FPGA Based Acoustic Modem for Underwater Communication

Jagdale M.R
PG student, Department of Electronics & Communication Engineering
BhivarabaiSawant Institute of Technology& Research, Wagholi Pune, Maharashtra, India
madhuri3jagdale@gmail.com

Puranik V.G.
Associate Professor, Department of Electronics & Communication Engineering
BhivarabaiSawant Institute of Technology& Research, Wagholi Pune, Maharashtra, India
vishalpura@gmail.com

Abstract—The underwater communication modem is based on ultrasound a sensor which gives efficient result underwater applications. System performs Amplitude shift Key (ASK) also known as On-Off Shift Key (OOK) at the transmitter part and this signal is demodulated at receiver point with audio amplifier and diode detector. ASK modulation is the simplest type of digital modulation technique. In this carrier signal is getting modulated with baseband signal so for positive signal it gives level '1' and at negative signal it gives level 0. This design uses commercial ultrasound transducer of 200 kHz bandwidth. 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. So distance vs. voltage of the received signal is measured. It is observed that voltage decreases with increasing distance.

Keywords— *Field Programmable Gate Array, Acoustic modem, ASK modulation techniques etc.*

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I. Introduction

Nowadays Underwater communication has become the interesting topic. A concrete example is a sensor network consisting of freely floating autonomous drifters for underwater exploration. This project presents the design consideration, implementation details and initial experimental results of modem. This also discusses the various modulation techniques like ASK. This design uses commercial ultrasonic transducer of 200 kHz bandwidth. 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. 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. There is interfacing between sensors and controller i.e. FPGA. Also comparison between various output signals is checked. Application of underwater sensor node will be in underwater data collection, pollution monitoring offshore exploration, disaster prevention, assisted navigation & tactical surveillance application, 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.

1.2 Properties of underwater acoustic sensor community:

It uses acoustics waves, electromagnetic waves or optical waves:

Transmission loss: it is related to attenuation and Geometric spreading that is proportional to distance and impartial of frequency.

Noise: It of two type guy made noise and ambient noise.
Multipath: a couple of propagation reason to degradation of acoustic communication sign due to (ISI) Inter symbol Interference.

Doppler unfolds: It reasons degradation in overall performance of virtual communication. It generates outcomes: an easy frequency translation and continues spreading of frequency.

The underwater modem consists of 3 major components as underwater transducer, analog transceiver and digital platform for control and signal processing .The transducer is an ultrasound sensor for dependable verbal exchange. The sensor has frequency of 200 kHz and it has excessive performance and excessive reliability.

Objectives of Paper:

1) Observe data or message at receiver end which are transmitted from transmitter.
2) Observe various waveforms at transmitter & receiver
3) To observe results, graphs such as distance v/s peak voltage.

Necessity:

Nowadays there is a growing interest in underwater communication which is compactand low cost. This system operates on the low power so energy efficient. The sensor used iswaterproof and corrosion resistant. Hence there are wide advantages of this system.

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.

II. BLOCK DIAGRAM OF ACOUSTIC MODEM

An Acoustic modem design a Transmitter and an Acoustic Receiver Details about the ultrasonic transmitter and receiver are explained which gives function of transmitter and receiver.

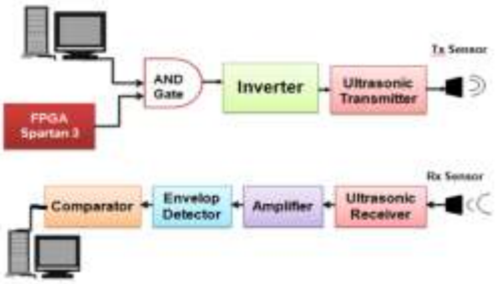

Fig.1 Block Diagram of an Underwater Acoustic Modem

1. PC: It is used to give the information signal. Then it is send through the USB to COM portconverter to AND gate. There MAX 232 is used as a dual driver or receiver. It is used to convertTTL signal to TIA signal compatible for the circuit. On PC terminal software is used to transmitand receive the information.
2. FPGA:The FPGA is a digital platform used to generate the carrier signal for the modulation.This is for the use of reconfigurable device to change the frequency of the carrier signal. It is fastand efficient. It gives signal to AND gate for OOK operation.
3. AND Gate for Modulation:There are many different types of signals used for underwater communication. Theseinclude FSK, PSK, orthogonal frequency direct modulation (OFDM), and DSSS. While anadaptive modem can ideally switch between any modulations schemes, for this ASK modulationis used. ASK is a fairly simple and widely used modulation scheme in underwatercommunication due to its intrinsic robustness to time and frequency spreading. Our receiver usesa non-coherent energy detection demodulation method.

Here I am using the AND gate for the Ask modulation to perform the on-off shift key.The gate is supplied with the 2V of power supply, the information signal from the user and thecarrier generated from the FPGA is modulated.
4.The inverter is used for the drive of the ultrasonic sensor these input signals transmitted to ultrasonic transmitter. Finally, the ultrasonic sensor transmits these amplified signals.
Transceiver sensors:
These sensors are piezoelectric ultrasound sensors with frequency of 200 kHz. These are for dualpurpose i.e. it can be used as both transmitter and receiver. The pair of sensor is used whichworks under water. These sensors are waterproof and corrosion resistant and perform reliablecommunication underwater.
6. Amplifiers:The received signal from the sensor is amplified with the audio operational amplifier which is atwo stage amplifier. At first stage 40 dB gain and at second 20 dB gains so in total it has 60 dBgains. It has a single power supply of 9V.
7. Envelop detector:This is demodulation block. Envelop detector is one of the technique used for demodulation. Thehalf wave rectifier is used in this to convert waveforms from NRZ to RZ.
8. Comparator: Comparator circuit is an operational amplifier with single power supply which amplifies thedifference between the positive and negative input. The original baseband signal is recoveredfrom this circuit.

ASK MODULATION CIRCUIT

1. System operates at the supply voltage of 12 V which is regulated to 9 V using 78L09regulators.
2. Ultrasound transmitter receiver piezoelectric transducer of 200 kHz, compact and lightweight.
3. Pulses of 40 kHz from FPGA to modulation circuit.
4. At receiver of transducer, two- stage audio amplifier has output gain of 60 dB is used. Itoperates on the power supply of 9 V. This supply is biased at the input to give 4.5 V signal toamplifiers.
5. Envelop detector to convert received signal into pulse.
6. In the signal detector circuit there is a comparator which is internally frequency compensatedand has power supply of 9V. It detects the original signal with reference voltage of 0.4 V.

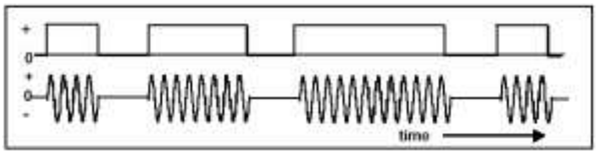

Fig. 2. Waveform ASK modulation

III. ULTRASOUND SENSORS

The piezoelectric crystal in the search unit converts the reflected sound wave or echoback into electric pulses. Ultrasonic pulses are also reflected from the back surface of thematerial and this signal represents the total distance travelled. The pulse received from the backsurface can also represent the width, length, or thickness of the material depending on itsorientation. Ultrasonic thickness testing measures the wall thicknesses of pipes and vessels bymeasuring the total distance travelled by the ultrasonic pulses, which is represented by thedistance from the initial pulse or front surface to the back reflection from the back surface.Ultrasonic transmitters and receivers are mainly made from small plates cut from certaincrystals. If no external forces act upon such a small plates electric charges are arranged in certainsymmetry and thus compensate each other. Due to external pressure the thickness of the smallplate is changed and thus the symmetry of the charge. An electric field develops and at the silvercoatedfaces of the crystal voltage can be tapped off. This effect is called Direct PiezoelectricEffect.

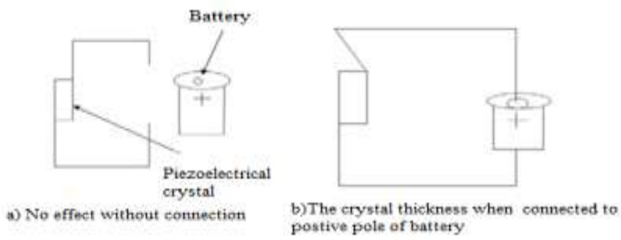

Fig. 3. Piezoelectric Effects caused due to various Circuit Design & Charging Processes

Specifications of sensor:

- 200 kHz of ultrasound piezoelectric sensors, transceiver (dual use).
- Receiver sensitivity – 56 dB, range of sensors is 0.2 to 1.2 m
- Capacitance is 380 pF, operating temperature -20 to 70oc.
- Resolution 2mm, storage temperature -30-800c

IV. Circuit Diagram

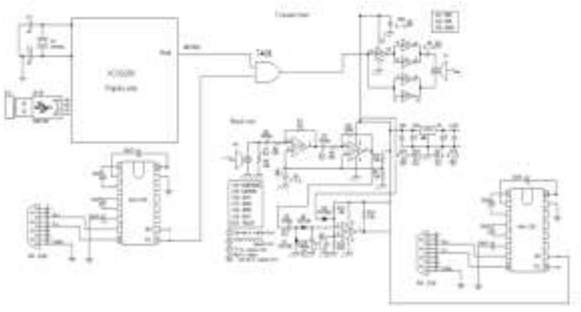

Fig. 4 Circuit diagram of acoustic modem

V. HW/ SW PLATFORM

Papilio One XC3s250 Spartan3 we can be the usage of. Arduino IDE we will use and Language of programming is relatively exceptional than VHDL however it ultimately gets converted into Bit document which can be loaded into FPGA. This IDE better handles floating factors and could provide u higher effects that why we have selected this Spartan-3E FPGA family.

A) Spartan-3E FPGA Family

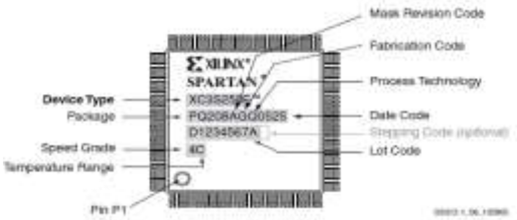

Fig. 5 Spartan 3 QFP package

Specifications

1. Fully Assembled with a Xilinx Spartan 3E and 4Mbit SPI Flash Memory.
2. Provides an Easy Introduction to FPGA, Digital Electronics, and System on a Chip design
3. Easily add New Functionality with Wings that Snap onto the Board
4. Two-Channel USB Connection for JTAG and Serial Communications
5. Four Independent Power Rails at 5V, 3.3V, 2.5V, and 1.2V.
6. Power Supplied by a Power Connector or USB
7. Input Voltage (recommended): 6.5-15V
8. 48 I/O lines.

B) Arduino:

- It's an open-source physical computing platform based on a simple microcontroller board,and a development environment for writing software for the board.
- Arduino can be used to develop interactive objects, taking inputs from a variety of switchesor sensors, and controlling a variety of lights, motors, and other physical outputs.
- Arduino projects can be stand-alone, or they can communicate with software running on yourcomputer (e.g. Flash, Processing, and MaxMSP.)
- The boards can be assembled by hand or purchased preassembled; the open-source IDE canbe downloaded for free.
- Inexpensive - Arduino boards are relatively inexpensive compared to other microcontrollerplatforms.

TERMINAL: Terminal emulation application for RS-232: useful and small terminal emulation application for the Serial port verbal exchange. Terminal can also act like telnet server and listen on selected TCP port. You can connect to it with any telnet client program from another computer in network (or over internet from different location) and see what's going on in terminal and send commands etc.
Features: -

- without installation, only single and small .exe file ~300KB
- simple file send, Rx and Tx characters counter
- baud rate up to 256kbps & custom baud rate
- up to 64 COM ports, log to file (hex & string)
- 24 custom transmit macros with auto repeat function
- scripting (with graph/visualization support)
- remote control over TCP/IP - telnet

VI. Results:

Test Environment for Underwater Data Communication**:**

To test we have used an Aquarium for Underwater data communication. The test environment for this acoustic data experiment setup used as a fixed two sensors which is act as transmitter sensor (in fig. shows input transducer) on one side and another is act as receiver sensor (in fig. shows output transducer) and water as transmission medium.

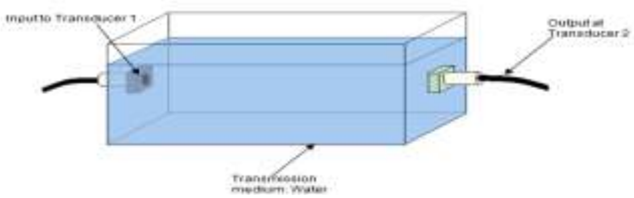

Fig. 6Water as transmission medium and the ultrasonic transducer setup

The communication experiment is done in following steps from transmitter part to receiver part. Data transmitted in the laptop it contain serial port. Digital data transmit from transmitter side sensor. The transmitted signal propagated through the water. Receiver receives this digital data at thereceiver side sensor. Finally this signal is in digital signal and displayed on the Terminal simulation programmer window.

An acoustic modem is used in military application for security so here transmit one security password from source to destination. Data tested on terminal software, here transmitting data from transmitter is **PASSWORD "JAGDALE_123&="**tested results steps are as follows:
Transmitted data is
PASSWORD "JAGDALE_123&="display on terminal software the terminal window is as follows:
Transmitter Window:

Fig. 7. Snapshot of input on Terminal (Message displayed at transmitter)

Fig. 8. Snapshot of output on Terminal (Message displayed at receiver)

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.

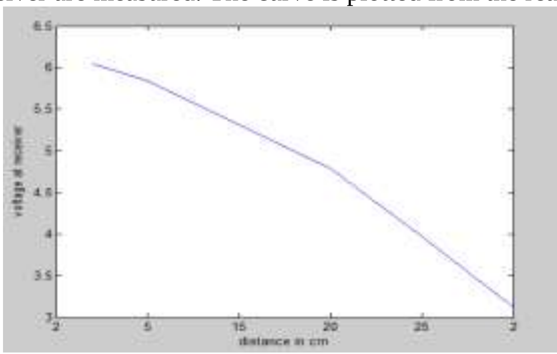

Fig.9 voltage vs distance curve at receiver

VII. CONCLUSIONS

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.

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