An Report on

Channel characteristics of UWASN using AUVs for different oceanographic applications

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In

Electronics and Telecommunication

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Certificate

This is to certify that the internship report titled, **Channel characteristics of UWASN using AUVs for different oceanographic applications** submitted by **Chinmay B. Gaikwad** (*GR NO.* 141684) and **Mahaveer V. Kaul** (*GR NO.* 141607) is a record of bona fide work carried out by them under guidance of **Prof. Padmaja Venkataraman** and **Prof. Kishori Deogonkar** in partial fulfillment of the requirement for the award of the Degree of Final Year Bachelor of Technology in **Electronics and Telecommunication**.

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Chinmay Gaikwad
Date: 2 December 2017

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Abstract

The Underwater Acoustic communication has been research for at least half century and significance of signal processing techniques to wireless communications is an emerging field that has achieved a lot of improvements. This form of communication has received increasing attention with applications ranging from surveillance, marine life study, aquatic monitoring and detection of minefields.

Underwater applications like Mine exploration, Pipeline / Cable laying, Hydrography, etc. warrant for different studies like Geo-technical, Geo-physical and other investigations in both Shallow and Deep water in the sea. Mostly, the mentioned studies are carried out using underwater marine acoustic instrumentations. The acoustic signals, in particular, shallow water suffers severe disturbances due to Ambient Noise in the sea. The Ambient noise in underwater is very unique, location specific and nearly deterministic also.

Wideband Code Division Multiple Access is a third-generation (3G) wireless standard which offers data speeds up to 384 Kbps for voice and data. In this paper, Simulation model of underwater acoustic network is done using WCDMA with different parameters of the filter at 5 MHz.

A bit error rate (BER) is defined as the rate at which errors occur in a transmission system. This can be directly translated into the number of errors that occur in a string of a stated number of bits. The definition of bit error rate can be translated into a simple formula:

If the medium between the transmitter and receiver is good and the signal to noise ratio is high, then the bit error rate will be very small possibly insignificant and having no noticeable effect on the overall system However if noise can be detected, then there is chance that the bit error rate will need to be considered. Although there are some differences in the way these systems work and the way in which bit error rate is affected, the basics of bit error rate itself are still the same. When data is transmitted over a data link, there is a possibility of errors being introduced into the system. If errors are introduced into the data, then the integrity of the system may be compromised. As a result, it is necessary to assess the performance of the system, and bit error rate, BER

Chapter 1 Introduction

1.1 Objective

1. To study about the basic structure of Underwater Acoustic Sensor Network (UWASN).
2. To study about characteristics of Underwater networking and various models
3. To study about the applications of UWASN in various fields like Aquiculture, Study of mine fields.
4. To study about the implementation of WCDMA modulation scheme to UWASN.
5. To study about bit error rate analysis of UWASN system with the help of MATLAB to analyze various parameters.

1.2 Introduction

The Underwater Acoustic communication has been research for at least half century and significance of signal processing techniques to wireless communications is an emerging field that has achieved a lot of improvements. This form of communication has received increasing attention with applications ranging from surveillance, marine life study, aquatic monitoring and detection of minefields. Wideband Code Division Multiple Access is a third-generation (3G) wireless standard which offers data speeds up to 384 Kbps for voice and data. In this paper, Simulation model of underwater acoustic network is done using WCDMA with different parameters of the filter at 5 MHz.

Underwater communication is quite different than terrestrial sensor network (TSN), RF waves are affected by high attenuation in water. Digital Signal processing techniques are being used to enhance and optimize the performance of communications system.

WCDMA, an ITU standard derived from Code-Division Multiple Access (CDMA). Officially known as IMT-2000 direct spread spectrum.

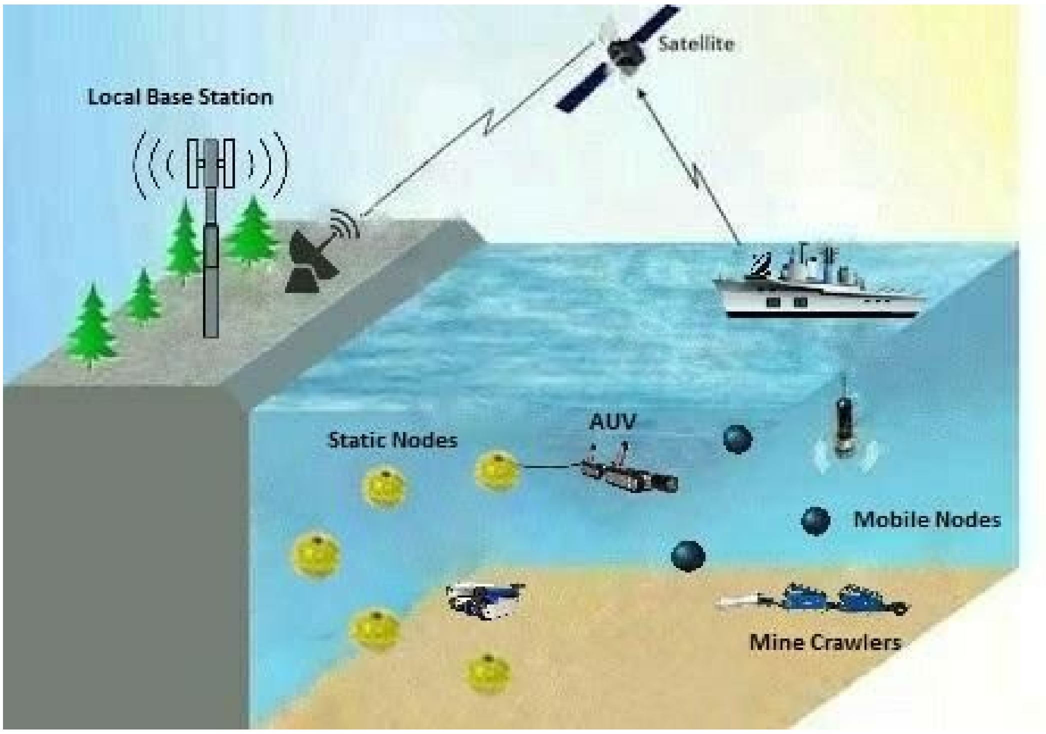
A bit error rate (BER) is defined as the rate at which errors occur in a transmission system. This can be illustrated as the number of errors that can occur in a stated number of bits. The definition of bit error rate can be translated into a simple formula:

Chapter 2
What is Underwater Acoustic Sensor Networks (UWASN)?

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

Underwater acoustic sensor networks (UWSNs) have a promising future in the area of information collection with more and more applications in recent years, such as ocean environmental surveillance, resource exploration and disaster prevention. Unlike terrestrial sensor nodes that rely on radio waves to communicate with each other, underwater sensor nodes utilize acoustic waves to transmit data, which constitutes a significant difference between underwater sensor networks and terrestrial sensor networks (TSNs).

First, underwater sensor nodes consume much more energy in transmission than terrestrial sensor nodes, not only which used in reception, but also in transmission. This phenomenon makes the confliction of packets more unacceptable in UWSNs than in TSNs. Second, the transmission range of an acoustic modem (2–4 km) is much greater than that of an RF modem (150 m). This feature leads to that circumstance whereby the transmitter cannot detect the confliction at the receiver. Meanwhile, the propagation speed of acoustic signals in underwater environments is about 1,500 m/s, which is thousands of times slower than RF propagation (i.e., 3 × 108 m/s). The channel status in short-range RF networks can only be measured by the transmission time; however, the propagation delay cannot be ignored in UWSNs. The unique characteristics of UWSNs bring about new challenges for MAC protocol design. Great energy consumption in transmission produces collision free protocols more suitable for UWSNs. Long communication ranges make the receiver the only point where the packets‟ confliction is detected. However, the long propagation delay makes handshake protocols like RTS and CTS inefficient for UWSNs, as they would greatly decrease the network throughput



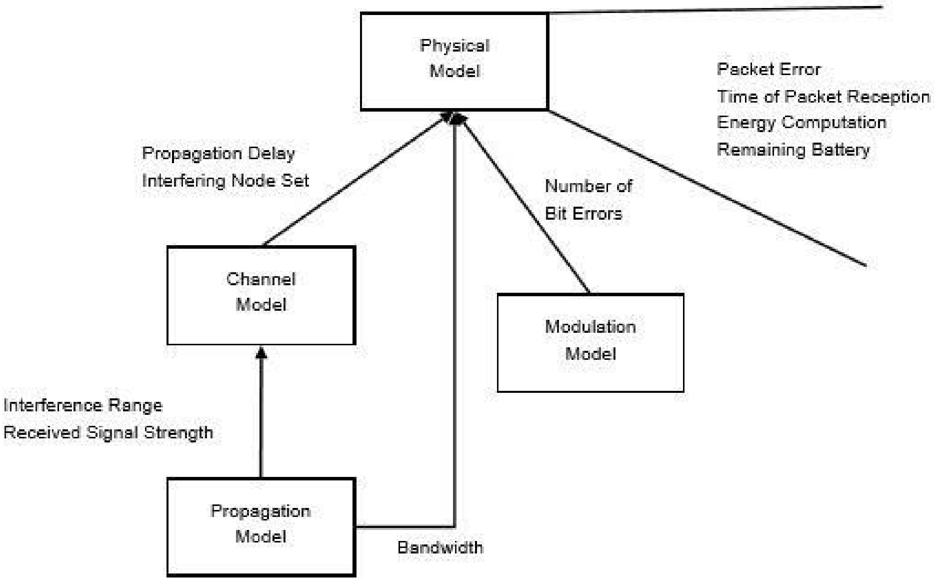
2.1 Simulation Tools

Although underwater acoustics has been studied for decades, underwater networking and protocol design is just beginning as a research field. One critical tool used for the design and testing of new protocols is a network simulator. For simulators to be useful tools, accurate models of both the channel and the modem need to be implemented. Since the underwater environment is so different from its terrestrial counterpart it is likely that existing wireless modules cannot be easily reused, and specific underwater extensions will be needed. The underwater environment differs from the terrestrial radio environment both in terms of its modem energy costs, and in terms of the channel propagation phenomena. The underwater channel is characterized by long propagation times and frequency-dependent attenuation that is highly affected by the distance between nodes as well as by the link orientation.

2.1.1 Network-Simulator 2

NS is a discrete event simulator targeted at networking research. Ns provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks.

The NS simulator divides the layers below the MAC layer into four components: Propagation, Channel, Physical, and Modulation. It provide modules for each layer, allowing protocol developers to concentrate efforts on the higher layers of the network protocol stack.



The ns2 channel and physical layer model

2.1.2 MATLAB-Simulink

MATLAB (matrix laboratory) is a fourth-generation high-level programming language and interactive environment for numerical computation, visualization and programming.

Simulink is a simulation and model-based design environment for dynamic and embedded systems, integrated with MATLAB. Simulink, also developed by MathWorks, is a data flow graphical programming language tool for modelling, simulating and analyzing multi-domain dynamic systems. It is basically a graphical block diagramming tool with customizable set of block libraries.

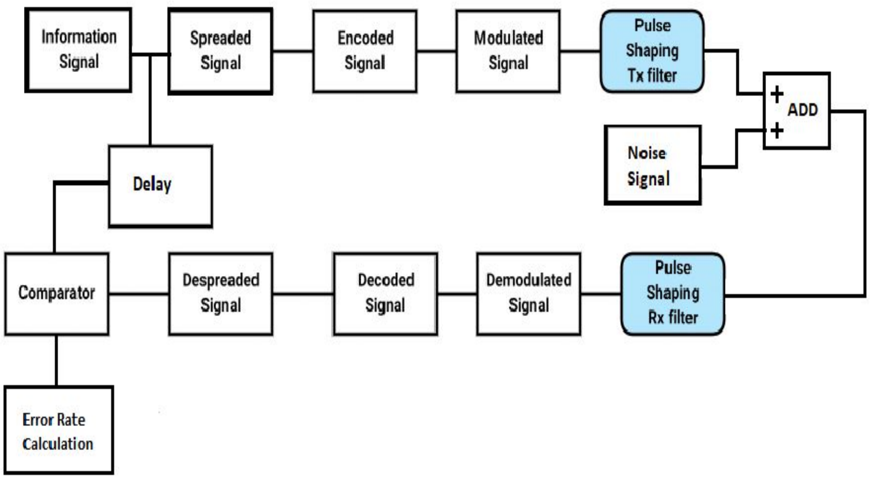
It allows to incorporate MATLAB algorithms into models as well as export the simulation results into MATLAB for further analysis.

2.2 WCDMA

WCDMA (known as IMT-2000 direct spread spectrum) is a third-generation (3G) mobile wireless technology that promises much higher data speeds to mobile and portable wireless devices than commonly offered in today's market. W-CDMA can support mobile/portable voice, images, data, and video communications at up to 2 Mbps (local area access) or 384 Kbps (wide area access). It enables several users to transmit their information over the same channel bandwidth. In the mode of transmission a tradeoff exists between bandwidth containment in frequency domain and ripple attenuation in time domain.

WCDMA supports multiple parallel variable rate services on each connection. Built in support for future capacity and coverage enhancing technologies like adaptive antennas, advanced receiver structures, and transmitter diversity. It also supports inter frequency hand over and hand over to other systems, including hand over to GSM.

WCDMA supports both FDD and TDD modes of operation. The enhancement in performance is obtained from a Direct Sequence Spread Spectrum (DSSS) signal through the processing gain. Each signal must have its own pseudorandom signal for DSSS signals to occupy the same channel bandwidth. Thus enable several users to transmit their information over the same channel bandwidth. This is the main concept of a WCDMA communication system.



BER calculation in WCDMA using MATLAB Simulink

2.2.1 Information Signal:

Bernoulli Binary Generator generates information signal that is compliant with the standard of WCDMA from Simulink library. It generates random binary numbers using Bernoulli Distribution theorem. The Bernoulli distribution has mean value 1-p and variance p (1-p). The probability of a zero parameter specifies p and can be any real number between zero and one.

2.2.2 PN Sequence Generator:

The PN Sequence is generated by pseudo random noise generator that is a binary linear feedback shift register with XOR gates and a shift register. This PN Sequence has the ability to create an identical sequence for both transmitter and receiver and yet retaining the desirable properties of a noise like randomness bit sequence

2.2.3 Differential Encoder:

It differentially encodes the input data. The output of this block is a logical difference between present input to this block and previous output of this block. The input can be a scalar, vector or frame based matrix

2.2.4 Square Root Raised Cosine Transmit Filter:

Square root raised cosine transmit filter up samples as well as filters the input signal. The group delay in the filter is the number of symbol periods between start of filter response and its peak response. This delay also determines the length of filter impulse response.

2.2.5 Square Root Raised Cosine Receive Filter:

It filters the input signal and also down samples using Square root raised cosine FIR filter. The group delay is in the filter is specified as the number of symbol periods between start of filter response and its peak response. This delay also determines the length of filter impulse response.

2.2.6 Noise

Noise input signal, it is actual set of values form the data that has been measured using hydrophones in shallow water.

2.3 Bit Error Rate (BER)

A bit error rate is the rate at which errors occur in a transmission system. This can be directly translated into the number of errors that occur in a string of a stated number of bits.

If the medium present between the transmitter and receiver is good and the signal SNR value is high, then it results into a very small or possibly insignificant bit error rate and thus having no noticeable effect on the overall system. BER analysis helps to assess the end to end performance of a transmission system that includes the transmitter, receiver and the medium present between the two. In this way, bit error rate enables the actual performance of an overall system.

In radio communications system, Signal to noise ratios (SNR) and Eb/No are the parameters that are more associated. The bit error rate, can also be defined in terms of the probability of error. The determination is done using three other variables, the error function (erf), the energy in one bit (Eb) and the noise power spectral density (No). Eb can be calculated by dividing the carrier power by the bit rate.

2.3.1 Factors Affecting Bit Error Rate

It can be seen from using Eb/No, that the bit error rate, BER can be affected by a number of factors. By manipulating the variables that can be controlled it is possible to optimize a system to provide the performance levels that are required. By reducing the bandwidth the level of interference can be reduced. However reducing the bandwidth limits the data throughput that can be achieved.

It is necessary to balance all the available factors to achieve a satisfactory bit error rate. Normally it is not possible to achieve all the requirements and some trade-offs are required.

Chapter 3

Network characteristics of UWASN

3.1 Packet Delivery Ratio (PDR)

The calculation of Packet Delivery Ratio (PDR) is based on the received and generated packets as recorded in the trace file. In general, PDR is defined as the ratio between the received packets by the destination and the generated packets by the source. Packet Delivery Ratio is calculated using awk script which processes the trace file and produces the result.

3.2 Throughput

Throughput or network throughput is the rate of successful message delivery over a communication channel. The data these messages belong to may be delivered over a physical or logical link, or it can pass through a certain network node. Throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second (p/s or pps) or data packets per time slot.

3.3 Energy

Chapter 4

Channel Models in Aquasim for UWASN

An accurate understanding and modelling of the underwater acoustic channel is the basis upon which all work for underwater networks is based. There exist several models for calculating and predicting the attenuation, which effects all other aspects of the underwater acoustic channel model. Furthermore, parameters from frequency, distance, depth, acidity to salinity and temperature of the underwater environment effect how the channel acts and in turn also result in changing network performance. As such, as a basis for further work, it is necessary to create suitable channel models for predicting the performance of an underwater channel. This section formulates underwater channel models and numerically compares them.

The performance of an underwater acoustic channel model depends on the propagation model. The changes in the propagation model is dependent on the attenuation model that is chosen. In this section we discuss the different propagation models based on the attenuation models.
The attenuation models we have considered are attenuation by absorption. We have considered the following models for the study:

A. Thorp Model
B. Fisher& Simmons Model
C. Ainslie and McColm Model
D. Ambient Noise Model.

4.1.1 Thorp Model:

This is the simplest equation as it takes into consideration only the frequency utilized and ignores the effects of the relaxation frequencies, salinity and acidity levels of the ocean.

$$\alpha = \frac{0.1f^2}{1+f^2} + \frac{40f^2}{4100+f^2} + 2.75\times10^{-4}\,.f^2 + 0.003$$

This model is applicable only for a temperature of 4° C and a depth of approximately is 1000m.

4.1.2 Fisher& Simmons Model

This model considers the effect of temperature and depth, while also considering the effects of relaxation frequencies caused by boric acid and magnesium sulphate.

$$\alpha = A_1P_1\frac{f_1f^2}{f_1^2+f^2} + A_2P_2\frac{f_2f^2}{f_2^2+f^2} + A_3P_3f^2$$

Here A1, A2 and A3 are functions of temperature and P1, P2 and P3 are functions of constant equilibrium pressure. These are represented as:

$$A_1 = 1.03\times10^{-8} + 2.36\times10^{-10}.T - 5.22\times10^{-12}.T^2$$
$$A_2 = 5.26\times10^{-8} + 7.52\times10^{-10}.T$$
$$A_3 = \left[55.9 + 2.37.T + 4.77\times10^{-2}.T^2 - 3.48\times10^{-4}.T^3\right].10^{-15}$$
$$f_1 = 1.32\times10^3(T + 273.1)e^{\frac{-1700}{T+273.1}}$$
$$f_2 = 1.55\times10^7(T + 273.1)e^{\frac{-3052}{T+273.1}}$$
$$P_1 = 1$$
$$P_2 = 1 - 10.3\times10^{-4} + 3.7\times10^{-7}.P^2$$
$$P_3 = 1 - 3.84\times10^{-4} + 7.57\times10^{-8}.P^2$$

This model operates at depth restriction of not greater than 8km and salinity restriction of 35ppm, and PH should be set at 8.

4.1.3 Ainslie and McColm Model

This model is an extension of Fisher & Simmons model. It proposed extra relaxations and simplifications as follows.

$$\alpha = 0.106\frac{f_1f^2}{f_1^2+f^2}e^{\frac{pH-8}{0.56}} + 0.52(1 + \frac{T}{43})(\frac{S}{35})\frac{f_2f^2}{f_2^2+f^2}e^{\frac{-D}{6}} + 4.9\times10^{-4}f^2e^{-(\frac{T}{27}+\frac{D}{17})}$$

The Ainslie & McColm model takes into consideration the effects of acidity of sea water and it is a function of depth unlike the Fisher & Simmons model which is a function of pressure.

Equation for f1 and f2 are as follows:

$$f_1 = 0.78\sqrt{\frac{S}{35}}e^{\frac{T}{26}}$$

$$f_2 = 42e^{\frac{T}{17}}$$

4.1.4 Ambient Noise Model

The ambient noise is Gaussian and has a continuous power spectrum density. The most prominent sources of ambient noise are turbulence, shipping, wind driven waves and thermal noise.

The ambient noise in the ocean is colored and hence different factors have pronounced effects in specific frequency ranges. Turbulence noise influences only the very low frequency region, f<10 Hz. Noise caused by distant shipping is dominant in the frequency region 10 Hz -100 Hz. Surface motion, caused by wind-driven waves is the major factor contributing to the noise in the frequency region 100 Hz - 100 kHz (which is the operating region used by the majority of acoustic systems). Finally, thermal noise becomes dominant for f>100 kHz

Chapter 5

Channel characteristics of UWASN

5.1 Signal to Noise ratio (SNR)

Using knowledge of the signal attenuation A(l, f) and the noise p.s.d. N(f) the SNR observed at the receiver may be calculated.

$$SNR(l, f) = \frac{P}{A(l, f)N(f)\Delta f}$$

Where SNR(l, f) is the SNR over a distance l and transmission center frequency f. Similar to the received signal power, the attenuation model choice also adds a dependence upon depth, temperature, salinity and acidity of the specific oceanic region that is of interest, for the SNR.

5.2 Optimal Frequency

The attenuation noise (AN) factor, given by

$$-[10\log A(l,f) + 10\log N(f)]$$

Provides the frequency dependent part of the SNR. By close analysis of this relationship, it can also be determined that for each transmission distance l there exists an optimal frequency at which the maximal narrow-band SNR is obtained. Since the SNR is inversely proportional to the AN factor, the optimal frequency is that for which the value of 1/AN represented in dB pre μPa per Hz) is the highest over the combination of a certain distance, fo(l).

Using these Optimal Frequencies one may choose a transmission bandwidth around fo(l) and adjust the transmission power to meet requirements of a desired SNR level.

5.3 Channel Capacity

Channel capacity governs many aspects of network design and can lead to significant changes in topologies, protocols and access schemes utilized in order to maximize the overall throughput.

As per the Shannon theorem the channel capacity C, i.e. the theoretical upper bound on data that can be sent with a signal power of S subject to additive white Gaussian noise is:

$$C = B \log_2 \left(1 + \frac{S}{N}\right)$$

Where B is the channel bandwidth in Hz and S N represent the SNR.

Chapter 6

Implementation of UWASN

In this section, we first give an overview of the Aqua-Sim and we present the implementation of Aqua-Sim, including physical layer models, MAC layer classes, and routing layer classes as well as some other commonly used classes.

6.1 R-MAC Protocol:

R-MAC is proposed in and is a reservation based MAC protocol. R-MAC is divided into three phases. In the initial phase, nodes measure the distances to neighbors by sending some small control packets. Based on the measurements, every node will randomly choose a period for its data transmission and inform others in Phase 2. In Phase 3, nodes cooperate with each other to schedule data transmissions to avoid collisions. Although R-MAC is much more complicated than other MAC protocols, it has the same interface as others and no changes are needed in other parts of AquaSim.

6.2 VBF Protocol:

Vector-Based Forwarding (VBF) protocol is a geographic routing protocol. Each node in the network is assumed to know its position. In VBF, the forwarding path follows a vector from the source to the target, which is called forwarding vector. The position information of the source, target, and forwarder is carried in the header of the data packet. When a node receives a packet, it calculates its distance to the forwarding vector. If the distance is less than a pre-defined threshold, called radius, this node is qualified to forward the packet. In VBF, the forwarding path is virtually a pipe from the source to the target, called forwarding pipe. VBF is very robust against mobile networks, error-prone channels and vulnerable sensor nodes.

Chapter 7

Simulation

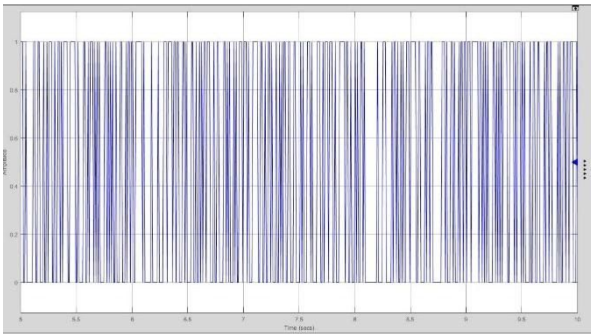
7.1 Parameters

Sr No.	**Parameter**	**Specification**
1	Area	100x100 m
2	MAC	Mac\underwatermac\rmac
3	Network	Channel\underwaterchannel
4	Nodes	10
	Sink	1
	Source	1
	Fast moving	2
	Slow moving	1
	Static	5
5	Idle power	0.01 W
6	Initial energy	1000 J

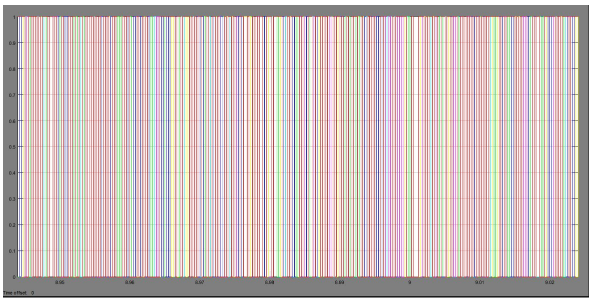
7	Simulation time	1000 sec

7.2 Graphs

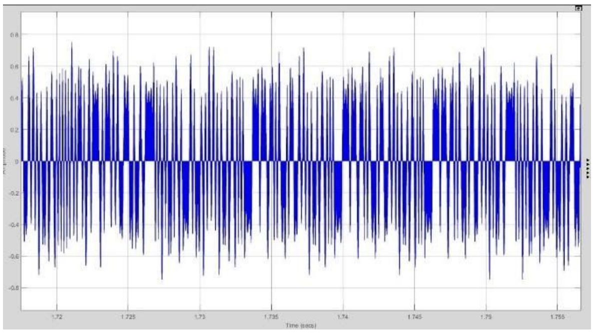
7.2.1 Bernoulli Signal Output



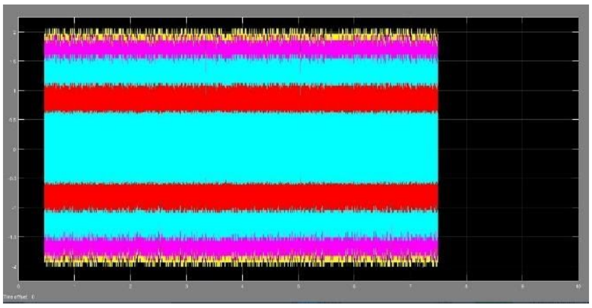
7.2.2 BPSK Demodulated



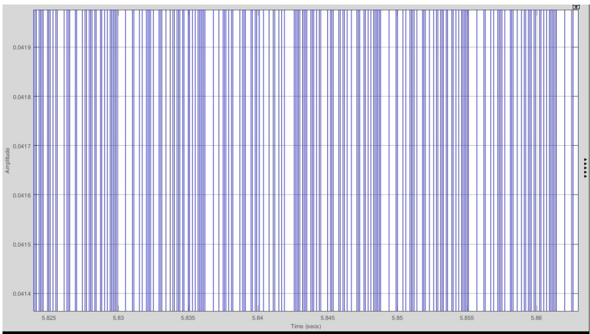
7.2.3 Raised cosine Transmit Filter BW



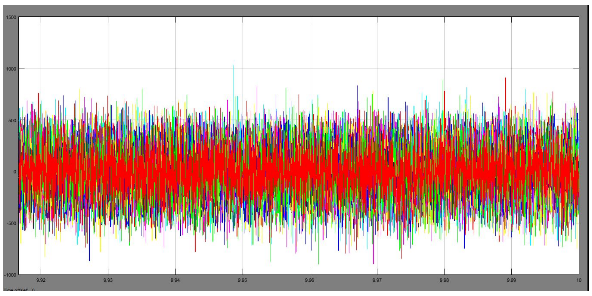
7.2.4 Raised Cosine Receive Filter



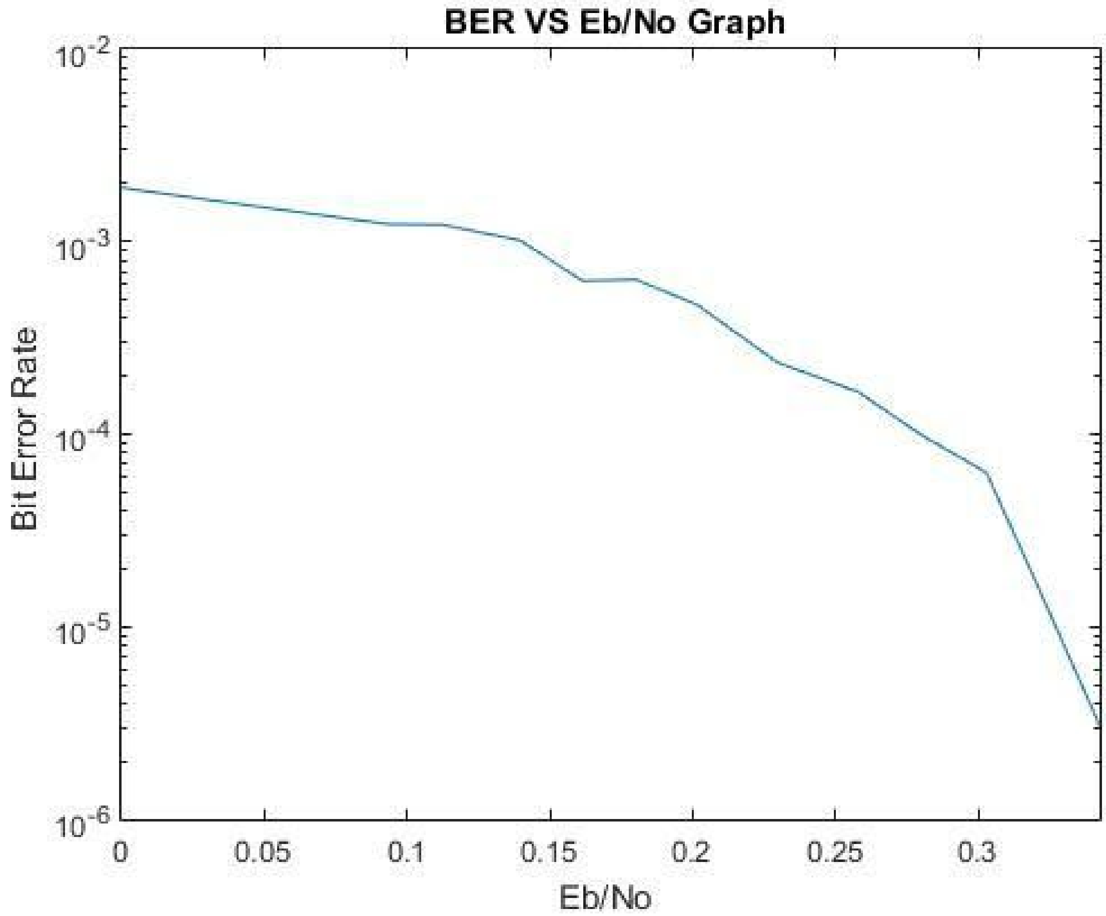
7.2.5 BPSK Modulated Signal



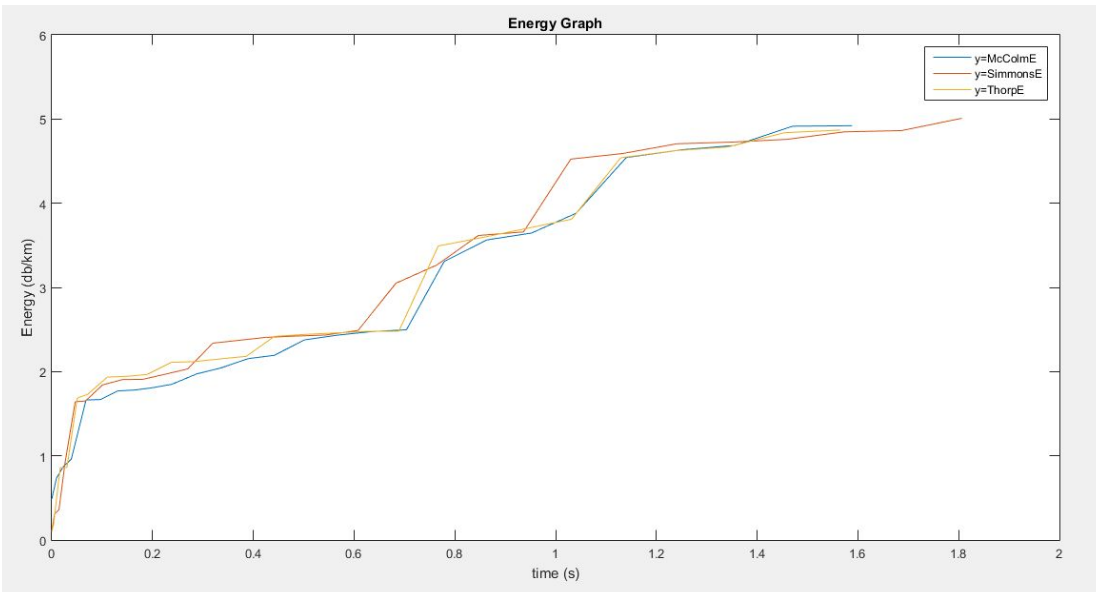
7.2.6 Noise Added Signal



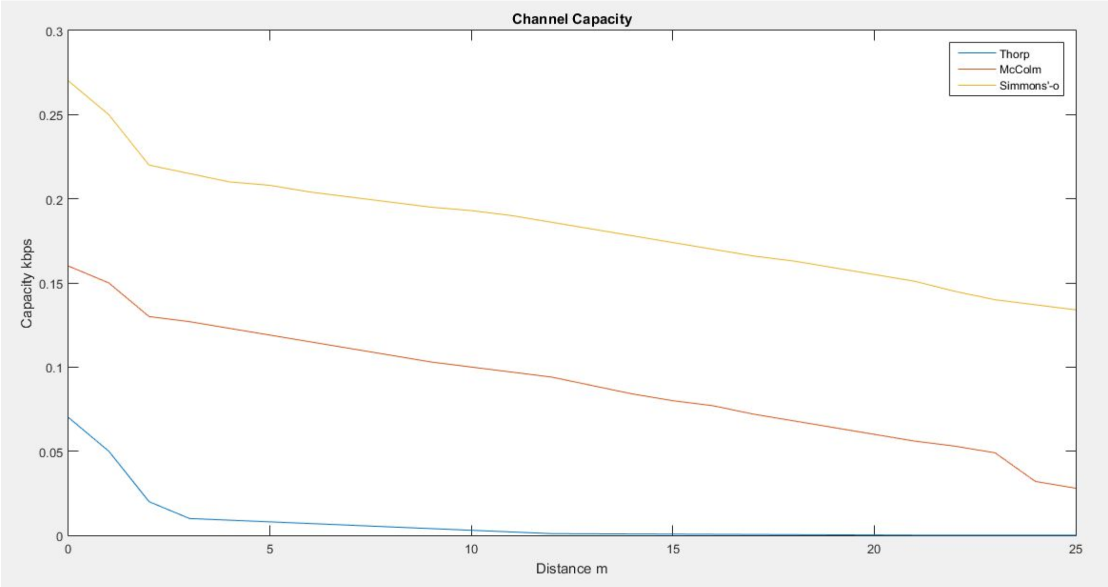
7.2.7 BER vs Eb/No:



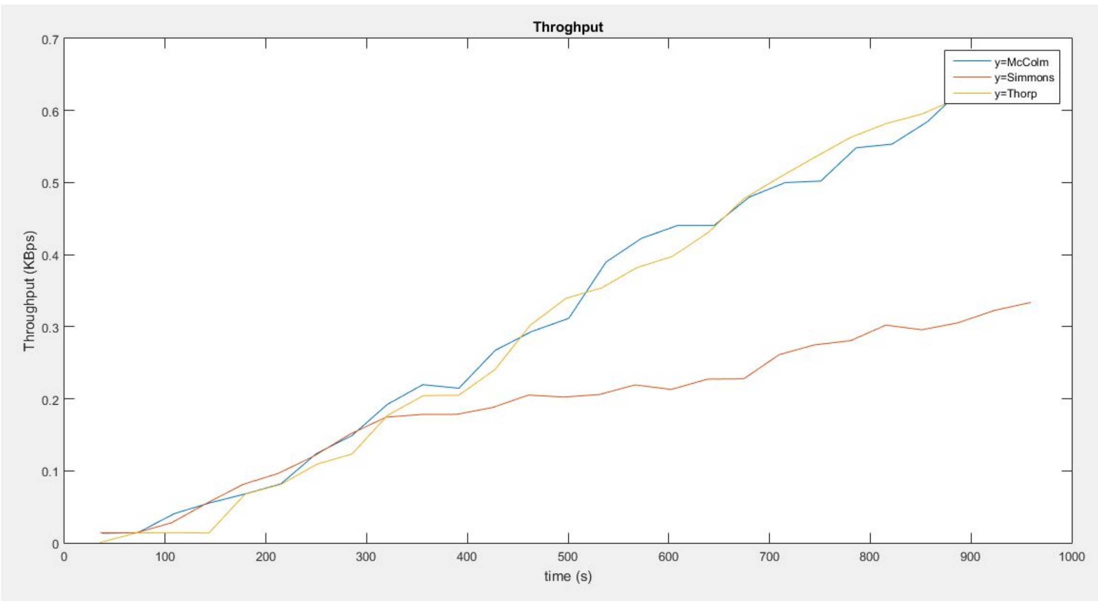
7.2.8 Energy graph



7.2.9 Channel capacity



7.2.10 Throughput



Chapter 8

Challenges in UWSAN

Main issues tackled by physical layer in UWSAN and discussed throughout this section are as follows: interface to physical transmission media, modulation, equalization filtering, and efficient carrier sense and collision detection (used by the MAC layer); additionally, other essential services include bit rate, bit synchronization and forward error correction.

Multipath in underwater channel is caused by two relevant factors: Wave reflection at bottom surface or any object and sound reflection in water

Doppler Effect, the relative motion of transmitter and receiver produces Doppler Effect which causes additional signal distortion

Chapter 9

CONCLUSION

As a summary of what is considered in this paper, a general view was taken about Wideband Code Division Multiple Access (WCDMA) its definition, types and practical applications also considered principle of operation with derivation of mathematical parameters of operation and also considered its ability to overcome difficulties in underwater communications through use of DSSS.

Bit error rate of overall system does not depend on the modulation technique is used in simulation but depends on bandwidth of information signal along with noise signal. It is important to note that, As Eb/No increases Bit error rate decreases

In UWSAN, energy consumption is largest concern, because nodes are battery powered thus energy efficiency at physical layer is mandatory. Hence further research should be conducted so as to achieve more robust communications, as well as high quality of service, it is necessary to develop a type of adaptive receiver for the acoustic link

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