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Underwater communication using Ultrasound based on FPGA

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***Abstract*— The paper presents the design consideration, implementation details of acoustic modem. The underwater channel is highly variable; each point can have changes in signal, which change according to environmental factors as well as the locations of the communicating nodes. Reliable communication becomes difficult. Modulations schemes are used such as ASK; this design uses commercial ultrasonic transducer of 200 kHz bandwidth. Transmitted message can be displayed as well as it can be analyzed using different simulation tools at base station. Underwater modem has three parts as an underwater sensor, transceiver (matching pre-amplifier and amplifier), a digital platform for control and signal processing. There is interfacing between sensors and controller i.e. FPGA. Also comparison between various output signals is checked.**

Index Terms*— Field Programmable Gate Array, Acoustic modem, modulation techniques

I. Introduction

The interest about underwater application is increasing due to physical, chemical and biological time series data from long term sensor. Despite the substantial effort for monitoring ecological aspects of aquatic systems, the comparison between Underwater modem and on ground radio is given below.

Sr. no.	Underwater acoustic	On ground Radio
1	Low bandwidth (KHz)	High bandwidth (MHz)
2	Long delay	Short delay
3	Distance dependent on bandwidth	Distance independent on bandwidth
4	Few simulation tools available	Several simulation tools available
5	Hard to experiment	Easy to experiment

Table .1 Differences between underwater and On ground communication modem

The table shows main differences between underwater acoustic network and terrestrial radio network. The preferred mode of wireless communication in these networks is based on acoustic signals. This is due to the fact that radio frequencies suffer high attenuation underwater. Optical communication is possible but only in clear water at relatively short distances. Now a day's there is interest in the design and deployment of underwater acoustic communication network.

Application of this modem will be in oceanographic data collection, pollution monitoring offshore exploration, disaster prevention, assisted navigation & tactical surveillance application unmanned or autonomous underwater vehicles equipped with sensor will enable to gathering of scientific data. It consists of variable number of sensor & vehicles that are deployed to perform collaborative monitoring task over give area. This provides the reliable and energy efficient communication adaptive physical layer. The underwater devices are battery operated so energy efficiency is important. In this advanced modulation techniques are used such as ASK.

The underwater modem consists of three main parts as underwater transducer, analog transceiver and digital platform for control and signal processing .The transducer is an ultrasound sensor for reliable communication. The sensor has frequency of 200 kHz and it has high performance and high reliability. The analog transceiver consists of a high power transmitter and a highly sensitive receiver both of which are optimized to operate in the transducer's resonance frequency range. The transmitter is responsible for amplifying the modulated signal from the digital hardware platform and sending it to the transducer so that it may be transmitted through the water. The receiver amplifies the signal that is detected by the transducer so that the digital hardware platform can effectively demodulate the signal and analyze the transmitted data. Due to its high linearity, the transmitter may be used with any modulation technique that can be programmed into the digital hardware platform.

The main purpose of a communication system is to transfer information from a source to a Destination. A message signal containing information is used to control parameters of a carrier signal i.e. the information is embedded onto the carrier. The carrier could either a sinusoidal wave or a pulse train. At the destination the carrier plus message must be demodulated so that the message can be received. If the message signal controls-

Amplitude = Amplitude Shift Keying (ASK)
Frequency = Frequency Shift Keying (FSK)
Phase = Phase Shift Keying (PSK)

Table shows the ASK modem's time and frequency parameters which were selected based on the properties of the transducer. The 'mark' frequency represents the frequency used to represent a digital '1 ' when converted to baseband and the 'space' frequency represents the frequency used to represent a digital '0' when converted to baseband. The sampling frequency is used for sending and receiving the modulated waveform on the carrier frequency while the baseband frequency is used for all baseband processing.

Properties	Assignment
Modulation	ASK
Carrier frequency	40KHz
Mark frequency	NA
Space frequency	NA
Symbol duration	1.04ms
Baseband Frequency	960

Table. 2 Time and frequency parameters of ASK

II. UNDERWATER MODEM DESIGN

In this the main hardware parts for the modem are designed. This consists of the blocks for the modulation and demodulation process. From this the physical layer is designed through the below hardware parts.

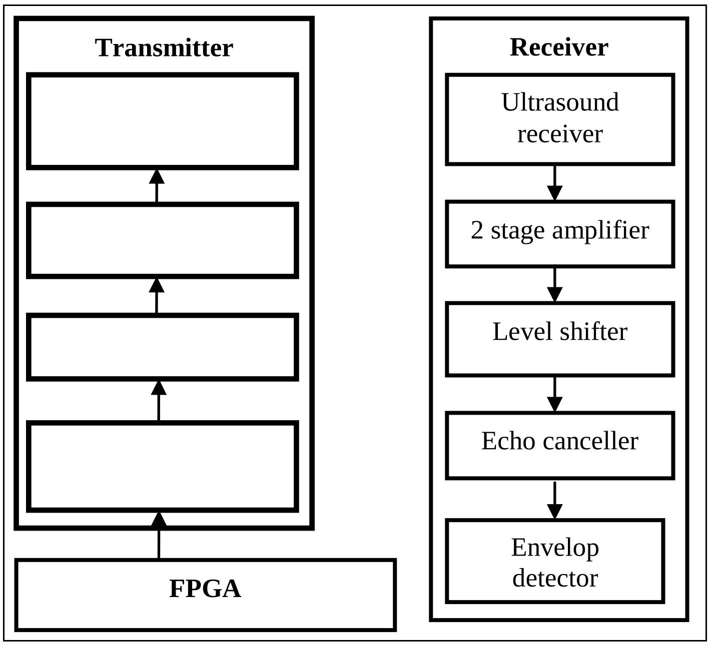

Fig. 1 Block diagram of underwater acoustic modem

A. Modulation

There are many different types of signals used for underwater communication. These include FSK, PSK, orthogonal frequency direct modulation (OFDM), and DSSS. While an adaptive modem can ideally switch between any modulations schemes, for this ASK modulation is used. ASK is a fairly simple and widely used modulation scheme in underwater communication due to its intrinsic robustness to time and frequency spreading. Our receiver uses a non-coherent energy detection demodulation method.

B. FPGA

The FPGA orchestrates the digital platform. This includes providing data for serial communication, setting the parameters for the various parts of the digital hardware, and ultimately interfacing with higher level network stack.

C. Amplifiers

Pulses from the control unit to the ultrasonic transmitter are amplified using a driver and the analog signal from the receiver is amplified using a precision instrumentation amplifier. The amplifier at receiver has gain of 1000. The output of this amplifier is fed to level shifter.

D. Level shifter

A major component of an adaptive modem is the ability to change aspects of the modem including selecting a modulation scheme, the data rate, the transmit power, and other configurable portions of the design. Many of these depend upon current and future characteristics of the acoustic channel. This is to shift the level from NRZ to RZ.

E. Echo cancellation

In this multipath are rejected, as the signal from transmitter will reflect in multiple paths to receiver. At this part the useful path is selected and others are rejected.

F. Envelop detector

This is demodulation block. Envelop detector is one of the technique used for demodulation. The original wave is recovered from this method.

III. HARDWARE PLATFORM

Papilio One XC3s250 Spartan3 we will be using. Arduino IDE we will use and Language of programming is somewhat different than VHDL but it finally gets converted into Bit file which can be loaded into FPGA. This IDE better handles floating points and will give u better results that why we have chosen this.

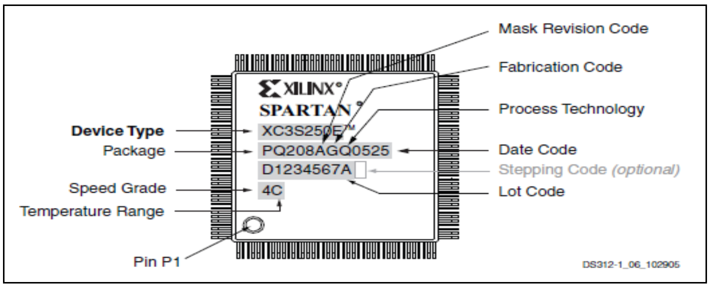

Fig. 2 Spartan 3 QFP package

A. Specifications

- Densities up to 33,192 logic cells, including optional shift register or distributed RAM support
- Efficient wide multiplexers, wide logic
- Fast look-ahead carry logic
- Enhanced 18 x 18 multipliers with optional pipeline
- IEEE 1149.1/1532 JTAG programming/debug port
- Hierarchical Select RAM™ memory architecture
- Up to 648 Kbits of fast block RAM
- Up to 231 Kbits of efficient distributed RAM

- Up to eight Digital Clock Managers (DCMs)
- Clock skew elimination (delay locked loop)
- Frequency synthesis, multiplication, division
- High-resolution phase shifting
- Wide frequency range (5 MHz to over 300 MHz) Eight global clocks plus eight additional clocks per each half of device, plus abundant low-skew routing.

IV. ULTRASOUND SENSORS

The table.3 below shows specifications of the ultrasound sensor used and the fig 3 shows diagram of sensor. It is 200khz transceivers can be used as both transmitter and receiver.

Center Frequency (KHz)	200.0±20
Bandwidt(-6dB)	200KHZ
Receiving Sensitivity at 20cm	-56 dB
Range(m)	0.2-1.2
Resolution	2mm
Capacitance (at1KHz ±25%)	380pF
Max.Driving Voltage(cont)	60
Total Beam Angle	-7 typical
Operation Temperature	-20-70℃
Storage Temperature	-30-80℃

Table.3 Specifications of sensor

These sensors are small in size and simple to use. It doesn't need any high security measures. Also it can be automated with the controller or FPGA. Capacitive transducer act as both transmitter and receiver for communication.

Sensor is of higher efficiency and has very high reliability. These are safe for use with simple operation. This can be interfaced with the display devices easily. They can perform easily as they are small in size. Ultrasound waves are more noise free than the other waves of communication.

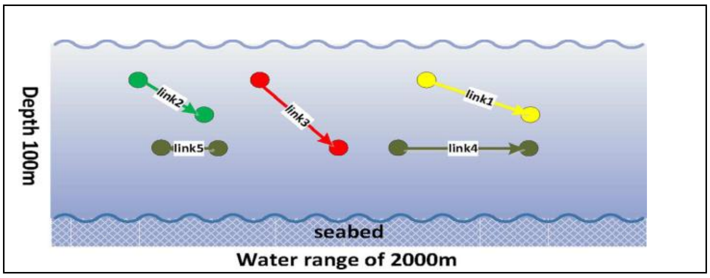

Fig. 3 Underwater Environment and the sensor nodes

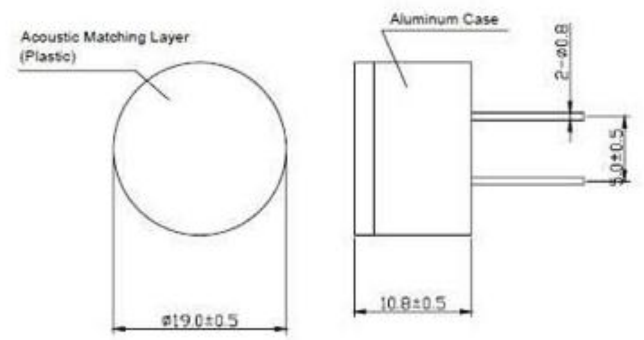

Fig. 4 Diagram of Ultrasound sensor

V. PCB LAYOUT

A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be *single sided* (one copper layer), *double sided* (two copper layers) or *multi-layer*. Conductors on different layers are connected with plated-through holes called vias. Advanced PCBs may contain components - capacitors, resistors or active devices - embedded in the substrate.

Printed circuit boards are used in all but the simplest electronic products. Alternatives to PCBs include wire wrap and point-to-point construction. PCBs require the additional design effort to lay out the circuit but manufacturing and assembly can be automated. Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods as component are mounted and wired with one single part. Furthermore, operator wiring errors are eliminated.

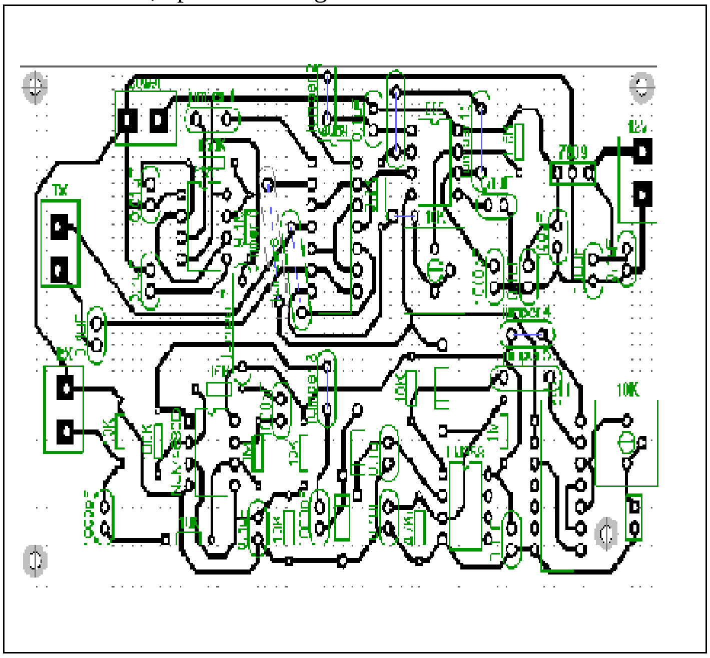

Fig. 5 PCB layout using Dip trace software

VI. RESULT

Here I have taken the measurements. The voltage at receiver and distance measured between transmitter and receiver are measured. The curve is plotted from the readings.

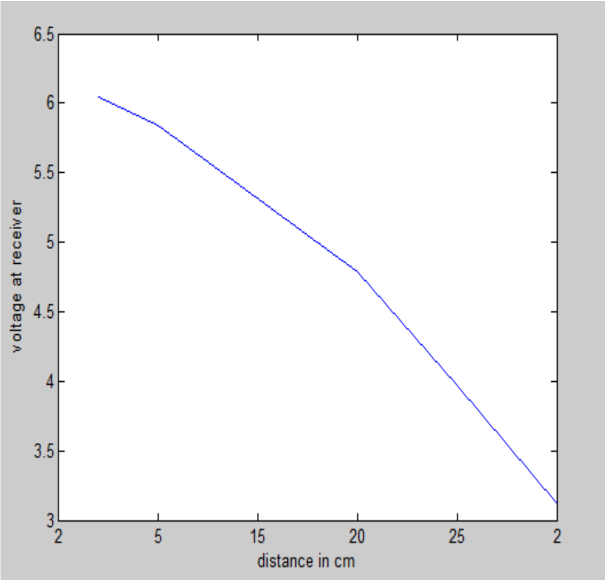

Fig. 6 voltage vs distance curve at reciever

From this we can check the signal quality at reciver. By cheking the results we can again and again take the reading and improve the signal quality.

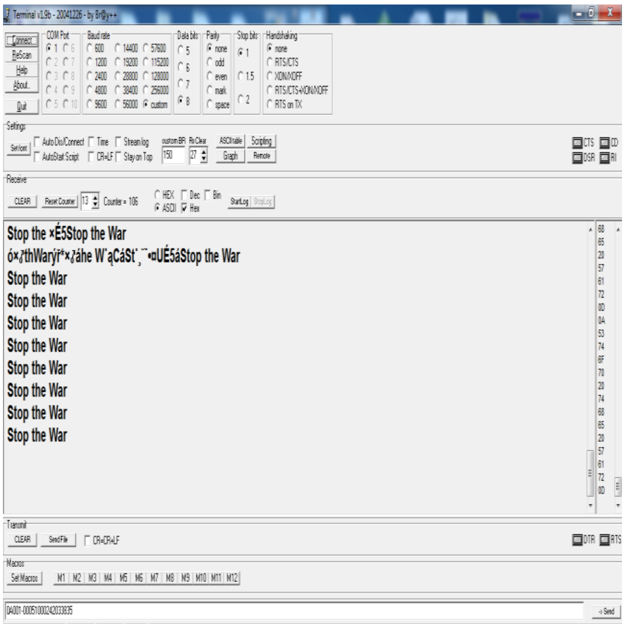

Fig. 6 Message displayed at reciever

Fig 6 shows the message displayed at receiver. From this we can check the reliability of communication using ultrasound.

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