



Ultrasonic Low Power Energy Aware Acoustic Data Modem for Underwater Data Communications in Underwater WSN

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Abstract – In the past years we have seen many developments and research have been done on Underwater Acoustic communication due to its applications as in military, disaster prevention, and objects, monuments and other resource detection inside the sea. Since there's a vast application of this, so underwater research work should be further investigated and designed to make further improvement in it. However, many researches are also going on to develop communication technique in underwater sensor networks. Previously underwater communication done by Radio frequency but RF-based communication is not much successful because of some drawbacks. First one is that radio waves need large antennae and high transmission power. And due to this low transmission power its limit is also very limited and we can't receive good signal if its range increase more the 120cm, finally we have concluded that if we want Underwater communication then Acoustic data communication is the best technique in comparison to Radio wave and Ultrasonic . Our aim is to develop an acoustic modem for underwater communication, which will be an energy concern, and we also use Low power and increase the data rate. It is so because we know that it's very tough to recharge the battery deep inside the sea. As a consequence we should design an acoustic modem which uses low power or low energy and its better that the modem cost should be low.

Keywords— Acoustic, Underwater communication, Acoustic modem, Underwater transducer, Ana log transeiver.

I. INTRODUCTION

Continuous developments in the field of AUWDC have made its component easily available smart and tiny. Wireless sensor networks in water can provide us large amount of data and information deep inside from the sea. It also provides us a vast area of research over it, due to its wide application. Its application not only limited up to the military or navy purpose but it can be used for disaster prevention caused due to water as T-Tsunami, Pollution alert, deep inside resource detection, Seismic monitoring, Ocean currents monitoring, Autonomous underwater vehicle etc. As its application widely increased so underwater sensor networks have been further investigated,

however research have been also conducted to improve the communication technique.

Typical RF based communication is not appropriate in an underwater environment for two reasons.

- Radio waves require large antenna and high transmission power.
- The Berkeley Mica 2 Motes, the most popular experimental platform have been reported to have a transmission range of 120cm in underwater at 433 MHz.

So acoustic or ultrasonic wave should be used for underwater communication rather than a radio wave. So for underwater communication the objective is to develop an acoustic modem where we have to consider an energy aware acoustic modem. This is because the battery cannot be recharged underwater as well as in a terrestrial environment. Thus the acoustic modem has to be designed with low power. We have implemented an energy aware acoustic modem.

Main contributions of the paper are as:

- Low power based acoustic modem is developed. The modem operates with a 3.3 V power supply.
- The modem is of low cost with the capability for digital data communication. As there is no existing modem with this capability based on low cost so our modem is significant in this respect.

It provides the basis for a ubiquitous device underwater as well as in terrestrial environment i.e., the modem is smarter, smaller and cheaper.

There are 3 main components for underwater acoustic modems:

- An underwater transducer

- b) An analog transceiver
- c) A digital platform for control and signal processing.

The remainder of this paper is organized as: Acoustic modems work is related in section 2. Design principles and a hardware implementation of an acoustic modem is described in section 3. Homemade transducer is described in section 4 along with its electrical and mechanical properties determined experimentally. Section III describes the design of our analog Transceiver and Section IV describes the design transceiver. We present experimental results in Section V and compare the power and cost of our modem to existing modem designs in Section VI. We conclude with a discussion on future work in Section 4 describes underwater communication using software. The performance evaluation via underwater experiment is presented in Section 5. The comparisons and design challenges are provided in Section 6. In Section 7, we give some conclusions and future work.

II. RELATED WORK

Many researchers have given significant attention to underwater acoustic communication. Commercial acoustic modems are usually bulky and expensive. They are not designed with low power and consume large amount of energy. Thus we concluded that long lived sensor networks over battery powered nodes could not be implemented. In our project we focus on a low power and low cost acoustic modem. [1] There are acoustic modems designed with low power such as CORAL. It uses special acoustic hardware which consists of piezo transducers, a microcontroller based architecture and interface circuitry. The difference between CORAL and our modem is the power supply. While the power supply of CORAL is 5V, the power supply of our modem is 3.3V. So a Mica2 Sensor Board was proposed by the authors. Our modem uses ultrasonic sensors and its power supply is 3.3V. Also by taking the underwater test, it proves, itself, with underwater usage.

III. HARDWARE IMPLEMENTATION OF ACOUSTIC

WE NOW DISCUSS THE DESIGN PRINCIPLES OF AN ACOUSTIC MODEM. THESE PRINCIPLES ARE USED TO PERFORM UNDERWATER COMMUNICATION EFFECTIVELY.

(a) Low power based modem: Sensor networks composed of sensor nodes are based on a low-power design. Batteries cannot be recharged underwater. Thus, to allow the long-

lived operation of sensor nodes, we have to design a low-power modem.

(b) Low-cost based modem: Commercial acoustic modems are usually bulky and expensive. So it did not allow for much wider deployment. We, therefore have to make a low-cost modem for wider dissemination.

(c) Modem with the capability for digital data communication: Analog data such as voice has been sent for underwater communication. There has been no underwater communication using a microcontroller which processes digital data. So many researchers have investigated the same by sending digital data. So we have to develop an acoustic modem to communicate digital data by means of a microcontroller.

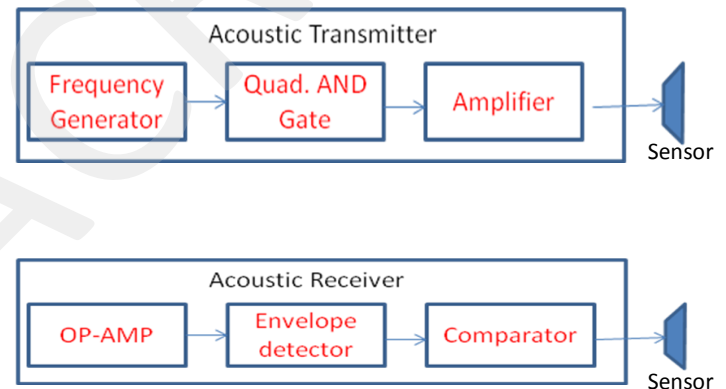


Fig: 1- Acoustic Hardware Model

Our acoustic modem is divided into two main parts:

(a) an Acoustic Transmitter and an Acoustic Receiver
Details about the ultrasonic transmitter and receiver are explained in the next section in which we can understand the basic function of Acoustic Transmitter and Receiver.

3.1 Acoustic Transmitter and Receiver

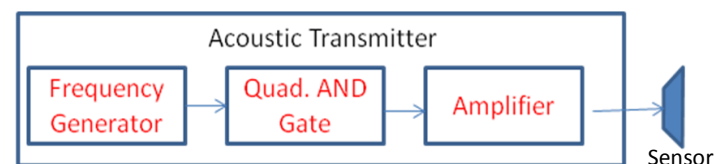


Fig: 2-Acoustic Transmitter

Acoustic transmitter consist of four parts namely Frequency Generator, Quad. AND gate, Amplifier and Acoustic sensor. Frequency generator generates a frequency of 40 KHz and further on a speed of 9.6Kbps is also generated but since this speed is too much high and will generate noise, so it's converted into 1.2Kbps by software coding. Now Quad AND gate is used to combine the generated frequency with 1.2Kbps speed and then it goes to Amplifier which is used to amplify this signal before transmit ion, and thus the amplified signal transmitted to sensor.

Acoustic Receiver receives this signal and then it first goes to OP-AMP.

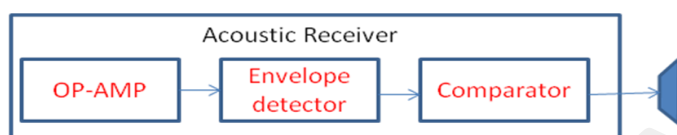


Fig: 3- Acoustic Receiver

Since the received signal at the receiver end is minute and it is to be amplified before processed or used. OP-AMP is used to amplify that signal so that receiver use this signal and display a good digital signal, then Envelope detector detect the original signal from the Amplified signal and further processed that signal which is to be used. Then the signal is further processed to the Comparator which is used to remove the noise which is present in the remaining signal. Then the noise free signal is transmitted to the receiver end Acoustic sensor and thus the received message is shown on the receiver side system. To display the message on the system Analog system is to be converted into digital signal which is done by the TTL (Transistor-transistor Logic). To regenerate data software is used at the sensor Node or we can say that it is done by coding.

IV. TRANSDUCER

Here we describe the design of our homemade transducer and explaining the reasons behind the selection of its Piezo-ceramic, urethane compound, and wire lead. Then the transducer's electrical and mechanical properties are presented which are used to govern the rest of the modem design.

A. TRANSDUCER DESIGN

Piezoelectric materials are used to make underwater transducers. Transducers are usually Omni directional in the horizontal plane to reduce reflection off the surface and bottom for underwater communication. This is especially important for shallow water communications.



Fig: 4-Acoustic Transducer

The 2D Omni-directional beam pattern can be achieved using a radially expanding ring or using a ring made of several ceramics cemented together. A radially expanding ceramic ring provides 2D Omni-directionality in the plane perpendicular to the axis and near Omni-directionality in planes through the axis if the height of the ring is small compared to the wavelength of sound being sent through the medium [12]. The radially expanding ceramic is relatively inexpensive to manufacture. A ring made of several ceramics cemented together provides greater electromechanical Coupling, power output, and electrical efficiency; the piezoelectric constant and coupling coefficient are approximately double that of a one-piece ceramic ring [Ken1]. They work better because the polarization can be placed in the direction of primary stresses and strains along the circumference. However, these are much more difficult to manufacture and are therefore much more expensive than a one piece radial expanding piezoelectric ceramic ring. We thus selected to use a single radially expanding ring, a <\$10 Steminc model SMC26D22H13SMQA to achieve an Omni directional beam pattern at low-cost. The most common method of making transducers from a ring ceramic is to add two leads, and pot it for waterproofing [1]. We used shielded cables for the transducer leads to ensure the leads would not pick up unwanted electromagnetic noise and attached the leads using solder with 3% silver. The piezoelectric ceramic needs to be encapsulated in a potting compound to prevent contact with any conductive fluids. Urethanes are the most

common material used for potting because of their versatility. The most important design consideration is to find a urethane that is acoustically transparent in the medium that the transducer will be used; this is more important for higher frequency or more sensitive applications where the wavelength and amplitude is smaller than the thickness of the potting material. Generally, similar density provides similar acoustical properties. Mineral oil is another good way to pot the ceramics because it is inert and has similar acoustical properties as water. Some prefer using mineral oil to urethane because it is not permanent. However, the oil still needs to be contained by something, which is often a urethane tube. We selected a two-part urethane potting compound, EN12, manufactured by Cytec Industries [13] as it has a density identical to that of water, providing for efficient mechanical to acoustical energy coupling.

B. THE TRANSMITTED SIGNAL IN ACOUSTIC TRANSMITTER:-

The modulation method used in this work is an ASK. The ASK identifies whether the signal is sent or not, and generates the signal according to this fact. For example, when transmitting the bit '1', the frequency generator generates 40 kHz during t time. Otherwise, it does not generate the frequency during t time. That is, the frequency generator uses an on/off method according to the data from the MCU and transmits the data. For more explanation we provide Fig. 3. The amplifier uses the RS232 IC to amplify the signals which come from the frequency generator. Fig. 3 shows these amplified signals.

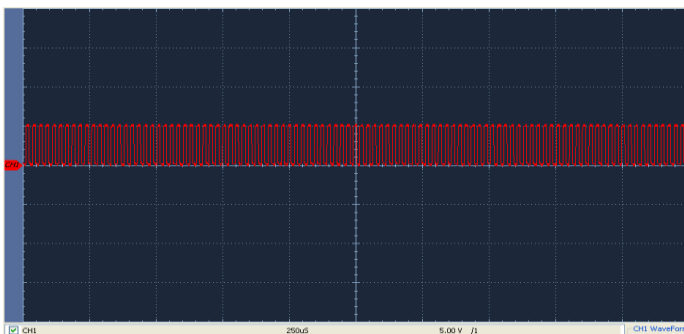


Fig: 5- 40 KHz Carrier Signal

C. THE RECEIVED SIGNAL IN ACOUSTIC RECEIVER-

The ultrasonic sensor receives the transmitted signals and sends them to the amplifier. Because the received signals are a minute signal, they have to be amplified. Fig. 4(a) shows the amplified signal in the amplifier. Then, the comparator1 removes the noise. The envelope detector detects the original signals from the amplified signals. Finally, the comparator2 transforms these analog signals into digital signals and sends them to the sensor node. The demodulated signal, later to be transmitted to the sensor node, in the comparotor2 is shown in Fig. 4(b). These signals are entered into the comparator port in the sensor node. The sensor node uses software to retrieve the original data.

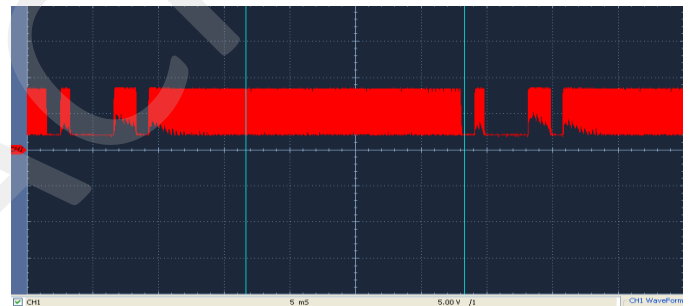


Fig: 6- Receiver side Amplified Signal by OP-AMP

in Fig. 6. These signals are entered into the comparator port in the sensor node. The sensor node uses software to retrieve the original data.

D. TEST ENVIRONMENT FOR UNDERWATER DATA COMMUNICATION:-

To perform this test we have used an Aquarium for this Underwater Data Communication. Fig. 6(a) shows the Test environment for this Acoustic Data Experiment. If we want to understand this in more detail then Fig 6(b) gives the full explanation of the system. Fig 6(a) just gives the explanation about the test setup of Aquarium, in which we have fixed Transmitter sensor on the one side and a Receiver sensor on the other side.

The communication experiment is done in following mentioned steps. At First in the transmitter part we input

the data to be transmitted in the laptop/notebook. Essential condition of the laptop/Notebook to be used that it must contain serial port. Now as the data is entered into the transmitter side it first convert from digital to analog signal and then this analog signal is to be processed in the transmitter side and then it finally goes to the transmitter side sensor. The transmitted signal propagates further through the water via sound; the frequency is to be generated at the transmitter side for this sound propagation through software coding. Then this Analogy signal is received at the receiver side through receiver sensors. These signals are minute and needs to be amplified so these signals are sent to Amplifier. Finally this signal is converted in digital signal and displayed on the Notebook/Laptop. UI which has been used in this Experiment is Hyper-Terminal. And text data is to be sent from the transmitter side and received at the receiver end. And at last text data is to be received at the Receiver side Notebook.

E. THE SENDING PERIOD AND COMMUNICATION DISTANCE:-

In our Test Environment, we carried out the experiment by changing the transmitting signal period. In our experiment the length of payload was set up to 20bytes. During transmission for each sending period transmitter send 100 packets at the receiver end. Number of packets received is recorded correctly at the receiver end to compute the packet delivery ratio. In fig.7 different packet deliver ratios can be seen when the sending period is changed.

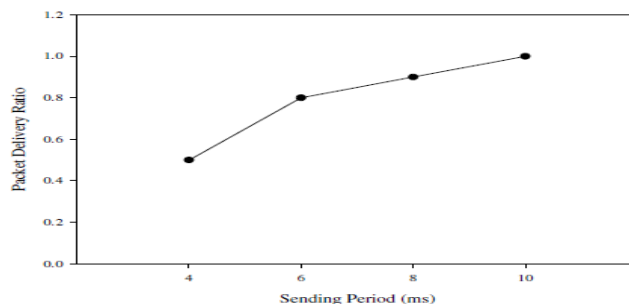


Fig:7. Packet Delivery Ratio Vs the Sending Period

In the figure it can be noticed that packet delivery ratios increased as the sending period increases. In 5ms sending period we obtain a packet deliver ratio of 1. This means that no any error generated in the packet deliver ratio. And by this packet deliver ratio we can also verify that speed of data transmission is 1.2 Kbps which is more than the previous research works, also for future work we can increase the data rate by decreasing the packet delivery ratio further.

Although we did not consider the communication distance, it is so because our purpose is that our modem performs perfectly and accurately with good data rate transmission speed. Fortunately our test setup is of 1m, in which data can be communicated easily and for further testing we need a large distance test setup facility.

F. THE COMPARISON AND DESIGN CHALLENGES

To evaluate the performance of our acoustic modem, we provide Table 1.

Table.1:- Comparison of Different Acoustic Modems

Acoustic Modem	Power Supply(Microcontroller)	Underwater Experiment	Data Rate (bps)	Frequency (KHz)	Transmitting /Receiving Device
CORAL	5V(TI MSP430)	0 (Only Sensors)	---	1.7	Piezo-transducers
Acoustic Communication	5V(MICA2 Mote)	X	<10	4.5	Sounder Microphone
Low-Power Acoustic Modem	5V(MICA2 Mote)	X	---	18	Projector/Speaker, Hydrophone/Microphone
Our Modem	5V	1(Only Sensors)	1200	40	Acoustic Transducers

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Table 1 has the evaluations of and comparisons of the performance of the acoustic modems. Because these modems were very recently developed with low-power and low-cost, we compared them so that we could represent the superiority of our modem from the performance perspective. The comparisons of the acoustic modems are as follows. First, the power supply of our modem was 3.3V, and all the others had a 5V power supply. Here, we did not know the power supply of the acoustic communication [9]. So, we inferred its power supply from the usage of the sounder and microphone as used in low power acoustic modem [11]. In the energy consumption perspective, our modem was the best of all the others. Second, while our modem and the CORAL [8] were used in the underwater experiment, the Acoustic Communication [9] and the Low-Power Acoustic Modem [11] were not performed in the underwater test. Also, while the test of CORAL [8] put only sensors in the water, our test involved testing the acoustic modem and sensors in the water. From an objective point of view as to the number of devices in the water, our test was much more concerned with the underwater experiment. Third, while the data rate of our modem was 100bps, the data rate of the Acoustic Communication [9] was less than 10bps. By this fact, the data rate of our modem was ten times as fast as that of the Acoustic Communication [9]. We did not know the data rate of the CORAL [8] and the Low-Power Acoustic Modem [11]. From the viewpoint of the data rate, our modem had the best performance. Fourth, the frequencies of the CORAL [8], the Acoustic Communication [9], the Low Power Acoustic Modem [11], and our modem were 1.7 kHz, 4.5 kHz, 18 kHz, and 40 kHz respectively. Finally, the transmitting/receiving devices of the CORAL [8], the Acoustic Communication [9], the Low Power Acoustic Modem [11], and our modem were the piezo-transducers, the sounder and microphone, the projector/speaker and hydrophone/microphone, and the ultrasonic sensors respectively. So, only our modem used the ultrasonic sensors. As the above comparison indicated, we concluded that the functionality of our acoustic modem came significantly forward in the power supply, the underwater experiment, and the improved data rate aspects. The design challenges to overcome for the underwater modem are as follows. i) The directional property: The directional property of the ultrasonic sensor is so sensitive

that if the direction is not matched, its transmitting error is increased. To that end, the pinpoint development of an ultrasonic sensor is needed. The underwater acoustic modem also has to process a minute signal. ii) The reflection and refraction: The reflection and refraction of a signal in underwater are very hard. That is why underwater communication is more difficult than terrestrial communication. The underwater acoustic modem has to remove the noise such as the reflection and refraction.

V. CONCLUSION AND FUTURE WORK

Through related work, we knew the requirement that the underwater sensor networks must perform the acoustic communication. According to this requirement, this research with regard to an acoustic modem has significant meaning when performing acoustic communication. However, the hardware to support acoustic communication did not exist at all prior to our work. This work developed an acoustic modem as hardware to perform acoustic communication. Thus, the advantages of our acoustic modem are as follows. First, our acoustic modem is a low-powered acoustic modem. In the energy consumption perspective, our modem was the best of all the others. Second, our modem is a low cost based acoustic modem with the capability of digital data communication. Because there had been no prior existing modem with this capability based on low-cost, our modem is significant in this regard. Through Table 1, we do know the fact that our modem come to the fore among the acoustic modems which have developed recently. Some of the problems to be considered in our acoustic modem are: the directional property, the reflection, and the refraction. Our future work is the research to overcome these problems. Because the underwater applications have significant attraction of themselves, the acoustic modem with the functionality of the underwater communication will become much more significant. Therefore, it is our task to develop the acoustic modem to its fullest potential. In addition, this acoustic modem will become the basis for the underwater wireless sensor networks.

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