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Proceeding Paper

Efficient Underwater Wireless Data Transmission Technique and Signal Processing †

Dur-e-Jabeen [1,*], Habib Shaukat [1], Mehwish Siddiqui [1], Sarah Ahmed [2], Muhammad Yasir Zaheen [3], Amad Ud Din ahmad [4], Hassan Ali Mirza [5] and Muhammad Sami [6]

[1] Electronic Engineering, Sir Syed University of Engineering & Technology, Karachi 75300, Pakistan; hshaukat@ssuet.edu.pk (H.S.); mehwishs@ssuetkhi.onmicrosoft.com (M.S.)
[2] Bio Medical Engineering, Sir Syed University of Engineering & Technology, Karachi 75300, Pakistan; saraha@ssuetkhi.onmicrosoft.com
[3] Computer Engineering, Sir Syed University of Engineering & Technology, Karachi 75300, Pakistan; myasir@ssuetkhi.onmicrosoft.com
[4] Biofotech Pvt Limited, Lahore 54000, Pakistan; amaduddin33@yahoo.com
[5] Jubilee Corporation, Karachi 74200, Pakistan; hasanalimirza@hotmail.com
[6] DuPont Opr. Pakistan Pvt Ltd., Citi Towers, 5th Floor, Shara e Faisal, Karachi 75350, Pakistan; syedmsami0@gmail.com
* Correspondence: durejabeen@ssuet.edu.pk
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Abstract: This paper is based on a project titled underwater acoustic communication in which communication is performed between transmitter and receiver side underwater using water as a channel; data are is transmitted through a piezo transducer underwater, which are then be received by a receiver, i.e., a wireless hydrophone. Signal processing and analysis are performed on the received wireless signals. Data reception and propagation are important parts on the receiver side, which involve conditioning and processing of the received signal. Morse code is used to detect the signals and processed data, which are then analyzed using MATLAB simulation software.

Keywords: underwater communication; wireless communication; transmitter; signal processing; hydrophone

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1. Introduction

As working underwater is a challenging task [1,2], the demand for and characteristics of underwater communication systems [3] have intensified in the past few years. The aim of this project was to build a system that can be used for different applications. The requirement to transmit signals from underwater sensors and instruments to a surface location has been made clear [4]. An auditory solution is necessary, since sending data through a cable is frequently not practical.

The most common method used to communicate underwater is the acoustic approach [3–5], where a hydrophone picks up pressure signals and changes them back into electric signals after receiving them from a sound projector. Dual-function sound hydrophones are frequently referred to as transducers; nevertheless, most devices are tailored to one of the two functionalities. Both hydrophones and projectors are mostly built using piezoelectric material. Sound has, by far, the largest underwater propagation range relative to the used transmission power.

Therefore, in our project, acoustic communication is applied, and water is used as a channel, i.e., it takes the acoustic signal from the transmitter and delivers it to the receiver for further processing. Time variations of the channel [3], attenuation, reduced bandwidth, and multipath propagation issues makes underwater communication difficult, especially over elongated distances.

Underwater wireless communication can be compared with terrestrial communication at low data rates, although underwater communication uses acoustic waves instead of electromagnetic waves. Therefore, it is not possible to receive unmodified data without applying filters to counter effects causing discrepancies. Figure 1 [6] shows an underwater acoustic communication system (UAC).

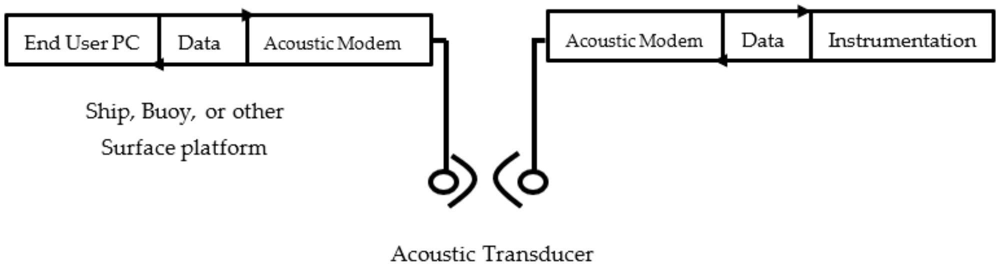

Figure 1. Acoustic communication system [6].

Underwater communication is a rapidly expanding topic of study that also extends to related fields like the military and business sectors [1]. Unmanned or autonomous underwater vehicles (UUVs or AUVs, respectively) can operate without interference due to their ability to sustain signal transmission, eliminate physical connections, and receive data from submerged equipment without the need for human interaction [7].

A transmission technique for underwater acoustic communication should be easy to implement, cost-effective, reliable, computationally efficient, energy-efficient, portable, encryption-capable, and applicable over long ranges, with the ability to easily retrieve transmitted signals in their original form. We were able to use Morse code for underwater communication but encountered difficulties in retrieving the transmitted signal in its original form; therefore, we applied digital filters using MATLAB software. Figure 2 shows the basic block diagram of the project.

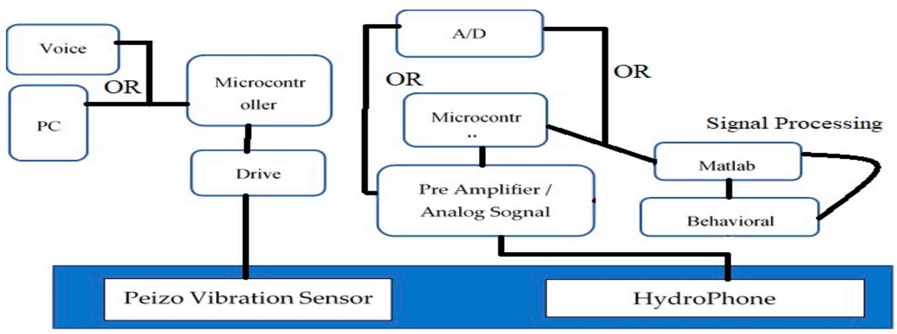

Figure 2. Block diagram of underwater signal processing.

2. Morse Code Technique

2.1. Overview

Text information can be transmitted using Morse code [8], which involves the use of a series of the on–off tones, which can also be identified with lights or clicks that can be directly detected by a skilled trainer or examiner without a special apparatus. International Morse Code uses standardized sequences of short and long signals called "dots" and "dashes" or "dots" and "dahs" to represent the ISO basic Latin alphabet, some additional Latin letters, the Arabic numerals, and a small set of punctuation and process signals [9–11]. Each letter or number is represented by a particular arrangement of dots and dashes. A dash lasts for three times as long as a dot. Each dot or dash is followed by a brief pause that lasts exactly as long as a dot. The standard table of Morse representation of numbers and characters is shown in Figure 3.

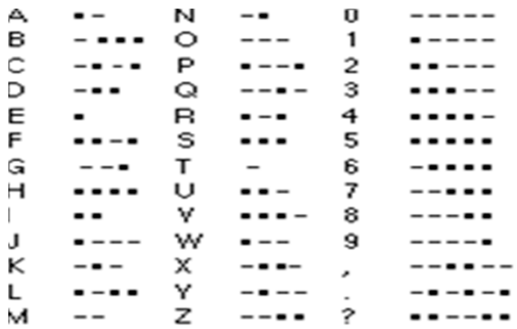

Figure 3. International Morse code representation [9].

2.2. Transmitter Hardware

Hardware was needed to transmit the message digitally, so we used an Arduino ATmega-1280 as a D/A converter, with an LCD display to show the data sent by the computer. The objective was to simultaneously beep and display the letters, numbers, and a few key punctuation marks in the correct order, followed by 50 random letters. The entire procedure was then repeated. The combination of beeps, flashes, and an LCD display is a useful method to help people remember Morse code [12]. A piezo buzzer was fully sealed and immersed in water for the successful production of sound beeps to be received by a hydrophone on the receiver end.

2.3. Hydrophone

An underwater microphone called a hydrophone is used to record or listen to underwater sound. The majority of hydrophones are built on the basis of a piezoelectric transducer, which produces electricity when exposed to changes in pressure. Since sound is a pressure wave, these piezoelectric materials or transducers can transform a sound signal into an electrical signal [13–17]. LAB-40 [13] is a robust and extremely sensitive acoustic wave (sound) sensor that we used for our experiment. LAB-40 was built with a wide dynamic range of amplitude, capturing everything from the sound of the tiniest fish to that of whales, dolphins, high-pressure acoustic waves from enormous ships, heavy explosives, etc., without overloading.

2.4. Receiver Hardware

As the hydrophone was directly subjected to the output, a special circuit was needed to translate the sounds of beeps recorded by the hydrophone and to understand the received message. A schematic diagram of the hydrophone used in this study is shown below in Figure 4. The device was designed with an embedded system that can decode Morse code and display the decoded message on a screen.

First, a hydrophone (that receives the sound signal) was connected between VCC voltage and the ground. Since the received sound signal had a very small magnitude, an operational amplifier was connected to the microphone by a coupling capacitor (C1) in order to amplify the sound signal to an appropriate magnitude. Then, the output of the op amp was connected to the ADC (analog-to-digital converter) pin of the microcontroller by a coupling capacitor (C2). In addition to the capacitor, a pull-down resistor was connected to the ADC pin in order to prevent noise from interfering with the signal. Furthermore, a pulse switch was connected to a pin of PORTB of the microcontroller and VCC voltage to allow the user to control the activation of the circuit. Finally, an LCD display was connected to the microcontroller [18,19].

As working underwater is a challenging task, the demand of for underwater communication systems has intensified in the past few years. The goal of this project was to develop a system to transport signals from underwater sensors and instruments to a surface location, which is necessary in many subsea applications. An auditory solution is necessary, since sending data through a cable is frequently not practical. The objectives of the project are as follows:

- Underwater data transmission;
- Underwater wireless data reception;
- Data reception through a hydrophone;
- Determination and analysis of the mechanisms involved in data signal processing;
- Use of a microcontroller board for A/D conversion and operational control of other components;
- Analysis of digitally converted data;
- Application of filtration algorithms to the received signal using MATLAB;
- Morse code translation on both the transmission and receiving sides to verify data propagation.

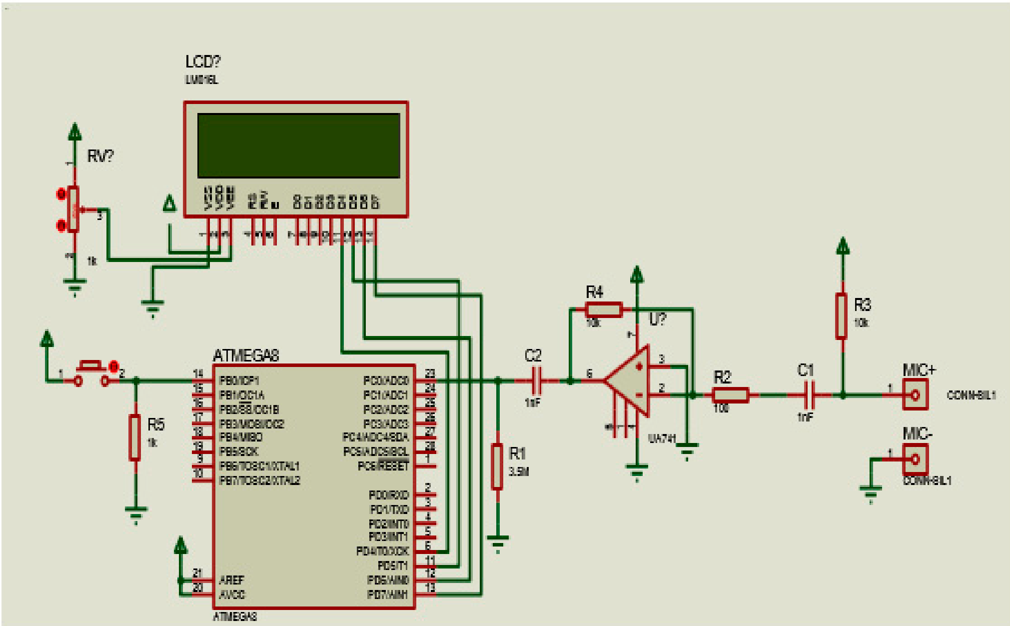

Figure 4. Schematic representation of the proposed Morse code interpreter.

3. Analysis of Received Data

Due to differences in noise and interference factors, as well as the high sensitivity of the hydrophone used in this study, the resultant signal was distorted. Therefore, we applied filters to restore the form of the originally transmitted signals. Figure 5 shows the signal received by the hydrophone without filters.

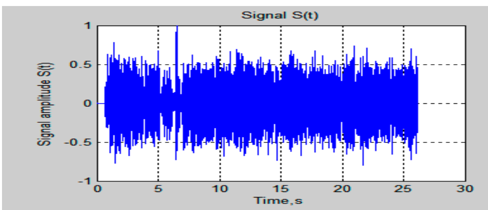

Figure 5. Signal received by the hydrophone.

3.1. Elliptical Filter

A signal processing filter known as an elliptic filter exhibits ripple behavior that is equalized in both the pass band and the stop band. No other filter of equal order can, for the given values of a ripple (whether the ripple is equalized or not), achieve a faster transition in gain between the pass band and the stop band because the amount of ripple in each band is individually adjustable, as mathematically expressed by Equation (1).

$$G_n(\omega) = \frac{1}{\sqrt{1 + \epsilon^2 R_n^2(\varepsilon, \omega/\omega_o)}} \quad (1)$$

Figure 6 shows the signal received by the hydrophone after applying an elliptical filter and LAB-40, as shown in Figure 7.

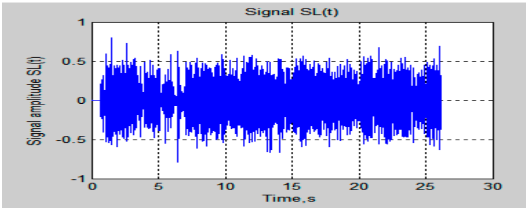

Figure 6. Received signal after applying an elliptical filter.

Figure 7. LAB-40-20 hydrophone [13].

3.2. Butterworth Filter

A form of signal processing filter called a Butterworth filter is constructed to have as flat of a frequency response as feasible in the pass band, also known as a "maximally flat magnitude filter". The frequency response of a Butterworth filter tends towards zero in the stop band and is maximally flat (i.e., has no ripples) in the pass band, as mathematically expressed by Equation (2).

$$G^2(\omega) = |H(j\omega)|^2 = \frac{G_o^2}{1 + \left(\frac{\omega}{\omega_c}\right)^{2n}} \quad (2)$$

4. Conclusions

Our study shows that the Morse code technique can be used to achieve underwater communication, with many possible applications. The Morse code technique can be used to transmit any textual data using sound waves. External noise should be minimized when transmitting and receiving. We used a hydrophone that is sensitive enough to pick up long-distance noises and interference. Elliptical filters are suitable for use on audio signals, as they can be efficiently applied and are always stable. Butterworth filters achieve the best filtering response, with no ripple effect has observed in the passing and rejecting frequency bands.

Author Contributions: D.-e.-J. worked on the concept as a whole, the simulation along with H.A.M., A.U.D.a. and M.S. (Muhammad Sami); H.S. handled the writing and formatting; M.S. (Mehwish Siddiqui) and S.A. provided assistance with the introduction; M.Y.Z. reviewed and examined the formatting of the paper; D.-e.-J. and H.S. wrote the final results. All authors have read and agreed to the published version of the manuscript.

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