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Underwater Communication Using Internet of Things

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Abstract:

Underwater communication is a slow lane, let’s face it. While traditional acoustic systems work well over long distances, they suffer from grating lag and low data rates. By developing a stylish, reasonably priced underwater wireless optical communication system intended for short-range, high- speed links, this project makes a significant advancement. An infrared (IR) laser and a standard TSOP1738 IR receiver are the easily accessible parts of our solution. Our command center is a Raspberry Pi, which engineers data rather than merely transmitting it. The Pi uses On-Off Keying (OOK) to blast the data after creating a rapid-fire 38 kHz carrier signal using hardware PWM—light ON for a ”1” and light OFF for a ”0.” To make sure the IR laser’s beam is concentrated and strong enough to penetrate the water, we employ a collimating lens and a basic transistor driver. To keep the electronics dry and safe, everything is enclosed in a waterproof housing. As an invisible light beam, the data passes through the water. Although factors like water clarity and alignment are important, our system works best in short-range, clear to moderately turbid conditions with low IR attenuation. The astute TSOP1738 sensor at the other end serves as a filter, automatically eliminating the 38 kHz carrier signal to expose the pure, authentic digital pulses. These pulses are then captured by an ESP32 microcontroller, which uses the Arduino IDE framework to reconstruct the data stream and prepare the data for display or additional analysis. Maintaining a strong optical link requires careful transmitter and receiver alignment. Our modulation and demodulation were perfect, according to preliminary bench tests conducted in the air. In order to determine crucial metrics like data rate, range, and bit error rate (BER), we then proceeded to shallow water trials. The outcomes were unambiguous: this inexpensive system uses off-the-shelf components to provide extremely dependable short- distance communication. In the end, this project demonstrates that optical wireless communication is a viable and effective way to transfer data underwater. We have completely circumvented the limitations of slow acoustics by combining the adaptable Raspberry Pi and ESP32 to create a platform ideal for sensor data collection, high-agility marine robotics, and the next generation of underwater IoT networks.

Keywords: Underwater Communication, Infrared Laser, TSOP1738, Raspberry Pi, ESP32, On-Off Keying, 38 kHz, Optical Transmission, Waterproof Housing, Collimating Lens, Bit Error Rate, Modulation, Demodulation, Short-Range, Signal Pro- cessing, Data Rate, Alignment, Arduino IDE, Marine Robotics, IoT Network

1. Introduction

Ocean exploration, environmental monitoring, and au- tonomous underwater vehicles all depend on underwater com- munication, but it has significant drawbacks. While radio frequency (RF) signals are rapidly absorbed in seawater, acoustic systems facilitate long-distance transmission but have low data rates, high latency, and noise interference. In order to address these issues, this project suggests an inexpensive underwater wireless optical communication (UWOC) system that incorporates Internet of Things technology.

The system transmits data using an infrared laser and detects it using a TSOP1738 receiver. An ESP32 decodes the received data after a Raspberry Pi creates a 38 kHz carrier signal and applies On-Off Keying (OOK) modulation. The project shows a dependable, cost-effective solution for underwater IoT networks and marine robotics applications, and it is designed for short-range communication in clear water.

2. Literature review

Theocharis Theocharidis and his associates describe in a paper that there are three primary underwater communication methods, each with a trade-off. Sound is slow, but it works well for long distances [1]. Although using radio waves, such as Wi-Fi, is quicker, its range is much smaller. The quickest way is to use light, but this method is unreliable in murky or cloudy water. According to the authors, in order to become smarter and more effective, future underwater systems will probably combine these techniques with artificial intelligence. The bene- fits, drawbacks, and most recent developments of underwater communication technologies are reviewed in this paper. It highlights issues like attenuation, slow data transfer rates, and high energy consumption, limited communication range, and a lack of uniformity. To increase performance and efficiency in underwater environments, the authors suggest several future directions, such as biomimetic techniques, AI-based optimisation, quantum communication, and hybrid communication systems [2]. This study is a systematic review of the IoUT, or Internet of Underwater Things. With an emphasis on uses like oceanography and environmental tracking, it explores the developments, difficulties, and potential of IoUT. Customised strategies for IoUT systems, such as integrating artificial intelligence/machine learning (AI/ML) and acoustic, optical, and electromagnetic communications, are also covered in the study [3]. In this paper, SVGS-DSGAT, a novel deep learning model for underwater robotic object detection and tracking enabled by the Internet of Things. It is intended to address the lack of accuracy and resilience of current techniques when handling high-noise and low-contrast underwater photos, utilising Internet of Things technology to process data in real time [4]. This is an overview of the Internet of Underwater Things (IoUT), including its architecture and applications [5]. A review of 5G-based underwater networks and the potential and challenges that go along with them, as well as a discussion of simulation tools for underwater networks, are among the main areas of focus. The article discusses six research studies on underwater communication technologies, specifically on triboelectric Nano generators (TENGs), optical, acoustic, and hybrid 5G communication systems. The main drawbacks mentioned are signal interference and limited communication distance. The researchers conclude that future studies should focus on providing sustainable power solutions and more efficient hybrid communication systems [6].

The proposed work is on Underwater wireless communication system using IOT for the health monitoring of a marine navigator. The proposed sys- tem employs a separate transmitter and receiver module in the water to transmit the marine researcher’s organic interactions to a tracking system on the surface [7]. This article explains the IoT-based implementation of underwater communication through Li-Fi (Visible Light Com- munication or VLC) technology as an alternative to acoustic communication. Li-Fi technology supports high data rates (hundreds of Mbps) for short-range communication and is an essential technology for environmental monitoring, underwater disaster management, and military purposes [8].This article gives a review of underwater and air- water wireless communication networks (WCNs), including a comparative analysis of radio frequency (RF), acoustic, optical, and magnetic induction (MI) communication systems It examines the pros and cons, as well as the security issues, of each type of technology, giving a complete analysis of their usability and performance in underwater environments[9,10].

This article investigates IoT-Based Underwater Wireless Communication. It presents a design for an underwater RF wireless communication network to overcome the drawbacks of acoustic/optical signals (low data rate and attenuation). The design creates the network, locates the position of devices on an IoT cloud, and calculates environmental parameters such as temperature and vibration [11]. The document describes an Automated Underwater Wireless Communication System Us- ing Li-Fi with IOT Support and GPS Positioning. It combines Li-Fi for communication, IoT for support, and GPS for positioning in the underwater setting [12]. This paper reviews the applications of optical wireless communication (OWC) in the tourism industry, particularly the use of Free Space Optics (FSO) and Li-Fi technology to create “Tourist Area Networks”. These networks are designed to provide high-speed data connectivity in both indoor and out- door settings, thereby improving tourist experiences through efficient wireless communication solutions [13].

The paper describes a Vertical-Cavity Surface- Emitting Laser (VCSEL)-based underwater optical communication system that can support data transfer rates of 1- 256Gbps, designed using Arduino and Proteus software. The main drawback of the system is its short range and the fact that it has been tested only in simulation models. Future research will concentrate on real-world applications, enhancing system stability, and developing the system to support Internet of Things (IoT) applications [14].

The article discusses the major underwater communication techniques, such as acoustic, optical, and radio frequency (RF), and their trade-offs between communication distance and bandwidth. The authors recommend that future research should be directed towards designing hybrid systems that can effectively address these trade-offs while being reliable, efficient, and sustainable for underwater networks [15]. The article discusses Underwater Wireless Optical Communication (UWOC) systems, analyzing different link topologies, the effects of different water types on signal transmission, and misalignment issues that impact the performance. It concludes by recommending the design of a hybrid system that can potentially provide more reliable and efficient underwater communication [16]. The paper con- ducts a survey and experimental validation of microarchitectural vulnerabilities in RISC-V processors, focusing on side-channel and speculative execution attacks. It offers a glimpse into the security challenges posed by open-source CPU architectures and the need for robust hardware-level solutions to address these threats [17]. The paper presents a thorough survey of underwater wireless communication techniques, including radio frequency (RF), optical, and acoustic transmission schemes. It examines their technical specifications, reviews the current state of research, and investigates their potential for future development to enhance underwater communication performance and reliability [18]. The paper shows the capability of a high-speed Underwater Wireless Optical Communication (UWOC) system at 2.3Gbit/s over 7m, utilizing a 520nm laser diode with an avalanche photodiode (APD). The proposed system provides a simple and low-cost solution for short-range underwater communication, illustrating the feasibility of UWOC systems. The paper reviews outdoor near-infrared Free Space Optical (FSO) communication links, focusing on their high data rates and different applications, as well as the difficulties caused by atmospheric turbulence and weather conditions [19,20].

This project aims to create an underwater wireless com- munication link using an infrared (IR) laser for transmission and a TSOP1738 IR receiver for detection. The transmitter is controlled by a Raspberry Pi, and the receiver is managed by an ESP32 microcontroller. The process involves encrypting, generating, modulating, transmitting, decrypting, and decoding optical signals as they pass through water.

1. Transmitting Section (Raspberry Pi)

At the transmitting end, a Raspberry Pi acts as the main controller, generating digital data that needs to be sent across the water.

Data Encryption: Before transmission, the original data is encrypted using a lightweight encryption algorithm (such as AES or a custom symmetric key method). This ensures that even if the optical signal is intercepted, the transmitted information remains secure and unreadable without the correct key. The encryption process converts plaintext data into cipher- text, which is then prepared for modulation and transmission.

Signal Generation and Modulation: The encrypted data is converted into an optical signal using an IR laser diode. To ensure efficient signal generation, the Raspberry Pi produces a 38 kHz carrier wave through one of its GPIO pins using hardware PWM.

The encrypted binary data is modulated using On-Off Keying (OOK):

- Logic ’1’ → Laser ON (38 kHz burst)
- Logic ’0’ → Laser OFF

A transistor driver boosts the GPIO output to safely power the laser diode. The beam passes through a collimating lens that narrows and focuses it, improving underwater transmission distance. The entire transmitter assembly is sealed in a waterproof casing with a transparent window to protect the electronics while allowing clear light output.

2. **Transmission Through Water**:

Once the encrypted optical signal leaves the transmitter, it travels through the water, carrying secure digital information in the form of light intensity variations. Signal quality depends heavily on water conditions:

a. Clear water → Better transmission range

b. Murky or deep water → Higher absorption and scattering Since IR light is absorbed relatively quickly underwater, the system is optimized for short-range communication in relatively clear water. Precise alignment between transmitter and receiver is essential to minimize data loss and signal distortion.

3. **Receiving Section (ESP32 + TSOP1738)**

On the receiving side, the TSOP1738 module captures incoming IR signals. It automatically filters and demodulates the 38 kHz carrier frequency, outputting clean digital signals corresponding to the transmitted encrypted data. The ESP32 reads this digital signal through one of its GPIO pins.

Data Decryption: After reconstructing the encrypted binary stream, the ESP32 applies the same symmetric key used at the transmitter to decrypt the ciphertext back into the original plaintext data.

This ensures:

- Secure communication
- Protection against unauthorized interception
- Data integrity during underwater transmission The recovered data can then be:
- Displayed via serial monitor
- Logged for analysis
- Transmitted over Wi-Fi for further processing

4. **Signal Processing and Communication Protocol**:

The communication between the two ends relies on: Modulation Technique:

On-Off Keying (OOK)

a. 38 kHz burst → Binary ’1’

b. No burst → Binary ’0’ Data Frame Structure:

To ensure reliable communication and synchronization, the system includes:

c. Start bit
d. Encrypted data bits
e. Stop bit

Optional improvements may include:

f. Checksum or CRC for error detection
g. Frame headers for packet identification.

The Raspberry Pi is programmed in Python, while the ESP32 uses the Arduino IDE for decoding and decrypting the signals.

5. Waterproofing and Alignment

Both transmitter and receiver are enclosed in sealed waterproof housings made of acrylic or glass to prevent water infiltration. Transparent optical windows allow efficient light transmission.

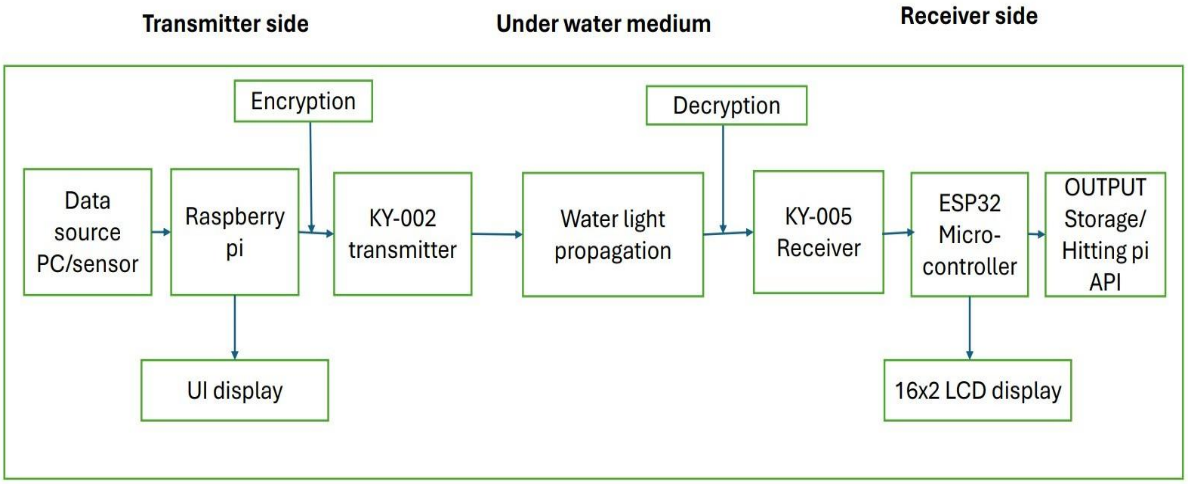

Fig. 1. Proposed Underwater Optical Communication System Architecture

Proper mechanical alignment ensures:

- Stable line-of-sight
- Reduced signal loss
- Improved communication reliability

These measures protect components from corrosion and electrical damage.

6. Testing and Evaluation

Before underwater deployment, the system is first tested in open air to verify:

a. Proper encryption and decryption
b. Correct modulation and demodulation

c. Data frame synchronization

It is then tested in shallow water to measure:

d. Transmission range
e. Data rate
f. Bit Error Rate (BER)
g. Encryption overhead impact on performance

Various conditions such as water clarity, distance, and alignment are evaluated to determine how each factor affects communication quality and security.

Security Enhancement Summary

By integrating encryption at the transmitter and decryption at the receiver, the system now provides:

h. Secure underwater optical communication
i. Protection against signal interception
j. Confidential data transfer
k. Enhanced system robustness

7. Conclusion:

This project effectively illustrates a straightforward and efficient method of data transmission underwater that uses light rather than wired or acoustic communication. An infrared (IR) laser serves as the transmitter in this configuration, and a TSOP1738 infrared detector for detection. An ESP32 microcontroller receives and decodes the data signals, which are generated and modulated by a Raspberry Pi, which manages the transmission. These parts work together to form a small, inexpensive system that can communicate underwater over short distances. The On Off Keying (OOK) technique, in which the laser alternates between turning on and off to represent binary data, was used to modulate the 38 kHz signal generated by the Raspberry Pi during the experiment. The TSOP1738 sensor detected the modulated light beam that had passed through the water and transformed it back into digital data. After processing this data, the ESP32 showed the information it had received, demonstrating that light-based data transmission through water is a feasible and dependable method for short distances. To evaluate the system's performance, tests were conducted in shallow water and the air. The significant quality was diminished by water and greater distance. It was also discovered that maintaining a steady connection required precise alignment between the transmitter and receiver. The setup performed well for short-range, line- of-sight communication, despite the range being constrained by the high absorption of infrared light in water. This project shows that inexpensive and readily accessible components can be used to accomplish underwater laser communication. For uses such as IoT-based monitoring systems, underwater sensor networks, and tiny underwater robots, where short. Green or blue lasers, which travel more effectively in water, could be used to enhance the system in the future. and by using more sophisticated modulation techniques to boost dependability and speed. Improved signal amplifiers, automatic alignment systems, and waterproof housings can all aid in extending the communication range and improving the system's suitability for practical marine applications.

Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

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