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Research Article

Design of Underwater Acoustic Modem for Short Range Sensor Network

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Abstract

This paper presents the design consideration, implementation details and initial experimental results of our modem. This paper also discusses the various modulation technique like ASK,FSK. This design uses commercial ultrasonic transducer of 200kHz bandwidth. Massage from transmitter can be displayed in visual format as well as it can be analyzed using different simulation tools at base station. Under water modem consists of three component i) An underwater transducer ii) An analog transceiver (matching pre-amplifier and amplifier), iii) A digital platform for control and signal processing. In this paper comparison of results of communication with ASK,FSK modulation technique, microcontroller & FPGA.

Keywords*: ASK, FSK, FPGA, simulation tools, acoustic sensor network.*

1. Introduction

The knowledge about the ecosystem 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 infrastructure needed for sensor networks in marine and freshwater systems without question lags far behind that available for terrestrial counterparts.

Table: 1 Main differences between underwater acoustic network and terrestrial radio network (Paolo Casari Michel Zorzi, 34(2011)2013-2025)

Sr.No	Underwater acoustic	Terrestrial 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

Courtesy:[1] Paolo Casari Michel Zorzi ((2011) 2013-2025) Protocol design issues in underwater acoustic network ScienceDirect Computer Communication 34,Department of Information Engineering,University of Padova,Italy jornal Homepage : www.elsevier.com/locate/comcom

Now a day's interest in the design and deployment of underwater acoustic communication network. Application of underwater sensor node will be in oceanographic collection of data, monitoring of water pollution, disaster prevention, assisted navigation & tactical surveillance application. (UUV, AUVs) unmanned or autonomous underwater vehicles equipped with sensor will enable to gathering of scientific data. It consist of variable number of sensor & vehicles that are deployed to perform collaborative monitoring task over give area

1.1 Characteristics of underwater acoustic sensor network- (Ian F. Akyildiz , Dario Pompili, Tommaso Melodia, 2005)

*Communication media***:** 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 types 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.

1.2 Major challenges encounter in design of underwater acoustic network are as follows. (Ian F. Akyildiz *, Dario Pompili, Tommaso Melodia, 2005)

1) The available bandwidth is severely limited.
2) The underwater channel is impaired because of multi-pat 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.

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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.

2. Design of ask modem

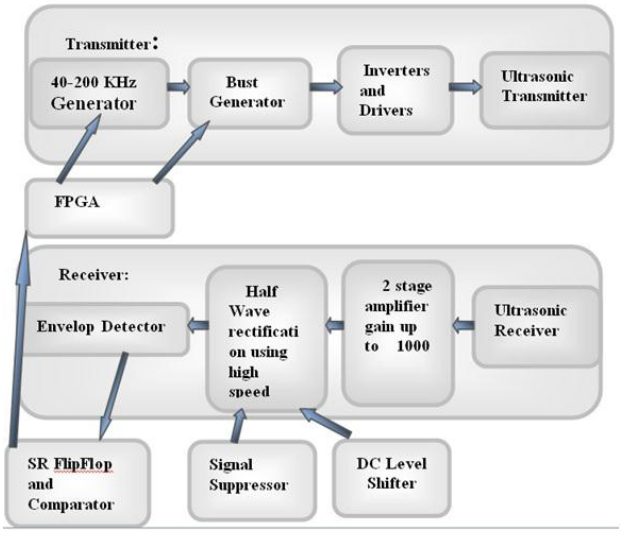

Figure1: Major components of an underwater acoustic ASK modem

A. Transmitter

1) Ultrasonic pulse oscillator: Time of the ultrasonic pulse is controlled by ooscillation circuit.The time of the oscillation pulse can be given by the following formula.

T_L= 0.69 x RB x C
T_H=0.69 x 9RA+RB)xC

2) 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.
3) 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.

B) Receiver

1) 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,
2) 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.
3) 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.
4) 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.
5) 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.

3. Design of Fsk modem

Underwater acoustic FSK modems consist of three main blocks:
(1)An underwater transducer,
(2)An analog transceiver (matching pre-amp and amplifier), and
(3) a digital platform for control and signal processing.

Block Diagram

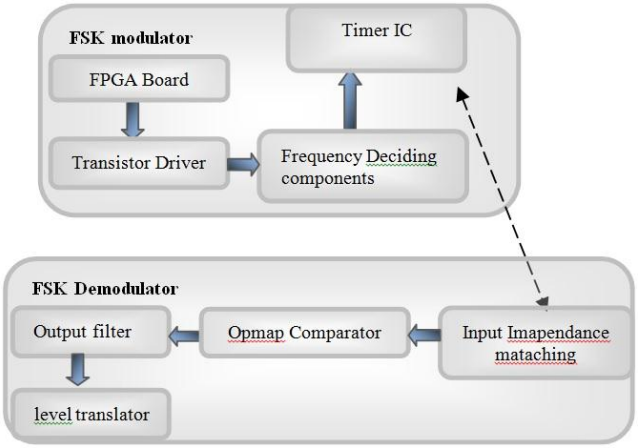

Figure 2: Major components of an underwater acoustic FSK modem

A) FSK modulator

Frequency Shift Keying plays a great role in wide range of applications in the field of communication and was considered efficient one in data transmission of wireless modems. In this circuit it was wired as a simple Astable multivibrator and in addition a transistor was connected through which input signal was given into the base of the transistor. The resistors R1, R2 and C determine the frequency of the FSK modulated signal in the astable mode of operation. The output frequency of the signal was based on the input digital signal given to the base of the transistor. When the given input was high the PNP transistor was Q is off and IC 555 timer works in the normal Astable mode of operation & out of it is the series of square wave pulses thus there will be no change in the frequency of the output signal. The output frequency when the input was high which is given by the equation

$$f= 1.45/(R1 + R2)C$$

Thus the resultant output FSK will give frequency of 1070Hz when input is high and frequency of 1270 when input is low. Thus in this way the FSK signal was obtained using NE555

B) FSK Demodulator

The IC PLL 565 has very wide applications and the most significant among them was employing IC PLL 565 as a FSK demodulator. PLL 565 the frequency shift is usually accomplished by driving a Voltage Controlled Oscillator with the received binary data signal. Thus the output correspond to the input logic 0 or 1 signals. It locks the input signal frequency and tracks it between the two possible frequencies with a DC shift at the output of this IC. The free-running frequency of the internal VCO of the PLL IC is determined by resistor R1 and C1.The output of VCO comparator was fed into the Phase comparator input to perform the locking operation of signal frequencies.

4. HW/SW Co-Design of Digital Modem

Papilio One XC3s250 Spartan3 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.

A) Spartan-3E FPGA Family

• Very low cost, high-performance logic solution
• Multi-voltage, multi-standard SelectIO™ interface pins
• LVCMOS, LVTTL, HSTL, and SSTL single-ended signal standards
• 622+ Mb/s data transfer rate per I/O
• Enhanced Double Data Rate (DDR) support
• DDR SDRAM support up to 333 Mb/s
• Abundant, flexible logic resources
• Efficient wide multiplexers, wide logic
• Fast look-ahead carry logic

B) Arduino

It is a single board microcontroller intended used for interactive objects or environments more accessible. Open source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM is main block of board. Current models consists of USB interface, for attach various extension boards it provide 6 analog pins for input, as well as 14 digital I/O pins

1) Hardware: An Arduino board consists of an Atmel 8-bit AVR microcontroller with complementary components to facilitate programming and incorporation into other circuits. Some shields communicate with the Arduino board directly, but many shields are individually addressable, allowing many shields to be stacked and used in parallel. Official Arduinos have used the mega AVR series of chips. A boot loader simplifies uploading of programs to programme an Arduino's microcontroller with the on-chip flash memory.

2) Software: The Arduino integrated development environment (IDE) is a cross-platform application used programming language as Java, and is derived from the IDE for the Processing programming language and the Wiring projects. It is used to introduce programming newcomers unfamiliar with software development. It includes a code editor. The Arduino IDE comes with a software library called Wiring, which makes many common input/output operations much easier.

C) Microcontroller

A HW/SW co-design for the digital modem to allow for accurate control and I/O. The co-design consists of the digital modem, a UART (Universal Asynchronous Receiver Transmitter) to connect to serial sensors or to a computer serial port for debugging, an interrupt controller to process interrupts received by the UART or the modem, logic to configure the on board ADC, DAC, and clock generator, and Microcontroller, an embedded

microprocessor to control the system. The Microcontroller is an 8-bit architecture optimized for implementation FSK modem. It interfaces to the digital modem through two fast simplex links (FSLs), point-to-point, uni-directional asynchronous FIFOs that can perform fast communication between any two design elements on the FPGA that implement the FSL interface. The Microcontroller interfaces to the interrupt controller and UART core over a peripheral local bus (PLB), based on the IBM standard 64-bit PLB architecture specification.

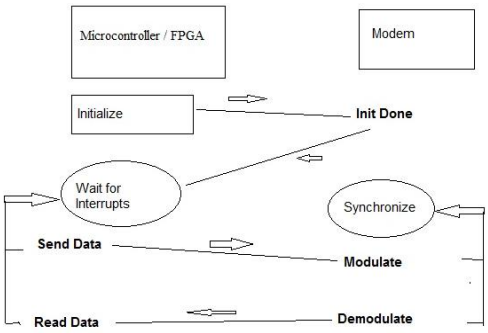

Figure 3: Modem Control flow.(B. Benson, Y. Li, R. Kastner, B.Faunce, K. Domond, D. Kimball, C. Schurgers,2010)

5. Initial Results

A) MATLAB 7.0: MATLAB 7.0 is high level language and interactive environment for numerical computation, visualization and programming.

Table: 2 Received signal in peak voltage

No.	D Distance between transmitter and receiver in cm	Received signal in peak voltage
1.	2 cm	6.04
2.	5 cm	5.84
3.	15 cm	4.79
4.	20cm	3.97
5.	25cm	3.12

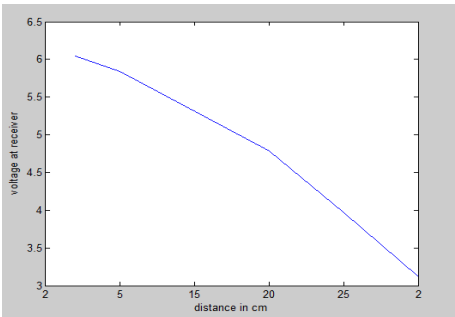

Figure 4: Experimentally determined voltage response at receiver with respect to distance.

Using MATLAB, You can analyze data, develop algorithms and create models and applications. It gives faster solution than with spreadsheets or traditional programming languages. MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. MATLAB used to manipulations of matrix, functions plot and data, algorithms implementation, creation of user interfaces, and interfacing with programs used languages such as C, C++, Java, and FORTRAN. MATLAB is also used for MuPAD symbolic engine, which allowing access to symbolic computing capabilities.

B) TERMINAL - terminal emulation program for RS-232: Useful and small terminal emulation program for the Serial port communication. Its uses seven com ports, you can use Transmit Macros. It is com port development tool Terminal is a simple serial port (COM) terminal emulation program. For communicating different devices terminal uses. For serial communication applications, it is very useful debugging tool.

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)
-scripting (with graph/visualization support)
-Remote control over TCP/IP – telnet
-run applications from macro commands

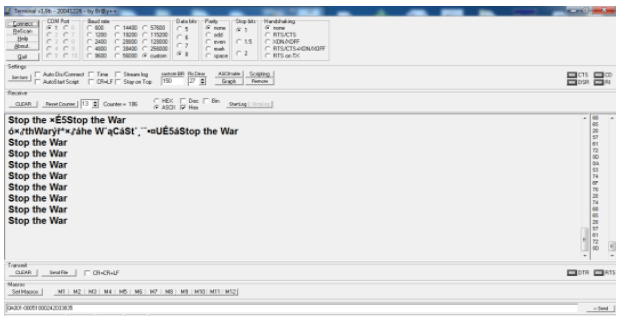

Figure 5: Snapshot of terminal window (result at receiver end).

Table 3.ASK modem parameters

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

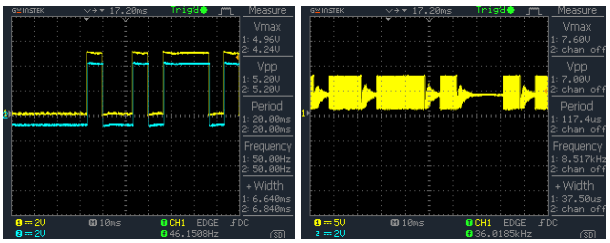

Figure 6: Snapshot of wave forms at ASK receiver end.

Table 4: FSK modem parameters

Properties	Assignment
Modulation	FSK
Carrier frequency	1KHz
Mark frequency	1.2KHz
Space frequency	1KHz
Symbol duration	6.6ms
Baseband Frequency	150Hz

Figure7: Snapshot of waveforms at FSK receiver end.

7. Modem comparison and conclusion

Table 4: Modem Comparison and Conclusion

Modulation Type	FSK	ASK
Carrier Frequency (KHz)	1KHz	40KHz
Mark Frequency (KHz)	1.2KHz	NA
Space frequency (KHz)	1KHz	NA
Symbol duration (ms)	6.6ms	1.04ms
Baseband frequency Hz	150Hz	960

Conclusion

Advantage of FSK over ASK is that,

-FSK can withstand variation in amplitude due to do addition of noise. But ASK being amplitude dependant, higher amplitude noise greatly hamper performance of ASK. So ASK can only be used in less noisy environment.
- FSK is not limited by presence of noise, but it is limited by separation of MARK and SPACE frequencies. If MARK and SPACE frequencies are not separated by great value, then it can severely degrade its performance
-FSK works at much less distances as compared to ASK.
-short FSK can be used more efficiently in noisy environment with condition that MARK and SPACE frequencies are sufficiently separated in their value

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