Low-Cost Underwater Wireless Communication System Development Using Piezo-Ceramic Transducer

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***Abstract*—In recent years, the need for reliable, short-ranged underwater wireless communication has been proliferated because of the surge in underwater exploration. Underwater Wireless Sensor Networks (UWSN) can be used in vehicles and sensors to perform collaborative monitoring and data collection task. Due to the high density and contamination, limited bandwidth, high propagation delay, media access control, and power constraint underwater communication is a very challenging task. Researchers developed different research methodologies to overcome this problem. In this paper, an acoustic communication-based system is proposed by using Piezo-Ceramic transducers and practically developed. The acoustic wave can travel easily in water without much attenuation. Piezo-Ceramic transducer creates vibration according to the electrical pulses and does not need much modification of real data signal. This paper describes a wireless low-cost acoustic system for underwater communication. The system is built with some filters and amplifiers and power booster circuits. Finally, a cost effective underwater communication system is proposed that has been successfully implemented on a submarine bot.**

***Keywords*—Acoustic system, Underwater communication, Power amplifier, Signal Processing, Receiver, Transmitter, Ultrasonic transducer.**

I. INTRODUCTION

A commonly used electromagnetic signal, radio signal's electromagnetic wave cannot pass through the water smoothly due to high attenuation and it's strength decrease and which is noticeable in the water. Optical signal attenuate for reflection, dispersion, etc. But sound wave can propagate through the water very well, so an acoustic system can be used to overcome this problem. The underwater communication system can be used to communicate with a submarine, in marine research, oceanography etc[1]. In recent years, rapid progress has been made in clean deep water communication and shallow water communication but it is considered very challenging. High-speed communication in the underwater acoustic channel is very difficult because of some factors such as multi-path propagation, small available bandwidth and high signal attenuation co-factor, refractive properties of the medium, severe fading, large Doppler shifts [2]. The available bandwidth in an underwater acoustic communication channel is severely limited for transmission loss which increases with both frequency and range[3]. An ultrasonic transducer is used here to send and receive data for reducing attenuation co-factor. In recent years many research works are done for underwater communication. For example, the Persistent Littoral Undersea Surveillance Network (PLUSNet) describes multi-sensor and multi-vehicle antisubmarine warfare (ASW) technique for underwater communications[4]. A short-range shallow water network is proposed for observing pollution in Newport Bay, CA[5]. A network of acoustic modems is proposed for low range, low power acoustic communications for seismic monitoring system development[6]. In this paper, in order to make underwater communication smooth a low power consumption digital acoustic system and cost effective underwater communication system is proposed and developed. Our proposed system is a new acoustic technology system in the world of underwater communication which is different from others and helpful for smooth underwater communication. Our underwater system consists of a transmitter, receiver, voltage booster, power amplifier and signal processing unit. In section II total system overview is discussed, Section III transmitter circuit full system is discussed, Section IV receiver circuit is discussed, Section V data analysis, difficulties and its solution and result analysis are discussed, Section VI conclusion section, here our future work and overall review of paper are discussed. Our main focus is to make this system cost effective, according to data Linkquest, Benthos, and DSPComm underwater communication system cost is more than $8000 [7]. But we make some change in our ultrasonic transducer to use it properly and also design our transmitter, receiver, voltage booster and power amplifier circuit so that cost will be minimized and the total cost to make our underwater wireless communication system is $625. Some problems are found when we started working with the ultrasonic transducer. Authors will describe the problems and their solutions in different sections.

II. SYSTEM OVERVIEW

The present work demonstrates a stable low-cost underwater wireless communication system. It has been successfully tested on eight feet long water pool. The communication system is divided into two parts, namely- transmitter and receiver. The transmitter consists of three stage power amplifier. On the other hand, the receiver consists of three stage noise filter and three stages signal amplifier. A custom made transducer is used in both receiver and transmitter of the system. Piezo Ceramic Transducer named SMC20D17H5 is used which costs about $35.

Fig. 1: Piezo-ceramic Transducer without coating (left) and with coating (right)

This ultrasonic transducer [8] is used for transmitting and receiving data. If an electrical (voltage) signal is applied to it, it generates radial mode vibration and if it senses vibrations, it generates an analog electrical (Voltage) signal. It has very low internal damping. When an electrical pulse is applied, it takes 4-5 cycles to propagate the wave. Its typical output impedance is 50 Ohms and the center frequency is around 47KHz. It can create radial mode vibrations means sound waves. But the materials used in the transducer (silver electrode) is very sensitive to the water at the presence of voltage. When 40v DC voltage is applied to the silver electrode of the ultrasonic transducer, the electrode starts to react with the water and within a few minutes, it has been damaged completely. To solve this chemical reaction problem, a resin coating is applied to encapsulate the silver electrode from the water and the problem is solved.

It is tested on a 100uV input signal & 15V (p-p) output signal is obtained.

III. Transmitter

In this section, transmitter converts electrical signals into ultrasounds and this ultrasonic sounds can propagate through the water easily. Transmitter unit can be divided into four stages:

1) Signal processing
2) Voltage booster
3) Power amplifier
4) Transducer

A. Signal processing

First of all the data is converted into a character string and send to the main processing unit of the transmitter, which is actually a micro-controller. The character string is converted into an 8-bit binary number. The 8-bit binary is divided into two 4-bit binary segments.
A start bit is added to those 4-bin binary segment separately to make the starting clear to identify and error detection.

B. Voltage Booster

For long range transmission, ultrasonic transducer requires higher voltage. As the primary power is supplied from a 12v battery, the voltage has been boosted to 40v to increase the range. The is LM2577 is used for the boosting purpose [9].

C. Power Amplifier

For power amplification, a boosted voltage from the boost converter is used. As a transmitter transducer requires enough power to deliver the signal through the water so Darlington pair circuit is used to increase the current. [10].

IV. Receiver

The receiver converts the ultrasonic sound signals into electrical signals. The receiver is a very high gain multistage signal amplifier. The receiver unit can be divided into some stages :

1) Transducer
2) Amplifier
3) Filter
4) Clipper
5) Microcontroller

It is a three stage amplifier. It's Gain is more than 100000. It has been tested on 100uV to 15 Volts. It has some high pass and low pass filters.

A. Amplifier

Three stage high gain amplifiers are used. In the first stage, the signal is amplified by a transistor PN2222. To determine the gain following equations are used[11].

$$Gain = \frac{V_{out}}{V_{in}} = \frac{\triangle V_E}{\triangle V_B} = -\frac{R_E}{R_C} \tag{1}$$

Then the signal is passed through a bandpass filter. In the second stagethe pre-amplifier's signal is amplified again by an op-amp LM318. Finally, this signal reached to the third stage through another bandpass filter and amplified to an output of peak to peak 12-15 volt.

V. Data Transfer Process

Frequency Shift Keying (FSK) modulation is used for the underwater communication system.

- 4 bit communication system is used (can be extended to 8 bit).
- Start bit: 47kHz frequency, 3 clock cycles time.
- Binary 0: 47kHz frequency, 1 clock cycles time.
- Binary 1: 47kHz frequency, 2 clock cycles time.

In the developed system every clock cycle uses 47 kHz frequency for 50 ms. Here 50 ms is the optimal time for that carrier frequency as lowering time will cause more distortion. Start-bit contains 3 clock cycle, Binary 0 and 1 take 1 and 2 clock cycles and there is a gap one cycle between every bit transmission. So the total time is,

*Maximum time = 50*start bit + 50*4*binary 1 + 50*4*Gap*
*or, Maximum time = (50*3 + 50*4*2 + 50*4*1) ms*
or, Maximum time = 750 ms
*So, time for 1-byte (8-bit) = 750*2 ms = 1500 ms.*
So, The minimum data rate = 1/1.5 byte/second = 0.67 byte/second

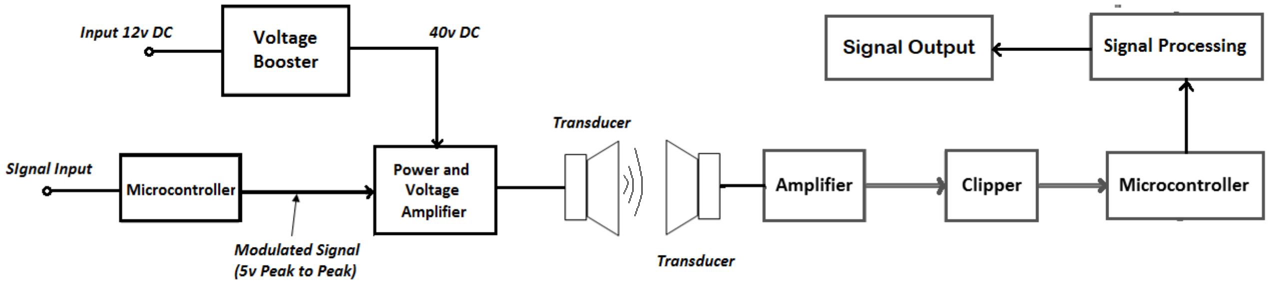

Fig. 2: Block diagram of one way signal transmission & receiving system.

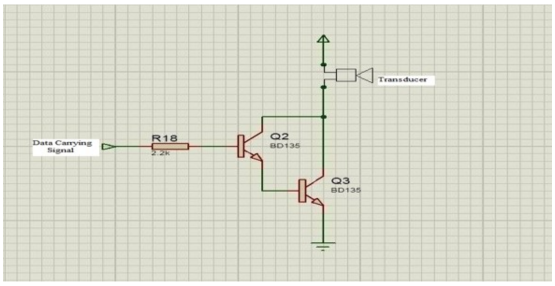

Fig. 3: Power Amplifier Circuit Diagram

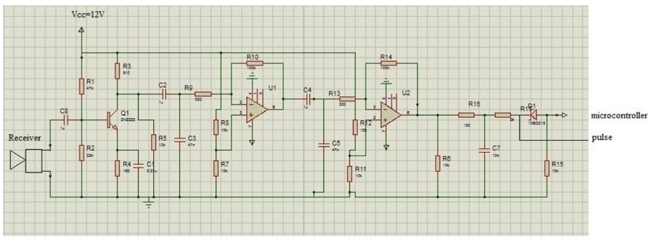

Fig. 4: Signal Receiver Circuit Diagram

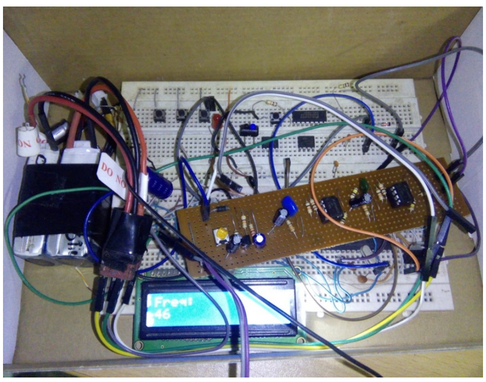

Fig. 5: Receiver Circuit Setup

A. *Command flow diagram of data transmitter*

In figure command flow diagram of data transmitter is shown.

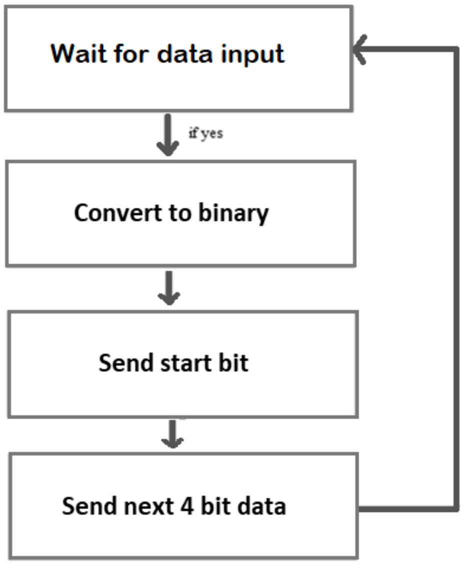

Fig. 6: Flow diagram of data transmitter (used in submarine bot)

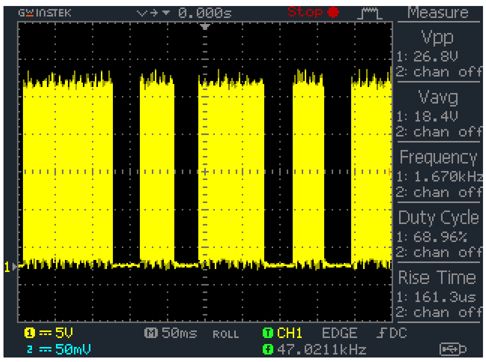

Fig. 7: Transmitted Signal

B. Command flow diagram of data receiver

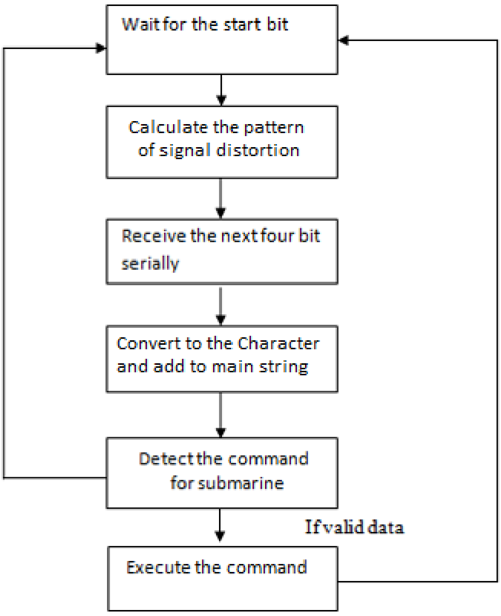

Fig. 8: Flow diagram of data receiver (used in submarine bot)

In figure command flow diagram of data receiver is shown.

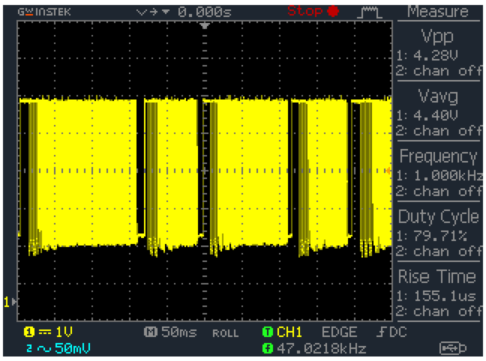

Fig. 9: Received Signal

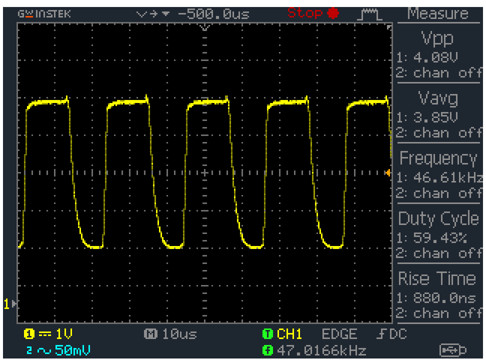

Fig. 10: Received Signal

C. Error Correction

The start bit is predefined and is known to the transmitter and receiver unit. If any distortion occurs, it affects both the start-bit and data bit in the same way. Calculating the distortion in the start-bit, an algorithm is developed to attempt a recovery in all individual bits. However, the recovery can work on only for a certain amount of distortion.

VI. Conclusion

In this work, main focus was to establish a smooth communication for the underwater acoustic channel. Frequency Shift Keying (FSK) modulation technique is used here for data transmission. Four bit communication system is developed and studied here. The data transfer result is very smooth which has been seen shown in the oscilloscope graph. The future plan of this project is to increase the range of communication distance by implementing powerful voltage booster and making the error correction algorithm more efficient and also working with higher frequency to get increased data transfer rate.

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References

[1] Chitre, M., Shahabudeen, S. and Stojanovic, M., 2008. Underwater acoustic communications and networking: Recent advances and future challenges. Marine technology society journal, 42(1), pp.103-116.

[2] Ling, J., Yardibi, T., Su, X., He, H. and Li, J., 2009. Enhanced channel estimation and symbol detection for high speed multi-input multi-output underwater acoustic communications. The Journal of the Acoustical Society of America, 125(5), pp.3067-3078.

[3] Stojanovic, M., 1996. Recent advances in high-speed underwater acoustic communications. IEEE Journal of Oceanic engineering, 21(2), pp.125-136.

[4] Grund, M., Freitag, L., Preisig, J. and Ball, K., 2006, September. The PLUSNet underwater communications system: acoustic telemetry for undersea surveillance. In OCEANS 2006 (pp. 1-5). IEEE.

[5] Jurdak, R., Lopes, C.V. and Baldi, P., 2004. Battery lifetime estimation and optimization for underwater sensor networks. IEEE Sensor Network Operations, 2006, pp.397-420.

[6] Wills, J., Ye, W. and Heidemann, J., 2006, September. Low-power acoustic modem for dense underwater sensor networks. In Proceedings of the 1st ACM international workshop on Underwater networks (pp. 79-85). ACM.

[7] LinkQuest, Inc. Underwater Acoustic Modems[Online].

[8] Lee, S-H., and T. J. Royston. "Modeling piezoceramic transducer hysteresis in the structural vibration control problem." The Journal of the Acoustical Society of America 108.6 (2000): 2843-2855.

[9] Cao, Xinping, et al. "Electromagnetic energy harvesting circuit with feedforward and feedback DCDC PWM boost converter for vibration power generator system." IEEE Transactions on Power Electronics 22.2 (2007): 679-685.

[10] Sidney, Darlington. "Semiconductor signal translating device." U.S. Patent No. 2,663,806. 22 Dec. 1953.

[11] Jeppson, K.O., 1994. Modeling the influence of the transistor gain ratio and the input-to-output coupling capacitance on the CMOS inverter delay. IEEE Journal of Solid-State Circuits, 29(6), pp.646-654.