared Communications". IEEE. 2020

[13] Anwesha Chakraborty, Trina Dutta, Sushmita Mondal, Asoke Nath,"Latest advancement in Light Fidelity (Li-Fi Technology)", International Journal of Advance Research in Computer Science Management Studies, IEEE-2020