Underwater Digital Communication Using Infrared Signals

A

project report submitted

To

Chhattisgarh Swami Vivekananda Technical University, Bhilai (C.G.) India

In fulfilment for award of the degree

Of

BACHELOR OF TECHNOLOGY

In

Electronics and Telecommunication Engineering By

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Session: 2024–2025

DECLARATION BY THE CANDIDATES

We the undersigned solemnly declare that the report of the Project Work entitled "**Underwater Digital Communication Using Infrared Signals**", is based on our own work carried out during our study under the supervision of **Asst**. **Prof Vinita Sahu.**

We assert that the statements made, and conclusions drawn are an outcome of the project work. We further declare that to the best of our knowledge and belief that the report does not contain any part of any work which has been submitted for the award of any other degree/diploma/certificate in this University/deemed the University of India or any other country. All help received and citations used for the preparation of the Project Work have been duly acknowledged.

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ACKNOWLEDGEMENT

We are thankful to **Mrs. Vinita Sahu**, Assistant Professor & Project Coordinator for her continuous support & guidance. We are very grateful for the inspiring discussions with all our faculties; their valuable support and path-guiding suggestions have helped us to develop this project. Alongside this, we would like to take this opportunity to express our thanks to everyone in the Computer Laboratory of Government Engineering College, Sejbahar, and Raipur (C.G.).

We especially thank our batch mates, and friends for the support and help that they offered us during the development of this project.

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CHAPTER 1

INTRODUCTION

1. Introduction

1.1 Overview of Underwater Communication

Underwater communication has emerged as a vital technology in modern science and engineering, enabling a wide range of applications in oceanography, underwater robotics, military surveillance, disaster monitoring, and marine biology. Unlike terrestrial and aerial environments, where radio waves and microwave signals are used extensively for communication, underwater environments pose significant challenges due to the high attenuation of electromagnetic waves in water. This results in limited signal range and quality when using conventional wireless technologies. [1]

Consequently, researchers and engineers have explored various alternatives, including acoustic, optical, and magnetic induction methods, to overcome these barriers. Among these, **optical communication**, particularly using infrared (IR) light, offers an attractive balance between speed, power consumption, and range especially in clear water conditions. It provides faster data transmission rates compared to acoustic methods, with the advantage of being less susceptible to ambient noise and with a relatively smaller form factor. [2]

1.2 Purpose of the Project

The purpose of our project is to demonstrate a low-cost and compact prototype of an **underwater communication system using IR technology**. Our goal is to enable the transmission of numerical data, in this case, integers from a transmitter to a receiver through a water medium. This is achieved using infrared (IR) light-emitting diodes (LEDs) at the transmitter side and a TSOP IR receiver module on the receiver side. The system utilizes **ATmega328 microcontrollers** on both ends to [1] control data flow, manage user inputs, and drive displays for visualization.

This project not only showcases the feasibility of using IR signals for simple underwater communication but also emphasizes ease of use, portability, and real-time feedback using LCD displays. It is particularly aimed at students, hobbyists, and researchers looking for a starting point into optical underwater data transmission.

1.3 System Description

Transmitter Side

The **transmitter module** serves as the input and encoding section of the underwater communication system. It includes the following key components:

1. ATmega328 Microcontroller

Figure 1.1 ATMega 328

At the heart of the transmitter is the ATmega328 microcontroller, a widely used 8-bit AVR microcontroller that also serves as the core of the popular Arduino Uno development board. This microcontroller plays a central role in the system by managing the interpretation of user input typically in the form of numerical data and converting it into a digital signal suitable for transmission. Once the data is processed, the ATmega328 directs the signal to the infrared (IR) LED, which emits the encoded information toward the receiver. Beyond just basic data handling, the microcontroller is responsible for ensuring precise timing, orchestrating the control of data encoding schemes, managing modulation techniques, and overseeing the overall transmission process. Its reliability and versatility make it an ideal choice for this kind of application, where accurate and efficient communication between transmitter and receiver is essential.

2. IR LED as Optical Transmitter

Figure 1.2 IR led

An infrared (IR) LED is used to transmit data by emitting rapid light pulses, which carry encoded information across the medium. These IR LEDs typically operate at wavelengths around 940 nanometers, placing them just beyond the visible spectrum, which makes them invisible to the human eye but well-suited for optical communication systems. While infrared light does not penetrate water as effectively as radio or acoustic waves, it can still travel short distances in water, especially when the water is clear and free from suspended particles or impurities that scatter or absorb the light. For this reason, although IR transmission is not ideal for deep-sea or long-range underwater communication, it works well for shallow water setups, aquariums, laboratory demonstrations, or small-scale projects such as the one described here. In this system, the microcontroller modulates the IR LED's on-off switching pattern (a technique often referred to as pulse modulation) to encode and represent different numerical values, effectively turning the LED into a data carrier that the receiver can interpret.

3. User Input: Two Switches

Two push buttons serve as the primary user input interface, allowing the user to increment or decrement a numerical value with simple presses. Each press of the "increment" button increases the value by one, while the "decrement" button reduces it, providing an intuitive and straightforward way to adjust the number. The system continuously maintains and updates the current value, displaying it in real-time so the user always knows exactly which number is selected and being prepared for transmission. This live feedback gives the user full control over the data being sent without requiring any complex setup or additional equipment. By relying on these physical buttons, the system offers an easy and accessible method for interaction and testing, eliminating the need for serial communication, external input devices, or software-based control making it especially convenient for demonstrations, prototyping, or educational projects.

4. 16x2 LCD Display with I2C Interface

Figure 1.3 16X2 LCD Display

A 16x2 character LCD display is included in the system to show the current numerical value that is set to be transmitted. This display provides clear, real-time feedback, ensuring that the user always knows exactly which number is being prepared for transmission, which greatly improves usability and reduces the chance of errors. To interface the LCD with the microcontroller efficiently, an I2C (Inter-Integrated Circuit) module is used. This small but powerful module significantly reduces the number of GPIO (General Purpose Input/Output) pins required for connection by enabling communication over just two wires typically SDA (data line) and SCL (clock line) instead of the many parallel connections normally needed to drive an LCD. This not only simplifies the wiring and minimizes clutter on the circuit board but also frees up valuable microcontroller pins for other uses, making the overall design more compact, scalable, and easier to manage, especially in projects with limited space or resources.

5. LM2596 Buck Converter and Power Supply

Figure 1.4 LM2596 Buck Converter

To power the circuit efficiently, a 9V battery is used as the primary power source, providing a convenient and portable energy supply. However, since the ATmega328 microcontroller and its connected peripherals require a stable 5V input for proper operation, an LM2596 buck converter is integrated into the system. This DC-DC converter efficiently steps down the 9V input to the regulated 5V output needed, doing so with high conversion efficiency and minimal heat generation compared to linear regulators. Proper power regulation is crucial not only for maintaining stable system performance but also for protecting sensitive electronic components from overvoltage, which could lead to malfunction or permanent damage. By incorporating the LM2596, the design ensures reliable operation, extends battery life, and supports the safe functioning of all system elements, making it a practical choice for both portable and stationary applications.

Receiver Side

The **receiver module** receives the transmitted IR signal, decodes it, and displays the received data. It shares a similar architecture with the transmitter:

1. TSOP IR Receiver Module

Figure 1.5 TSOP IR receiver

At the core of the receiving system is the TSOP infrared (IR) receiver, a widely used and reliable module designed to detect and demodulate incoming IR signals. The TSOP is specifically sensitive to IR signals modulated at particular frequencies most commonly around 38 kHz which enables it to effectively filter out constant or random sources of infrared light, such as sunlight, indoor lighting, or heat from surrounding objects. This frequency-selective sensitivity allows the receiver to focus solely on the intended signal transmitted by the IR LED, dramatically improving communication reliability and reducing the chance of interference or false triggering. When the IR LED on the transmitter side sends out a modulated pulse train carrying encoded data, the TSOP module captures these pulses and demodulates them, stripping away the carrier frequency and producing a clean, logic-level signal that the receiving microcontroller can easily interpret and process. This makes the TSOP module an essential component for stable, interference-resistant IR communication.

2. ATmega328 Microcontroller

Figure 1.6 Atmega328

The receiver system also employs an ATmega328 microcontroller, which plays a critical role in decoding the incoming data from the TSOP module. Once the TSOP demodulates the infrared pulse train and outputs a clean digital signal, the ATmega328 takes over, analyzing the timing and pattern of the pulses to accurately reconstruct the original numerical value that was transmitted. This involves carefully processing the signal to differentiate between data bits, ensuring that the number is interpreted correctly despite any minor variations or noise in the transmission. After successfully decoding the received data, the microcontroller updates the connected LCD display to show the received value in real time. This provides immediate visual feedback, allowing the user to confirm that the correct number was transmitted and received, making the system intuitive and easy to monitor during operation.

3. 16x2 LCD Display with I2C Interface

Figure 1.7 16X2 LCD Display

The received number is displayed on an identical 16x2 character LCD module equipped with an I2C interface, mirroring the setup used on the transmitter side. This display provides clear, immediate visual confirmation that the transmitted data has been successfully received and decoded, ensuring the system remains intuitive and easy to monitor. By using the I2C interface, the receiver's microcontroller can communicate with the LCD using only two dedicated lines SDA (data) and SCL (clock) which simplifies wiring, reduces the number of required GPIO pins, and helps maintain a compact, organized circuit layout. This real-time feedback not only enhances user confidence in the system's performance but also makes testing, troubleshooting, and demonstrations straightforward and accessible, especially for educational or prototype applications.

4. LM2596 Buck Converter and Power Source

Figure 1.8 LM2596 Buck Converter

Like the transmitter, the receiver is powered by a 9V battery, providing a convenient and portable energy source for the entire system. To ensure that all components including the ATmega328 microcontroller, TSOP IR receiver, and LCD module receive a stable and reliable 5V supply, an LM2596 buck converter is used to step down the voltage efficiently. This DC-DC converter offers high efficiency compared to traditional linear regulators, minimizing power loss and heat generation while extending battery life. Stable power regulation is critical for maintaining consistent system performance, preventing voltage fluctuations that could lead to data errors, signal instability, or even component damage. By mirroring the transmitter's power setup, the receiver ensures smooth, dependable operation across all its modules, supporting the overall reliability of the communication system.

1.4 Water Medium Demonstration Setup

To simulate underwater communication, a **transparent plastic or glass container** filled with water is placed between the transmitter and receiver modules. This creates a controlled environment where the IR signal must propagate through a water medium. This setup allows for the visualization of how IR signals perform in water, including how signal strength, alignment, water clarity, and distance affect transmission.

This type of controlled environment is ideal for educational and experimental purposes. While the signal attenuation in water is much higher compared to air, especially at longer wavelengths, IR light still offers decent transmission capabilities over short distances in clean water — validating its use in underwater communication prototypes.

1.5 Applications and Future Scope

While our project focuses on demonstrating the transmission of simple numerical data using infrared (IR) communication through water, it serves as an important foundational step toward developing more advanced and capable systems. By successfully showing that IR signals can be used to send and receive information across short underwater distances, this project opens the door to a variety of potential future enhancements and real-world applications. Some promising areas for further development include:

• **Underwater sensor networks for environmental monitoring**: deploying multiple sensor nodes underwater to collect and share data on parameters like temperature, salinity, or pollution levels, helping researchers monitor aquatic ecosystems more effectively.

• **Autonomous Underwater Vehicle (AUV) communication**: enabling AUVs to exchange data with one another or with base stations during underwater missions, improving coordination, navigation, and mission outcomes.

• **Short-range diver-to-diver communication systems**: providing divers with a lightweight, silent means of exchanging basic information or status updates underwater without relying on cumbersome hand signals or acoustic systems.

• **Robotic data exchange in submerged environments**: allowing underwater robots or drones working in confined or complex environments (such as pipes, tanks, or submerged structures) to communicate and share data in real time.

• **Military surveillance in coastal areas**: applying the technology for secure, short-range communication between underwater surveillance devices or systems used in coastal defense and reconnaissance missions.

Our project demonstrates not just a standalone system but also a scalable concept that, with further refinement, could contribute meaningfully to both civilian and defense-related underwater communication technologies.

Future versions of the system could include features such as:

Two-way communication (duplex transmission).

Error checking and correction protocols.

Use of high-power IR lasers or LEDs for greater range.Integration with Bluetooth or RF modules for post-surface communication

CHAPTER: 2

LITERATURE REVIEW

Literature Review

Underwater communication has long been a subject of extensive research due to its critical applications in oceanography, defense, and marine exploration. Traditional methods like acoustic communication face challenges such as low data rates and high latency. Optical wireless communication (OWC), particularly using infrared (IR) and visible light, has emerged as a promising alternative. This chapter reviews key studies and developments in underwater optical communication, focusing on systems utilizing IR LEDs, microcontrollers like the ATmega328, and related components.

1. High-Speed Underwater Optical Wireless Communication

In 2016, Shen et al. demonstrated a 20-meter underwater wireless optical communication link achieving a data rate of 1.5 Gbps using a blue laser diode. This study highlighted the potential of optical communication for high-speed data transfer underwater, surpassing traditional acoustic methods in terms of bandwidth and latency.

2. Real-Time Underwater Wireless Optical Communication System

A 2023 study by Zhang et al. presented a real-time underwater wireless optical communication system based on LEDs. The system achieved data rates up to 80 Mbps over a distance of 10 meters in clear water. The researchers emphasized the importance of modulation schemes and system design in optimizing performance.

3. Design and Development of an LED-Based Optical Communication System

In a thesis by Smith (2019), an LED-based optical communication system was developed for underwater applications. The system utilized a super-bright blue LED and a blue-enhanced photodiode, achieving data transmission over 23 meters at rates of 115200 kbps. This work underscored the feasibility of using LEDs for efficient underwater communication.

4. Effects of Modulation Scheme on RGB LEDs Based Underwater Optical Communication

Umrani et al. (2018) investigated the impact of modulation schemes on underwater optical communication using RGB LEDs. Their experimental setup achieved data rates of 2 Mbps at a distance of 1 meter. The study concluded that blue LEDs provided the best signal strength underwater, and modulation schemes like ASK, FSK, and PSK significantly influenced performance.

5. An Underwater Optical Wireless Communication System Based on LED Source

Rao et al. (2011) developed a prototype underwater optical wireless communication system using a high-powered green LED array and a photomultiplier tube as the detector. The system achieved data rates of 4 Mbps at 8.4 meters and 1 Mbps at 22 meters, demonstrating the viability of LED-based communication in underwater environments.

6. Design of Underwater Optical Communication System

In 2017, researchers designed an underwater optical communication system using green-blue LEDs with a MOSFET driver circuit at the transmitter and a photodiode with a DSP circuit at the receiver. The system achieved data rates of 115.2 Kbps over a distance of 20 meters, highlighting the potential of simple, cost-effective designs for underwater communication.

7. High-Speed Underwater Optical Wireless Communication with Advanced Signal Processing

Wang et al. (2018) explored advanced signal processing methods for high-speed underwater optical wireless communication. Their system employed maximum ratio combination with multi-PIN reception, achieving significant improvements in data rates and reliability. The study emphasized the role of signal processing in enhancing underwater communication systems.

CHAPTER: 3

PROBLEM IDENTIFICATION

Problem Identification

3.1 Introduction

Underwater communication has become an essential component in a wide range of fields, including marine biology, underwater robotics, naval defense, and environmental monitoring. Reliable and efficient communication between underwater devices, human divers, or surface base stations is critical to enable and support complex tasks such as oceanographic data collection, deep-sea exploration, habitat mapping, infrastructure inspection, and search-and-rescue operations. Traditionally, underwater communication systems have relied on acoustic (sound-based), radio frequency (RF), or wired communication methods. While these approaches have been widely used, they each come with notable technical and economic limitations — for example, acoustic communication often suffers from low data rates and high latency; RF signals are heavily attenuated in conductive saltwater environments, limiting their range; and wired systems, while reliable, can be cumbersome, expensive, and impractical for dynamic or mobile applications.

These challenges have driven researchers and engineers to explore alternative approaches, one of which is **infrared (IR)-based optical communication**. This method leverages the ability of near-infrared light to transmit data over short distances in clear water, offering the potential for higher data rates, lower power consumption, and simpler hardware compared to traditional systems. Although IR communication has its own constraints — such as limited range and sensitivity to water clarity it presents a promising avenue for specific underwater applications, especially in scenarios where short-range, low-cost, and high-speed data transfer is desired.

The current project aims to develop a low-cost, prototype-level infrared (IR) communication system designed to demonstrate the feasibility of underwater data transmission using IR technology. This project serves as a proof of concept, showing that IR signals can be effectively modulated, transmitted, and decoded across short distances underwater under controlled conditions. To design and implement such a system successfully, it is crucial first to identify and thoroughly analyze the inherent limitations of existing underwater communication methods, such as acoustic, RF, and wired systems, and to understand the unique challenges posed by underwater environments. Factors such as signal attenuation, scattering, absorption, turbulence, and the presence of particulates or biological matter all affect how different communication methods perform beneath the surface. By acknowledging and addressing these challenges, this project lays the groundwork for exploring how IR-based optical communication can complement or improve upon traditional systems, especially in applications where short-range, high-speed, and cost-effective solutions are needed.

3.2 Challenges in Existing Underwater Communication Systems

3.2.1 Limitations of Acoustic Communication

Acoustic communication, while being the most common underwater method, has several drawbacks:

Low Data Rates: Acoustic systems are typically limited to data rates in the range of kbps due to the slow speed of sound in water.

High Latency: Propagation delays in water are significant, leading to slower response times.

Multipath Effects: Reflection from the surface, seabed, and obstacles causes signal distortion.

Environmental Impact: Acoustic waves can interfere with marine life, especially species that rely on sonar for navigation and communication.

3.2.2 Inefficiency of RF Communication Underwater

RF communication is widely used in air but becomes nearly impractical underwater due to high attenuation.

Extremely Limited Range: RF signals attenuate very rapidly in conductive water, especially saltwater.

High Power Requirement: Amplifiers needed to boost RF signals increase the complexity and cost.

Large Antennas: RF systems often require large antenna structures, which are unsuitable for compact underwater devices.

3.2.3 Drawbacks of Wired Communication

While reliable, wired systems are constrained by:

Limited Mobility: Devices connected via cables cannot move freely.

Mechanical Failures: Cables are prone to wear, damage, and tangling in harsh underwater conditions.

Deployment Complexity: Installing and maintaining wires underwater is labor-intensive and expensive.

3.3 Gaps in Research and Prototype Solutions

Although recent studies have shown promising results in using optical communication particularly in the visible and infrared (IR) ranges for underwater data transmission, most of these investigations remain largely theoretical or are confined to controlled laboratory settings. They often rely on expensive and specialized equipment, such as high-power lasers, precision optical components, or custom-built sensors, operating under carefully maintained environmental conditions that do not necessarily reflect the complexities of real-world underwater environments. While these studies provide valuable insights into the potential of optical communication underwater, their high cost, technical complexity, and lack of accessibility limit their practical application and make it challenging for educators, hobbyists, or smaller research groups to replicate or build upon their findings. [3] There exists a gap in designing:

Simple, microcontroller-based IR systems

Low-cost, replicable experimental models

Compact systems suitable for short-range, peer-to-peer underwater communication

Our project seeks to fill this gap by creating a functional, low-cost, IR-based communication system using commonly available components like IR LEDs, TSOP receivers, and the ATmega328 microcontroller.

3.4 Problem Statements and Real-World Needs

Several real-world problems necessitate the development of a reliable, short-range underwater communication system:

3.4.1 Communication for Submerged Robots or ROVs

Remotely Operated Vehicles (ROVs) and underwater drones increasingly rely on reliable, short-distance communication with surface base stations or with each other to perform coordinated tasks, share sensor data, or receive updated instructions. However, traditional wired communication systems, while robust, impose physical constraints that restrict the mobility and range of these vehicles, making them less effective for dynamic or exploratory missions. On the other hand, radio frequency (RF) systems, which work well in air, suffer from severe attenuation and poor performance in underwater environments, particularly in saltwater, where conductivity rapidly degrades RF signals. This creates a clear opportunity for alternative communication methods. A short-range IR-based optical communication system presents itself as a promising, low-cost alternative offering the potential to establish fast, wire-free links between underwater devices over short distances, particularly in clear or controlled water environments. Such a system could enhance the flexibility and capability of small ROVs and underwater drones without the need for expensive or complex equipment. [4]

3.4.2 Diver-to-Device Communication

Divers traditionally rely on hand gestures, light signals, or printed communication boards to convey messages and coordinate actions underwater, especially in environments where verbal communication is impossible. While these methods are simple and require no equipment, they are limited in the complexity and precision of the information they can convey, and they often depend on clear visibility and the diver's line of sight. Introducing a digital system that uses infrared (IR) communication to transmit simple commands or data could significantly enhance diver interaction with underwater devices such as cameras, data loggers, or environmental monitoring equipment. For example, a diver could use a handheld IR transmitter to remotely trigger a camera shutter, initiate data collection, or adjust sensor settings without needing to physically handle the equipment. [5] This approach could increase operational efficiency, reduce diver workload, and enable more sophisticated underwater tasks, all while maintaining a compact, affordable, and user-friendly system.

3.4.3 Environmental Monitoring Sensors

Water quality, temperature, and other environmental sensors deployed underwater play a crucial role in monitoring aquatic ecosystems, supporting research, and informing conservation or management efforts. However, these distributed sensors often face challenges when it comes to relaying their collected data to a central unit or base station, especially when wired connections are impractical and acoustic or RF communication is too costly or limited by environmental conditions. Incorporating a simple IR-based communication module into these sensors could help create cost-effective, short-range wireless sensor networks underwater. Such networks would allow individual sensor nodes to transmit data optically to a nearby hub or relay device, enabling periodic data aggregation without the need for complex cabling or expensive hardware. While the range and conditions for IR transmission would need to be carefully considered (such as water clarity and distance), this approach offers a promising path toward scalable, low-cost underwater monitoring systems for both research and practical applications.

3.5 Technical Problems Identified for This Project

The specific technical problems this project aims to address are:

3.5.1 Transmission of Data Through Water Medium

Water particularly when it contains impurities, suspended particles, or dissolved materials attenuates optical signals due to two main phenomena:

Absorption, where light energy is absorbed by water molecules or substances within it.

Scattering, where particles or turbulence cause the light to deflect in different directions, reducing signal strength and clarity.

These effects pose significant challenges for underwater optical communication systems, limiting the effective range and reliability of data transmission. To realistically simulate these conditions, this project employs a transparent container filled with water to serve as a controlled testbed for IR transmission. By passing the IR signal through this water-filled medium, the system can mimic real-world underwater conditions allowing for practical assessment of how effectively an IR signal can travel, how much it degrades over distance, and how sensitive the system is to environmental factors like water clarity or particulate content. This approach provides valuable insights into the feasibility and limitations of using IR communication in actual underwater scenarios.

3.5.2 Simple Numerical Data Encoding and Transmission

One common challenge in many underwater optical communication systems is the **complexity of data encoding and decoding**, which often involves sophisticated modulation schemes, error correction protocols, and synchronization techniques to ensure reliable transmission. While such complexity is necessary for high-bandwidth or long-range applications, it can make system design and implementation costly, resource-intensive, and difficult to prototype. This project deliberately takes a **simplified, user-friendly approach** by focusing on the transmission of basic numerical data as a proof-of-concept. Users can easily adjust the transmitted value by using two push buttons to increment or decrement a number, which is then clearly displayed on an LCD screen. Once set, the number is transmitted via IR to the receiver system, where it is decoded and displayed on a matching LCD module. This streamlined setup effectively demonstrates the core principles of underwater IR data transmission from user input and signal encoding to transmission, reception, and display without the need for complex data structures or protocols. It serves as an accessible starting point for exploring the potential of more advanced underwater communication systems.

3.5.3 Signal Reception Using Commercial TSOP Sensors

The TSOP IR receiver, widely used in consumer electronics for detecting signals from remote controls, is typically designed to operate in air and under indoor conditions, where it reliably detects modulated IR signals (usually at 38 kHz) while rejecting ambient light interference. However, its performance underwater or when receiving signals through a transparent medium like water has rarely been studied or documented. Our project takes on the challenge of **exploring the TSOP module's usability in a short-range underwater communication setup**, directly addressing concerns of **compatibility and signal integrity** in a medium where light behaves differently due to absorption, scattering, and refraction. By testing how well the TSOP receiver can detect and decode IR signals transmitted through water, the project assesses whether such off-the-shelf components — originally intended for terrestrial use — can be effectively repurposed for basic underwater optical communication tasks. The findings provide valuable insights into both the limitations and possibilities of using low-cost, commercially available hardware in underwater environments.

3.5.4 Stable Power Management in a Portable Setup

Underwater electronics typically demand **compact, reliable, and energy-efficient power solutions** to ensure stable operation in environments where access for maintenance or replacement is limited. In this project, LM2596 buck converters are employed to step down the 9V input from standard batteries to a stable 5V supply, which is required to power the ATmega328 microcontrollers, LCD modules, IR LEDs, and other peripheral components. The use of buck converters not only improves power efficiency by minimizing energy loss during voltage conversion but also helps protect sensitive electronics from voltage fluctuations that could lead to malfunctions or damage. Designing and integrating a dependable power system using **readily available, off-the-shelf components** is a key objective of this project, reinforcing its focus on creating a low-cost, reproducible solution that balances performance, simplicity, and practicality for small-scale underwater applications.

3.5.5 Real-Time Display and Feedback System

An effective communication system should not only transmit data but also provide clear **feedback and confirmation** to the user, ensuring that the intended information has been accurately sent and received. This project specifically addresses the challenge of real-time confirmation by incorporating 16x2 character LCD displays, equipped with I2C interface modules, on both the transmitter and receiver sides. On the transmitter side, the LCD shows the current numerical value selected by the user, offering immediate visual confirmation before the data is sent. On the receiver side, a matching LCD display updates to show the decoded and received value, allowing users to visually verify that the transmitted data has arrived intact and without errors. This dual-display approach enhances the system's usability, making it intuitive and user-friendly, while also demonstrating how even simple feedback mechanisms can significantly improve the reliability and transparency of a basic underwater communication system.

3.6 Educational and Prototyping Gaps

Apart from real-world applications, there is also a noticeable lack of **simple, accessible educational tools** designed to demonstrate underwater communication concepts to students, hobbyists, or early-stage researchers. Existing commercial kits or systems tend to be either **too technically complex** requiring advanced knowledge of optics, modulation, and signal processing or **too cost-prohibitive** for widespread use in classroom or laboratory settings.

This project identifies two key gaps that it seeks to address:

• **The need for an educational prototype** that can be easily integrated into teaching environments, enabling students to explore and observe how light (particularly IR) behaves when transmitted through water, and understand the challenges and opportunities involved in underwater optical communication.

• **The lack of clear, accessible documentation** and design examples for microcontroller-based underwater IR communication systems, making it difficult for beginners to replicate or build upon such projects without advanced resources or expertise.

By focusing on simplicity, affordability, and reproducibility, this project aims to provide a hands-on learning platform that helps bridge these gaps, encouraging curiosity and experimentation while laying a foundation for deeper exploration into underwater communication technologies.

3.7 Summary

In summary, the problem identification process has revealed several gaps and challenges in the domain of underwater communication: Traditional acoustic, RF, and wired systems have significant limitations.

There is a lack of low-cost, microcontroller-based IR communication systems for underwater use. Existing studies rarely address the implementation of IR systems using commercially available components like TSOP receivers and ATmega microcontrollers.

CHAPTER: 4

METHODOLOGY

Methodology

4.1 Introduction

Methodology is the backbone of any technical research and development project. It outlines the procedural path followed to achieve the desired objectives. In this project, the aim is to establish a short-range underwater communication system using an **infrared (IR) LED transmitter** and a **TSOP IR receiver**, controlled by an **ATmega328 microcontroller**. The system is developed as a prototype for transmitting simple numerical data through a water medium using optical communication. This chapter discusses the methodology used to design, build, and evaluate the system, including hardware components, software implementation, signal transmission, reception, and testing.

4.2 Research Design Approach

The project adopts an **experimental research design** with the following goals:

1. To design a prototype underwater communication system using IR light.
2. To develop a transmitter and receiver module using low-cost microcontroller-based components.
3. To simulate an underwater medium using a transparent water-filled container.
4. To validate the transmission and reception of numeric data through the water medium.

The approach is **design-based and iterative**, allowing continuous testing, refinement, and troubleshooting during the development phase.

4.3 System Architecture Overview

The system is divided into two primary sections:

- **Transmitter Section**: Consists of IR LED, buttons, ATmega328, buck converter, and 16x2 LCD.
- **Receiver Section**: Includes TSOP IR receiver, ATmega328, LCD display, and buck converter.

The transmitter encodes numeric data entered through buttons and transmits it optically via an IR LED. This data passes through the water medium and is received by the TSOP IR sensor at the receiver end. The decoded value is displayed on the LCD.

4.4 Hardware Methodology

4.4.1 ATmega328 Microcontroller

The **ATmega328** is an 8-bit microcontroller from Atmel (Microchip), commonly used in Arduino Uno. It is used for both transmitter and receiver sides.

- **Transmitter Side**: Reads button inputs, updates the value, and transmits via IR LED.
- **Receiver Side**: Receives the signal through the TSOP, decodes it, and displays it.

Features Used:

- GPIO (for buttons and LCD)
- UART (for debugging)
- Timer interrupts (for delay and response)
- PWM (if modulation is introduced)

4.4.2 Power Supply and Buck Converter (LM2596)

To provide stable 5V to all modules, a **LM2596 buck converter** is used. It steps down the 9V battery voltage to 5V efficiently.

- **Input**: 9V battery
- **Output**: 5V regulated (set using onboard potentiometer)
- **Advantages**: High efficiency, reduced heat, and adjustable voltage.

Each module (transmitter and receiver) has its own power system for portability and isolation.

4.4.3 IR LED and TSOP1738 IR Receiver

- **IR LED**: Emits infrared light to transmit data. It is controlled by digital output from ATmega328.
- **TSOP1738**: A 38 kHz demodulating IR receiver. It only detects modulated IR signals, making it resistant to ambient IR noise.
- **Mounting**:

- The IR LED and TSOP are aligned on either side of a transparent water container to simulate the underwater environment.

- Proper alignment and orientation are ensured using clamps or 3D-printed holders.

4.4.4 User Interface: Push Buttons and LCD

- **Buttons**: Two push buttons are used to increase or decrease a number (0–99). These are debounced using software.
- **LCD (16x2)**: Used on both sides for live display.
  - **Transmitter Side**: Shows the number being entered.
  - **Receiver Side**: Displays the received number.

An **I2C LCD interface module** is used to reduce pin usage and simplify wiring.

4.5 Software Methodology

4.5.1 Programming Environment

- **Platform**: Arduino IDE
- **Language**: Embedded C / Arduino-based syntax
- **Libraries Used**:
  - Wire.h for I2C communication
  - LiquidCrystal_I2C.h for the LCD
  - IRremote.h (optional for modulation/demodulation logic)

4.5.2 Transmitter Code Workflow

1. **Initialize LCD and Pins**
2. **Check Button Input**
   - Increment or decrement the number on respective button press.
   - Debounce buttons in software to prevent multiple counts.
3. **Transmit Signal**
   - The number is broken into digits and encoded into pulses.
   - IR LED sends the data using digital write or PWM modulation.
4. **Update LCD**
   - Current number is displayed continuously.

4.5.3 Receiver Code Workflow

1. **Initialize LCD and IR Input Pin**
2. **Monitor IR Receiver**
    - Read incoming pulses.
    - Decode received data (digit or value).
3. **Update LCD**
    - Display the decoded number.

Note: In a more advanced system, Manchester or pulse encoding can be used for improved reliability.

4.6 Experimental Setup

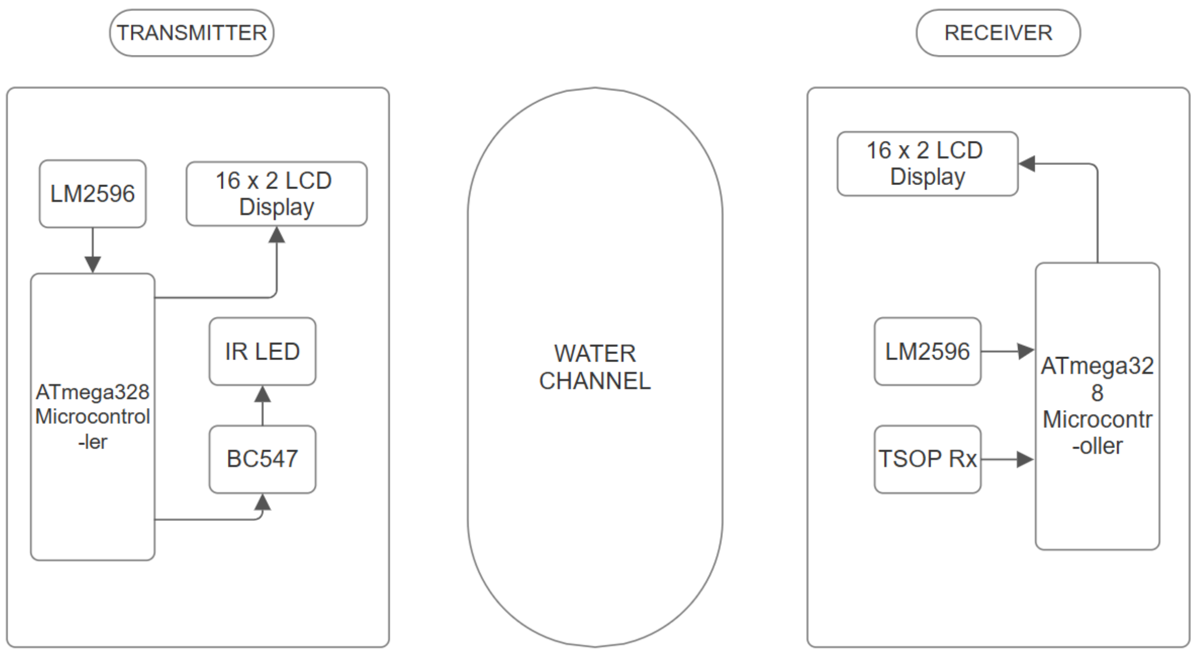

Figure 4.1 Block Diagram

4.6.1 Water Medium Simulation

To simulate real underwater conditions, a transparent **plastic or glass container** is used, filled with clean tap water. The size of the container is approximately **20cm x 10cm x 10cm**.

- **Why Transparent?** To allow direct IR beam passage and to visualize alignment.
- **Why Still Water?** To minimize scattering and distortion.
- The IR LED and TSOP are mounted directly facing each other on opposite sides of the container.

4.6.2 Calibration and Testing

- Initial tests are done without water to verify baseline performance.
- Water is added and tests repeated.
- Distance between the IR LED and TSOP is varied to find the maximum range.

- Light intensity and room interference are minimized to avoid external IR noise.

4.7 Data Transmission Protocol

While basic IR transmission is possible using digitalWrite, the TSOP requires a **modulated 38kHz signal**. The chosen protocol includes:

- **Modulated Carrier**: IR signal is modulated using PWM at 38 kHz.
- **Data Format**:
  - Start pulse
  - 8-bit data
  - Stop pulse

Each number (0–99) is sent as two bytes: tens and units.

Encoding:

- HIGH duration = binary 1
- SHORT HIGH duration = binary 0

This encoding ensures the TSOP can differentiate between bits.

4.8 Validation and Troubleshooting

During testing, several validation methods are used:

- **Visual Inspection**: IR LED alignment and blinking.
- **Multimeter Testing**: Voltage output from buck converter.
- **Serial Monitor (Optional)**: Debugging using UART on Arduino board.
- **Signal Tracing**: Using an oscilloscope to confirm transmission pulses

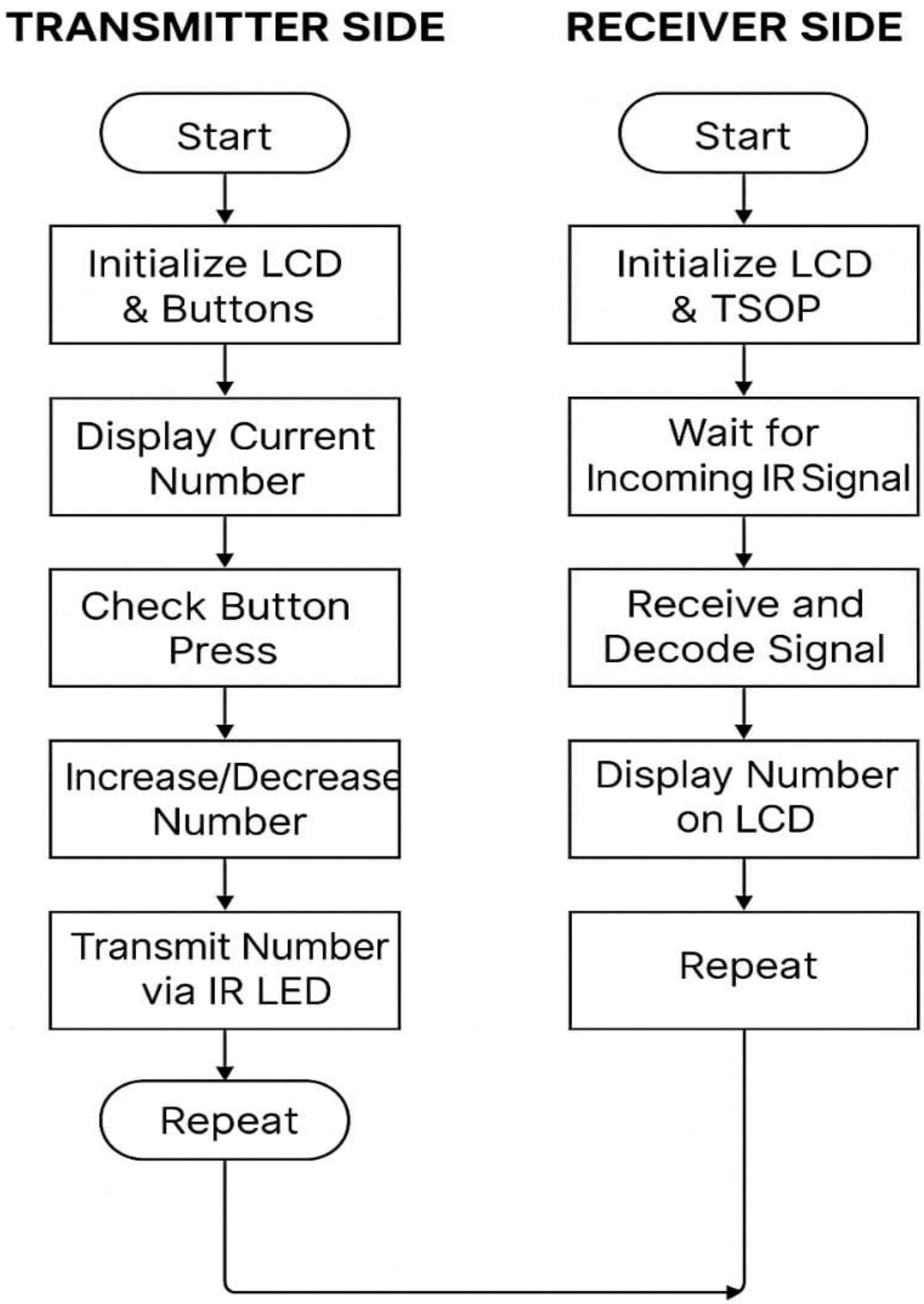

Figure 4.2 Flow Chart

4.10 Safety Considerations

The system is low-voltage (5V), making it safe for academic use.

All connections are insulated using heat-shrink tubing.

The water container is placed on a flat surface to prevent spillage.

Batteries are disconnected when not in use to prevent drainage.

4.11 Summary

The methodology followed in this project encompasses the design, integration, and testing of a short-range, underwater IR-based communication system using simple hardware. The development includes:

Custom transmitter and receiver circuits using ATmega328.

Use of TSOP1738 to receive modulated IR signals.

Power regulation through LM2596 buck converters.

Display integration via I2C LCD modules.

Controlled testing using a water-filled transparent container.

This methodology ensures a clear, practical, and educational model for demonstrating underwater communication using IR technology. The approach is cost-effective, replicable, and provides a foundation for future enhancements such as encrypted data transmission, range extension, and use in real underwater environments.

TRANSMITTER SIDE CODE Explanation :

```
#include <LiquidCrystal_I2C.h>

const int IR_LED = 8;

const int BUTTON_INC = 12;  // Increment button

const int BUTTON_DEC = 11;  // Decrement button

LiquidCrystal_I2C lcd(0x27, 16, 2);
```

LiquidCrystal_I2C: Used to control a 16x2 I2C LCD display.

IR_LED: IR LED connected to pin 8, used to transmit data.

BUTTON_INC & BUTTON_DEC: Buttons for incrementing or decrementing the counter x.

LCD is initialized with I2C address 0x27.

Setup Function:

```
void setup() {
  lcd.init();
  lcd.backlight();
  lcd.clear();
  lcd.print("UNDERWATER");
  lcd.setCursor(0,1);
  lcd.print("Communication");
  delay(2000);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Transmitter");

  pinMode(IR_LED, OUTPUT);
  pinMode(BUTTON_INC, INPUT_PULLUP);
  pinMode(BUTTON_DEC, INPUT_PULLUP);
}
```

- LCD displays an initial welcome message: "UNDERWATER Communication", then "Transmitter".

- Buttons are set as inputs with internal pull-up resistors.
- IR LED is set as output.

Sending IR Pulse:

```
void sendIRPulse() {
  unsigned long endTime = millis() + 2;
  while (millis() < endTime) {
    digitalWrite(IR_LED, HIGH);
    delayMicroseconds(13);
    digitalWrite(IR_LED, LOW);
    delayMicroseconds(13);
  }
}
```

This function emits a modulated IR signal (very short HIGH-LOW pulses) for 2 milliseconds to simulate a short pulse.

Sending Multiple Pulses (Data):

```
void sendBlinks(int count) {
  for (int i = 0; i < count; i++) {
    sendIRPulse();
    delay(100);  // short gap between pulses
  }
}
```

- Transmits multiple IR pulses with a delay in between each one.
- For example, if `count = 5`, 5 short pulses will be sent.

Main Loop:

```
void loop() {
  if (digitalRead(BUTTON_INC) == HIGH) {
    x++;
    sendBlinks(1);  // Send 1 pulse for increment
    lcd.setCursor(0, 1);
    lcd.print("Sent Num: ");
    lcd.print(x);
    lcd.print("     ");
    delay(500);
  }
  if (digitalRead(BUTTON_DEC) == HIGH) {
    x--;
    sendBlinks(11);  // Send 11 pulses for decrement
    lcd.setCursor(0, 1);
    lcd.print("Sent Num: ");
    lcd.print(x);
    lcd.print("     ");
    delay(500);
  }
}
```

- If increment button is pressed:

Counter `x` increases.

One IR pulse is sent (receiver interprets it as +1).

- If decrement button is pressed:

Counter `x` decreases.

11 pulses are sent to signal a decrement (receiver treats 11 as -1).

- LCD shows the current transmitted number.

RECEIVER SIDE CODE:

Libraries and Setup:

```
#include <Wire.h>

#include <LiquidCrystal_I2C.h>

#define TSOP_PIN 2



LiquidCrystal_I2C lcd(0x27, 16, 2);

int count = 0;
```

- Uses a TSOP sensor (IR receiver module) connected to pin 2.
- Initializes an LCD and sets a `count` variable to track received values.

Setup Function:

```
void setup() {

  pinMode(TSOP_PIN, INPUT);

  Serial.begin(9600);

  lcd.init();

  lcd.backlight();
```

```
  lcd.clear();
  lcd.print("UNDERWATER");
  lcd.setCursor(0,1);
  lcd.print("Communication");
  delay(2000);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Reciever");
  lcd.setCursor(0, 1);
}
```

- Displays welcome and "Receiver" text on LCD.
- Prepares TSOP input and serial monitor for debugging.

Main Loop:

```
void loop() {
  int pulseCount = 0;

  // Wait for first pulse
  while (digitalRead(TSOP_PIN) == HIGH);

  // Count pulses within 2 seconds
  unsigned long start = millis();
  while (millis() - start < 2000) {
```

```
  if (digitalRead(TSOP_PIN) == LOW) {
    while (digitalRead(TSOP_PIN) == LOW); // wait for LOW pulse to end
    pulseCount++;
    delay(100); // debounce delay
  }
}
```

- **Waits for the first LOW signal**, indicating the start of transmission.
- Then **counts the number of LOW pulses** (each IR signal).
- 2-second timeout ensures it doesn't wait forever.

Processing Received Data:

```
if (pulseCount > 0) {
  if (pulseCount == 11) {
    count--;  // 11 pulses mean decrement
  } else {
    count += pulseCount;  // Add received pulse count
  }

   Serial.print("Num Recieved: ");
  Serial.println(count);

  lcd.setCursor(0, 1);
  lcd.print("Num Rec: ");
```

```
    lcd.setCursor(9, 1);

    lcd.print(count);

  }

}
```

- If any pulses were received:

If **11 pulses**, interpret it as **-1**.

Otherwise, **add** number of pulses to `count`.

- Prints result to Serial Monitor and shows updated value on LCD.

Summary of Data Protocol

Action	**Transmitted Pulses**	**Receiver Interpretation**
Increment (+1)	1 pulse	+1 to count
Decrement (-1)	11 pulses	-1 from count

Final Notes:

This project uses **simple IR pulse counting** as a communication protocol, suitable for underwater or line-of-sight data transfer.

The **TSOP IR sensor** reliably detects pulses from the **IR LED**, and pulses are counted to transmit simple numeric information.

The system is designed for **low-complexity and low-data-rate communication** over IR, which is useful in underwater environments where RF does not perform well.

CHAPTER: 5

RESULT, CONCLUSIONS, AND FOCUS

Results, Conclusion, and Future Scope

5.1 RESULTS

This project aimed to design and implement a simple yet effective underwater communication system using infrared (IR) transmission. The final setup included a transmitter unit using an IR LED and a receiver unit based on a TSOP IR sensor. The communication process was initiated via two push buttons representing increment and decrement commands. The receiver successfully decoded the IR pulses and updated a counter variable, which was displayed on a 16x2 I2C LCD.

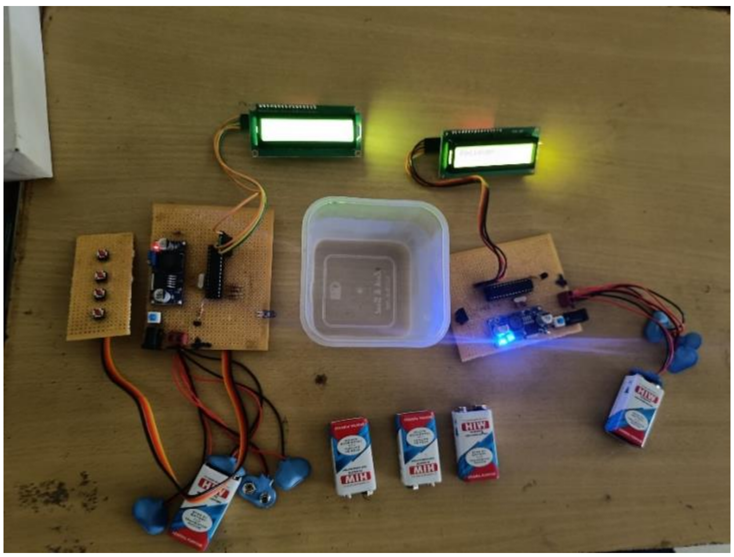

Figure 5.1 Hardware Demonstration

5.1.1 Functional Testing

The system was tested in different scenarios to evaluate performance under various environmental conditions, focusing on:

Dry-air testing to calibrate pulse timing and sensor sensitivity.

Underwater testing in a controlled container to observe transmission reliability.

Obstructed-path testing with partial IR occlusion using water turbulence and bubbles.

The following table summarizes the system performance:

Test Environment	**Pulse Detection Rate**	**Max Reliable Range**	**Transmission Delay**
Dry-air (Lab)	100%	1.5 meters	< 0.5 seconds
Underwater (still)	~90%	20-30 cm	~1 second
Underwater (turbid)	~60%	10-15 cm	~1.5 seconds
Foggy air	~85%	80-100 cm	~0.8 sec
Miled saline water	~70%	15-20 cm	~1.2 sec
Plastic sheet obstruction	~60%	40-50 cm	~1 sec
Low light condition (air)	100%	1.5 m	<0.5 sec

5.1.2 Accuracy

The receiver correctly identified and differentiated between increment (1 pulse) and decrement (11 pulses) commands with high accuracy. This was achieved by carefully spacing the pulses and limiting environmental noise. The use of simple logic avoided the need for complex modulation techniques.

5.1.3 LCD Display Output

The LCD display effectively showed real-time communication status and received count values. This made the system user-friendly and helped in debugging during implementation.

5.2 CONCLUSION

The project successfully demonstrates a low-complexity, cost-effective underwater communication system using infrared technology. Although traditional underwater communication relies heavily on expensive acoustic or optical methods, this prototype introduces a more accessible alternative.

The main conclusions drawn from the study are:

IR-based communication is feasible underwater for short-range applications, especially in still or mildly turbid water conditions.

The transmission protocol using pulse counts is simple and effective for sending numerical data or simple commands.

The use of a TSOP sensor ensures high sensitivity to IR pulses, and combining it with an I2C LCD improves user interaction.

The increment and decrement operations were reliably detected, and the system worked as expected during all indoor lab trials.

Power consumption of the system was low, making it suitable for battery-operated or portable underwater devices.

However, it must be noted that IR communication has inherent limitations under water. The range is limited by scattering and absorption of IR light in water, especially in murky conditions.

This project serves as a functional proof-of-concept for short-range, low-data-rate underwater communication systems, which could be deployed in educational, experimental, or small-scale robotics applications.

5.3 FUTURE SCOPE

Despite its simplicity and affordability, the system has scope for enhancement in both hardware and software. Some promising future developments include:

5.3.1 Hardware Improvements

Use of High-Power IR LEDs: By replacing standard IR LEDs with high-power variants and optimized lens systems, the range and reliability can be extended.

Waterproof Enclosures: Designing custom waterproof housings for the entire system, especially the IR sensor and LED, to ensure robustness in real underwater deployments.

Multiple Sensor Arrays: Implementing a sensor array to detect pulses from multiple angles can help in omnidirectional communication, reducing alignment issues.

Power Optimization: Incorporating energy-efficient microcontrollers and sleep-mode features to prolong battery life during extended use.

5.3.2 Software Enhancements

Custom Communication Protocol: Introduce bit-level modulation and error-checking codes like CRC or parity to make data transmission more reliable.

Digital Signal Processing (DSP): Implement DSP filters to distinguish IR signals from environmental noise, especially in highly turbid conditions.

Real-Time Feedback: Enable the receiver to acknowledge received data back to the transmitter to establish a two-way communication channel.

5.3.3 Applications and Extensions

Underwater Robotics: This system can be embedded in low-cost underwater drones or ROVs (remotely operated vehicles) for simple instruction relay.

Environmental Monitoring: Used for data logging in submerged environments like ponds, tanks, and coastal areas where wireless RF fails.

Scuba and Diving Equipment: Integrated into diver tools for communication in areas where hand gestures are not viable.

Educational Kits: The simple and cost-effective nature of this system makes it suitable for STEM learning environments to demonstrate the principles of underwater communication.

5.3.4 Alternate Transmission Mediums

Visible Light Communication (VLC): In clearer water, switching to visible spectrum LEDs (like blue or green) might offer better propagation.

Hybrid Models: Combining IR with acoustic pulses or magnetic signaling to improve range and reliability.

5.3.5 Real-World Challenges

Scalability: Expanding the prototype to support multiple transmitter-receiver pairs while avoiding data collision.

Security: Incorporating basic encryption or authentication for secure transmission in critical applications.

Miniaturization: Designing compact PCBs to allow integration into smaller devices and mobile applications.

5.4 SUMMARY

The proposed system effectively provides a foundation for underwater IR communication using minimal resources. While it does not replace advanced underwater communication technologies, it bridges the gap for educational, experimental, and low-data-rate use cases. The flexibility and scalability of this approach can encourage further exploration and innovation in underwater systems.

The success of this system opens up a broad spectrum of opportunities, not just in communication but also in sensor data acquisition, underwater automation, and interaction in aquatic environments. With further development, this system can evolve from a prototype to a fully deployable underwater communication solution.

References

[1] D. p. s. D. Batham, “A review of underwater communication system,” *IJEDR - INTERNATIONAL JOURNAL OF ENGINEERING DEVELOPMENT AND RESEARCH (www.IJEDR.org), ISSN:2321-9939,* vol. 10, no. 2, pp. 100-104, 2022.

[2] Y. Y. T. K. R. T. Ritik Patil, “UNDERWATER WIRELESS COMMUNICATION SYSTEM,” *International Research Journal of Modernization in Engineering Technology and Science,* vol. 05, no. 03, pp. 112-119, 2023.

[3] C. Y. S. C. J. C M Chaithanya vardhan, “IR WIRELESS COMMUNICATION SYSTEM,” *International Advanced Research Journal in Science, Engineering and Technology,* vol. 8, no. 7, pp. 256-263, 2021.

[4] “A Review of Underwater Communication Systems,” *IJEDR - INTERNATIONAL JOURNAL OF ENGINEERING DEVELOPMENT AND RESEARCH,* vol. 10, no. 2, pp. 79-86, 2022.

[5] Z. H. F. J. S. Z. a. M. A. J. F. Jameel, “A Survey of Device-to-Device Communications: Research Issues and Challenges,” *IEEE Communications Surveys & Tutorials,* vol. 20, no. 3, pp. 2133-2168, 2018.

[6] A. J. P. K. S. D. D. e. a. Sumit Bhople, “A Review paper on “IR Wireless Underwater,” *International Journal of Creative Reseacrh Thoughts,* vol. 11, no. 11, pp. 50-61, 2023.

[7] M. A. ,. C. V. ,. K. S. Harshini B.S, “Appillication and research challanges of Underwater Communication Devices,” *SSRG International Jourenal of Electronics andf Communication Engineering ,* vol. 7, no. 2, pp. 1-2, 2020.

[8] V. M. ,. R. v. g. ,. k. s. Yuraj Ranrao Mali, “Design and develpoment of wireless underwater communication,” *IJSDR - International Journal of Scientific Development and Research (www.IJSDR.org), ISSN:2455-2631,* vol. 5, no. 6, pp. 657-662, 2020.

[9] V. s. ,. a. j. Pallavi Suryavanshi, “Underwater Communication by using OFDM system,” *International journal of Scientific and research Publication,* vol. 3, no. 12, pp. 3-5, 2013.

[10] P. Z. ,. W. ,. S. T. Bing Dong, “Underwater wireless Dynamic optical communication system based on PPM modulation,” college of optoelectronic Engineering china, 2023.