Design and Implementation of Under Water Optical Wireless Communication

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Abstract

This study investigates the possibility of using Underwater Optical Wireless Communication (UOWC) based on infrared (IR) light for high-speed underwater data transmission. Conventional acoustic communication technologies are limited by low data rates and high latency, which makes UOWC a viable candidate for future underwater applications. The system being proposed employs IR LEDs as transmitters and photodiodes as receivers and ensures waterproofing. The system also incorporates signal processing for efficient data transmission. Comprehensive testing is done in controlled underwater environments, e.g., water tanks and swimming pools, to test the performance of the system under various conditions. Experimental results show that IR light can successfully penetrate water, allowing for trustworthy and high-rate data transfer. The system recorded much higher data rates than conventional acoustic methods. The choice of IR light over blue-green wavelengths is based on its cost-effectiveness and ease of integration. Performance varied in fresh and saltwater, requiring tailored solutions. The UOWC system carries important implications across a range of fields, such as scientific research, military, and industrial monitoring. It can be used to improve underwater exploration, environmental monitoring, and communication with submarines, autonomous underwater vehicles (AUVs), and other submerged structures.

Keywords: Underwater Optical Wireless Communication (UOWC), infrared transmission, data rate, underwater communication, environmental monitoring.

1. Introduction

The paper presents an overview of Underwater Optical Wireless Communication (UOWC)based on infrared (IR) light that presents a promising solution to the problems of the conventional underwater communication techniques, like low data rate and high latency [1]. The IR LEDs are used as transmitters and photodiodes as receivers, focusing on waterproofing and reliability for stable operation in underwater environments. While blue-green light exhibits lower absorption in water, IR was selected due to its cost-effectiveness, ease of integration with standard optoelectronic components, and reduced interference from ambient light sources.Extensive testing in controlled underwater environments demonstrates the system's efficiency in data transmission through different depths and types of water [2][3]. UOWC has significant implications for scientific research, military operations, and industrial applications. The technology's capability to provide high-speed data transmission underwater makes it a key development in underwater communication technology. This paper demonstrates UOWC’s potential to advance underwater communication technology. Acoustic communication limits high-speed underwater data transmission. The problem leads to limited real-time data sharing and operational efficiencies within underwater environments, important for scientific investigations, military operations, as well as industrial uses [4]. The difficulty is magnified by the constraints of sound signals in crowded or chaotic underwater environments, where signal degradation and interference are common. However, conventional methods have serious limitations, including poor data rate, high latency, and sensitivity to environmental conditions. Such limitations impede real-time data exchange and effective underwater operations, necessitating the use of a better communication solution. UOWC is a potential alternative, employing IR light for high-speed data transmission. In contrast to acoustic waves, optical signals propagate at much faster speeds and provide much better data rates. The system has been extensively tested in controlled environments and is capable of transmitting data effectively at varying depths and water conditions.

Underwater communication has been researched in multiple areas previously. Paper [5] gave the insight into coding, channel characterization, noise suppression, and acousto-optic hybrid systems. Paper [6] focused on channel understanding, modulation techniques, practical installation, performance testing, and usage. Paper [7] discussed UOWN structures, issues, localization, and full-duplex UOW channel modeling. Paper [8] discussed IR technology integration with Raspberry Pi Pico in underwater communication.

Traditional acoustic communication is challenged by data rate and responsiveness, and underwater operations are constrained by this [9][10]. IR-based UOWC can overcome this and advance data transmission to overcome these limitations and increase underwater communication capabilities [11]. The primary motivation behind this work is to design a high-speed, dependable underwater optical wireless communication (UOWC) system employing IR light.

This objective is broken down into the following specific objectives:

1. Design a reliable UOWC system with IR LEDs as transmitters and photodiodes as receivers, optimized for efficient data transmission in underwater environments.
2. Test the performance of the UOWC system through thorough testing in controlled underwater environments to evaluate data transmission reliability at different volumes and types of water.
3. Verify the feasibility and potential of IR-based UOWC systems and examine data transmissions performance of the same.

Through these objectives, the study seeks to establish a complete solution for improving underwater communication capacity using infrared (IR) light. This involves enhancing data transmission speed and reliability over conventional acoustic methods.

2. Methodology

2.1 Research Design and Approach

The "Underwater Optical Wireless Communication (UOWC) using IR Light" research uses an experimental research design that is centred on developing, implementing, and evaluating an underwater real-time communication system. The approach combines hardware components, such as IR LEDs and photodiodes, with an Arduino Uno to realize effective data transmission underwater [12][13].

2.2 Data Acquisition and Analysis:

• Temperature and Humidity Data: Gathered with the help of the DHT11 sensor. The sensor gives precise measurements of temperature and humidity values in the underwater environment, which are important to monitor the system operational conditions [14].

• Distance Data: Gathered via the HC-SR04 ultrasonic sensor. The sensor counts the distance between the transmitter and receiver for precise positioning and alignment to optimize data transfer.

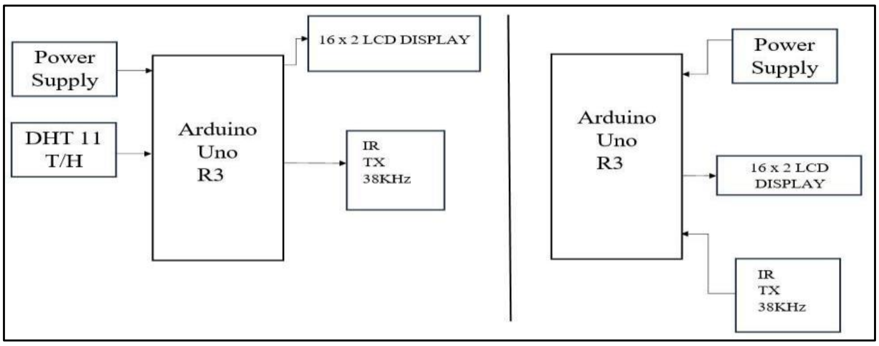

Fig1. UWOC Block diagram

2.3 Step-by-Step Explanation for Project Implementation

- UWOC Fundamentals: Learn about optical wireless communication, IR light transmission in water [15].
- Component Choosing: Utilize IR LEDs, photodiodes, DHT11 (humidity/temperature), HC-SR04 (distance), waterproofing [16][17].
- Experimental Environment: 5W IR LED (850nm), optimized photodiode, 1.5m x 1m x 1m water tank. Signal power through oscilloscope, BER from data purity.
- System Development: Put together IR LEDs, photodiodes, Arduino Uno for transmission/reception, waterproofing [18][19][20].
- System Assembly: Interface Arduino Uno with IR LEDs, photodiodes, and sensor-based sensing [21][22].
- Testing: Perform experiments in controlled water systems (tanks/pools).

2.4 Schematic Diagram

Figure 2 represents the schematic of the proposed model. It provides the detailed pin diagram of the model.

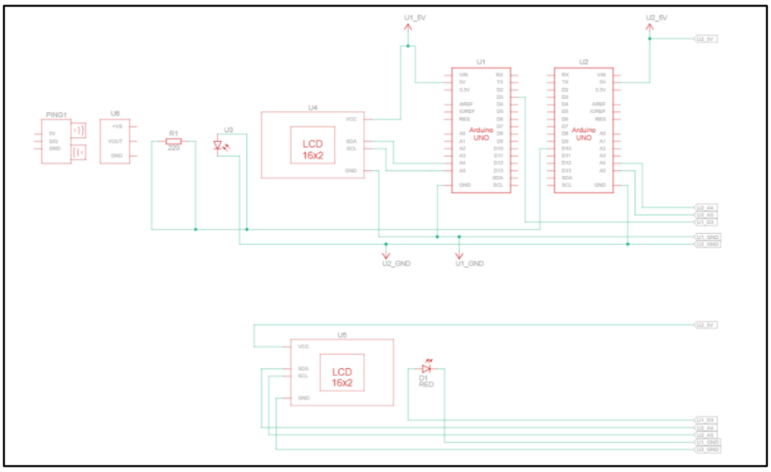

Fig:2 Pin diagram of the model

3. Results & Discussion

The system was able to effectively interconnect all modules for real-time transmission of temperature data with reduced latency and error. The system was able to achieve an efficient communication range of 5 meters in clear water, and a slight reduction occurred in turbid water conditions owing to the augmented attenuation.

Temperature readings, experimented on both LCD and serial monitor, confirmed system reliability and accuracy. The project was experimented in normal, warm, and coldwater conditions utilizing a DHT11 sensor with readings as seen in Table 1. This confirms its use in underwater communication, exploration, and environmental monitoring.

Water Condition	**Temperature (°C)**
Normal	~27
Warm	~38
Cold	~14

Table 1 : Analysis result

The system successfully monitored temperature changes in different water conditions. The readings indicated that the system was able to detect temperature changes precisely. Temperature measurement capability properly in underwater environments is crucial to uses like underwater exploration and environmental monitoring. Figure 3 to 6 represent the real time implementation of the proposed model.

Fig 4: Transmitter part

Fig 3: IR communication across the water medium

Fig 5: Receiver part

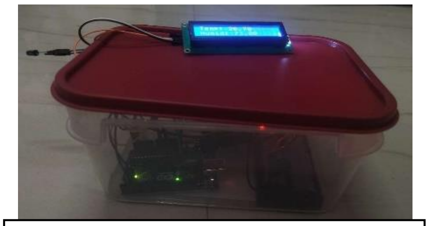

Fig 6: Water proofed

4. Conclusion

The deployment of suggested Underwater Optical Wireless Communication (UOWC) with infrared (IR) sensors for temperature data transmission has shown remarkable improvements [24][25]. The system supported data rates, allowing high-frequency transmission of temperature data. Near real-time transmission of data was ensured, allowing for instant analysis and response. Temperature data were transmitted accurately and reliably. The system worked best in clear water but exhibited decreased range and greater requirement for alignment adjustments in turbid and turbulent conditions. In general, this work was able to effectively demonstrate the potential of UOWC with IR sensors to improve underwater communication capabilities, with important applications in scientific research, military operations, and industrial monitoring.

5. References

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