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UNDERWATER ACOUSTIC MODEM FOR SHORT – RANGE SENSOR NETWORKS

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ABSTRACT

There is a growing interest in using underwater networked systems for oceanographic applications. These networks often rely on acoustic communication, which poses a number of challenges for reliable data transmission. Commercial underwater modem that do exist were design for sparse, long range application rather than for small dense, sensor nets. This paper gives the design consideration, implementation details and challenges in design consideration.

INTRODUCTION

Underwater acoustic communication is a technique of sending and receiving message below water. There are several ways of employing such communication but the most common is using hydrophones. Under water communication is difficult due to factors like multi-path propagation, time variations of the channel, small available bandwidth and strong signal attenuation, especially over long ranges. In underwater communication there are low data rates compared to terrestrial communication, since underwater communication uses acoustic waves instead of electromagnetic waves.

Underwater acoustic modems consist of three main components (Figure 1): (1) an underwater transducer, (2) an analog transceiver (matching pre-amp and amplifier), and (3) a digital platform for control and signal processing. A substantial portion of the cost of the modem is the underwater transducer; commercially available underwater omnidirectional transducers. Commercial transducers are expensive, due to the cost of ensuring consistent quality control of manufacturing piezoelectric materials and potting compounds, expensive calibration equipment and time-consuming characterization, all further exacerbated by low volume production.

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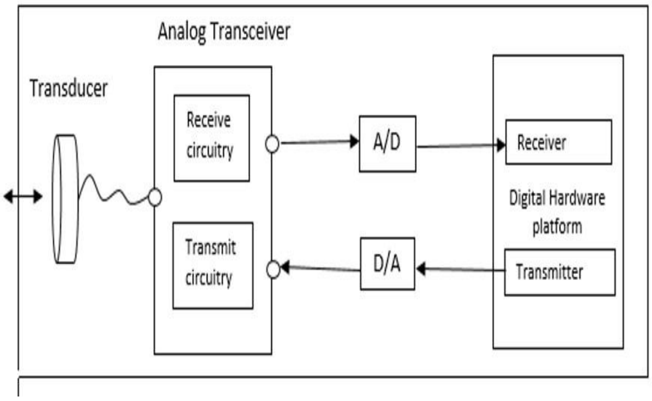

Figure 1 Major Components of an underwater acoustic modem

Transducer

A transducer is an electronic device that converts energy from one form to another. Common examples include microphones, loudspeakers, thermometers, position and pressure sensors, and antenna.

A. Transducer Design

Underwater transducer typically made up from piezoelectric material. Two main groups of materials are used for piezoelectric transducer: piezoelectric ceramics and single crystal materials. The ceramic materials (such as PZT ceramic) have a piezoelectric constant/sensitivity that is roughly two orders of magnitude higher than those of the natural single crystal materials and can be produced by inexpensive sintering processes. The piezoeffect in piezoceramics is "trained", so their high sensitivity degrades over time. This degradation is highly correlated with increased temperature. The less-sensitive, natural, single-crystal materials (gallium phosphate, quartz, tourmaline) have a higher – when carefully handled, almost unlimited – long term stability. There are also new single-crystal materials commercially available such as Lead Magnesium Niobate-Lead Titanate (PMN-PT). These materials offer improved sensitivity over PZT but have a lower maximum operating temperature and are currently more expensive to manufacture.

The 2D Omni- directional beam pattern can be achieved using a radially expanding ring or using a ring made of several ceramic material together. A radially expanding ceramic ring provides 2D omnidirectional in the plane perpendicular to the axis and near Omni directionality in the plane through the axis if the height of the ring is small compared to the wavelength of sound being send through the medium. The radially expanding ceramic is relatively inexpensive to manufacture. A ring made of several ceramic cemented together provides greater electromechanical coupling, power output and electrical efficiency; the piezoelectric constant and coupling coefficient are approximately double that of one –piece ceramic ring. The most common method to making a transducer from a ring ceramic is to add two leads and plot if for waterproofing. Using of shielded cable as a leads for transducer provides isolation from a unwanted electromagnetic noise.

Figure 2 piezoelectric ring ceramic

Characteristics of underwater acoustic sensor network

It uses acoustics waves, electromagnetic waves or optical waves.

Transmission loss: It is related to attenuation and Geometric spreading which is proportional to distance and independent of frequency.

Noise: It of two type's man made noise and ambient noise.

Multipath: Multiple propagation cause to degradation of acoustic communication signal due to (ISI) Inter symbol Interference.

Doppler spread: It causes degradation in performance of digital communication. It generates two effects: a simple frequency translation and continues spreading of frequency.

Major challenges encounter in design of underwater acoustic network

1) The available bandwidth is severely limited.

2) The underwater channel is impaired because of multipath hand fading.

3) Propagation delay in underwater is five orders of magnitude higher than in Radio Frequency (RF) terrestrial channels.

4) High bit error rates and temporary losses of connectivity (shadow zones) can be experienced.

5) Underwater sensors are characterized by high cost because of extra protective sheaths needed for sensors and also relatively small number of suppliers (i.e., not much economy of scale) is available.

6) Battery power is limited and usually batteries cannot be recharged as solar energy cannot be exploited.

7) Underwater sensors are failures sometimes because of fouling and corrosion

DESIGN OF ASK MODEM:

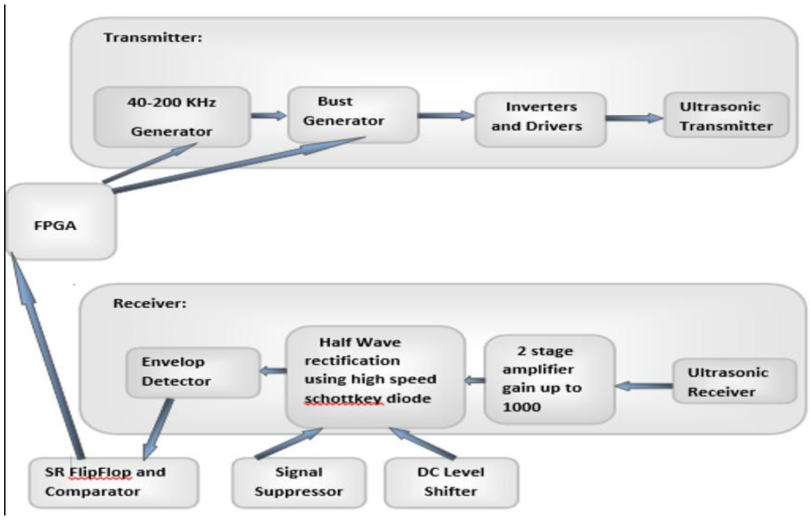

Figure 3 ASK modem block diagram

Transmitter

Ultrasonic pulse oscillator: Time of the ultrasonic pulse is controlled by oscillation circuit. The time of the oscillation pulse can be given by the following formula. TL= 0.69 x RB x C TH=0.69 x 9RA+RB)xC

Ultrasonic oscillator: This circuit is to make oscillate the ultrasonic frequency of 40KHz. Oscillation's operation is same as above circuit and makes oscillate at the frequency of 40 KHz which makes RB>RA to bring the duty (Ratio of ON/OFF) of the oscillation wave close to 50%.The frequency of the ultrasonic must be adjusted to the resonant frequency of the ultrasonic sensor. Therefore, to be able to adjust the oscillation frequency by making the RB the variable resistor (VR1). The output of ultrasonic pulse oscillator is connected with the reset terminal of ultrasonic oscillator through the inverter. Ultrasonic oscillator works in the oscillation, when the reset terminal is at the H level. The ultrasonic of 40 KHz is sent for the 1 millisecond and pauses for the 62 milliseconds.

Ultrasonic sensor drive circuit: The inverter is used for the drive of the ultrasonic sensor. For more transmission electric power, connect two inverters in parallel .The phase with the voltage to apply to the positive terminal and the negative terminal of the sensor has been 180 degrees difference. Because it gives the direct current with the capacitor, about two times of voltage of the inverter output are applied to the sensor.

Receiver

Signal amplification circuit: The ultrasonic signal which was received with the reception sensor is amplified by 1000 times (60dB) of voltage with the operational amplifier with two stages. It is 100 times at the first stage (40dB) and 10 times (20dB) at the next stage. The circuit works with the single power supply of +9 V. The half of the power supply voltage is applied as the bias voltage, for the positive input of the operational amplifiers.

Detection circuit: The detection is done to detect the received ultrasonic signal. It is the half-wave rectification circuit. In this the Shottky barrier diodes is used. The DC voltage according to the level of the detection signal is gotten by the capacitor. The Shottky barrier diodes are used because the high frequency characteristic is good.
Signal detector: This circuit used to detects the ultrasonic which returned from the measurement object. Comparator used to detect output of the detection circuit .The operational amplifier of the single power supply is used instead of the comparator. The operational amplifier used to amplifies difference between the positive input and the negative input. At the circuit this time, it connects the output of the detection circuit with the negative input of the signal detector and it makes the voltage of the positive input constant. There is another device in this circuit. It is the diode (D) which connects with the side of the positive input. The pulse signal of the transmitter is applied to diode. So, it makes not detect the transmission signal which was crowded when sending out the ultrasonic signal from the transmitter.
Time measurement gate circuit: This circuit is the gate circuit to measure the time which is reflected with the measurement object and returns after sending out the ultrasonic. It is using the SR (the set and the reset) flip flop. The set condition is the time which begins to let out the ultrasonic with the transmitter which uses the transmission timing pulse. Time which detected the signal with the signal detector of the receiver circuit is reset condition is the. That is, the time that the output of SR-FF (D) is in the ON condition becomes the time which returns after letting out the ultrasonic.
Measurement pulse oscillator: This circuit is the oscillator which makes the pulse to measure the propagation time of the ultrasonic. This oscillation circuit use the CMOS inverter.

Testing Result of Transmitter And Receiver Blocks

In this project transmit any alphabet data from transmitter at receiver receive that data here, one example is character ‘a’ is transmitted at transmitter and it work from transmitter to receiver to give output waveform in each block the result shown in below:

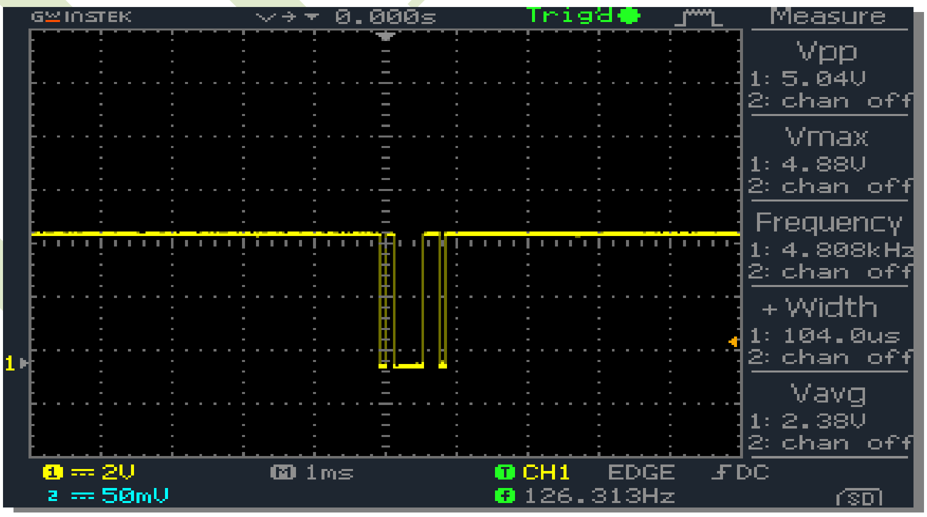

Figure 4 Serial data transmitting from pc1

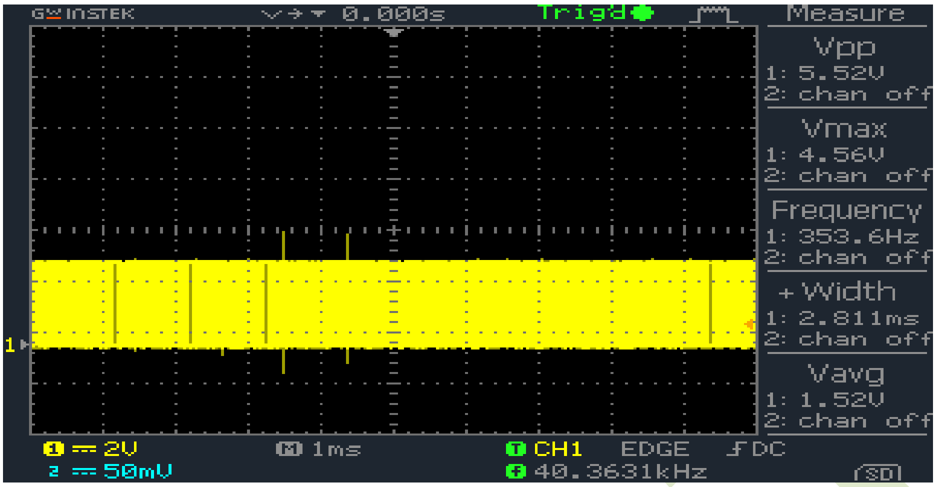

Figure 5 Carrier generated from FPGA

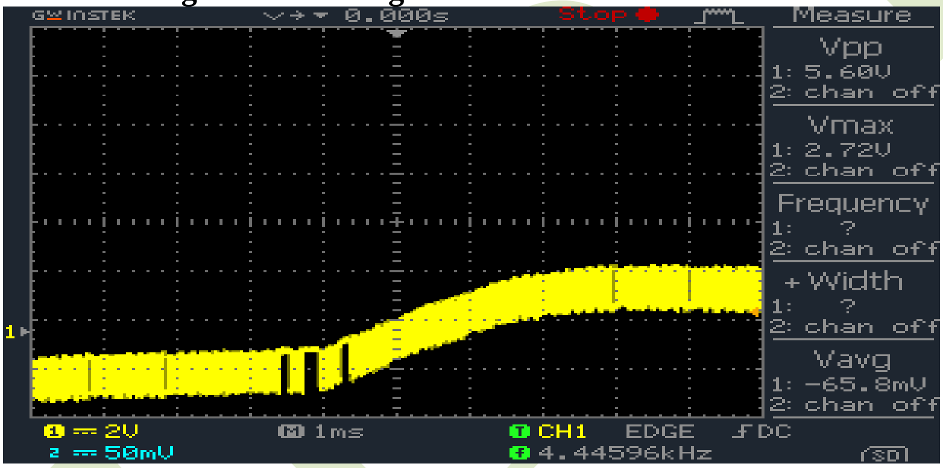

Figure 6 Transmitted waveform

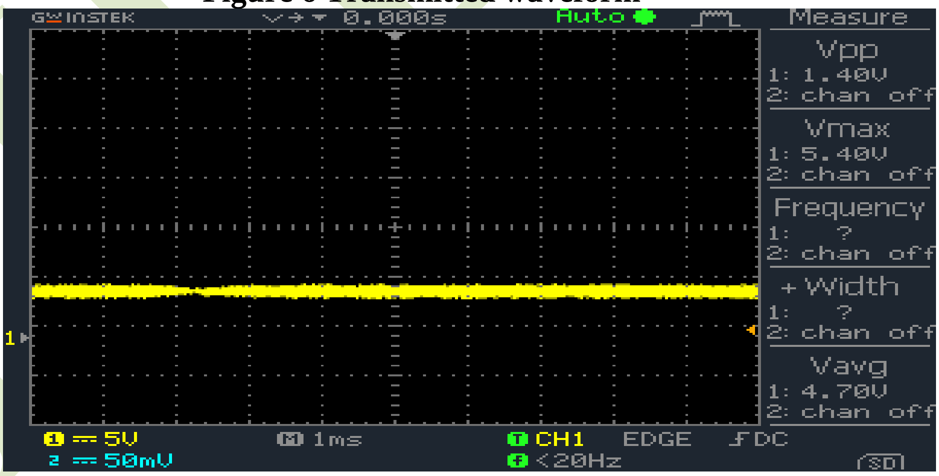

Figure 7 Received waveform

CONCLUSION

We compare our design with three commercial modems, two designed at private firm and one designed at Woods Hole Oceanographic. The distance and bit rates reported for the modems are the maximum distance and rates achievable under ideal conditions. The price of the commercial modem designs is based on marked prices whereas our design cost is based solely on parts costs and assembly labour. We observe that our modem currently stands as low-cost, comparable power alternative to existing modem designs

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