Simulation For Under Water Channel

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Abstract

Underwater acoustic communication is a rapidly growing field of research and engineering. The wave propagation in an underwater sound channel mainly gets affected by channel variations, multipath propagation Purpose of this paper is to introduce a new technique for de-noising underwater acoustic signal affected by ambient noise. Ambient noise is non-stationary and unwanted background noise caused due to manmade or natural causes. Thus we present a reliable simulation environment for underwater acoustic communication application that models the sound channel by incorporating multipath propagation, surface and bottom reflection coefficients, attenuation losses as well as the transmitter/receiver device employing Quadrature Phase-Shift Keying (QPSK) modulation techniques.

Keywords: *Under Water Acoustic Signal; Quadrature Phase-Shift Keying (QPSK); Sensor Equipped Aquatic (SEA); Quadrature amplitude modulation (QAM).*

1. Introduction

Under water communication is technique of sending and receiving the message below water. There is several way of using such communication but the most common is using hydrophones. The first underwater communication was started in 1945 by United States for communicating with submarines, was one of the first underwater communication systems. Today, underwater acoustics are used for communication in a broad--range of applications, mostly sensor based, including ocean sampling networks, environmental monitoring, undersea explorations, disaster prevention and assisted navigation, speech transmission between divers, distributed tactical surveillance, and mine reconnaissance [5; 6]. There are various ways for under water communication like by using EM waves, optical waves, current waves, acoustics waves. Acoustic wave is the most popular for this. In acoustic wave electrical signal is converted in to pressure signal using hydrophone. But there are various limitations such as multipath propagation, speed, noise and bandwidth. In practical application it is essential to de-noise underwater acoustic signal, which is received by a hydrophone in order to get actual information.

Underwater communications in general mainly gets affected due to-

• **Channel Variations-** Channel variations are variations in- Temperature - Salinity of water - pH of water Depth of water column or pressure and - Surface/bottom roughness.

• **Multipath Propagation-** The channel can be considered as a wave guide and due to the reflections at surface and bottom we have the consequence of multipath propagation of the signal.

• **Attenuation-** Acoustic energy is partly transformed into heat and lost due to sound scattering by in homogeneities.

• **Doppler Shift -** Due to the movement of the water surface, the ray getting reflected from surface can be seen as a ray actually getting transmitted from a moving transmitter, and thereby having Doppler shift in the received. - When the receiver and transmitter are moving with respect to each other, the emitted signal will either be compressed or expanded at the receiver. Thereby, Doppler Effect is observed.

Channel variations and multipath propagation keep a lot of hurdles for the achievement of high data rates and robust communication links. Moreover, the increasing absorption towards higher frequencies limits the usable bandwidth typically to only a few kHz at large distances.

In this paper, the channel has been modeled by considering direct and multipath propagation, surface and bottom reflection coefficients. In order to achieve high data rates it is natural to employ bandwidth efficient modulation. In our case Quadrature Phase-Shift Keying (QPSK, which is equivalent to 4-QAM) modulation techniques have been used for transmitter and receiver. We have considered in depth the channel variations, direct and multipath propagation as our investigation. Thus we present a reliable simulation environment for underwater acoustic communication applications (reducing the need of sea trails) that models the sound channel by incorporating direct and multipath propagation, surface and bottom reflection coefficients, attenuation, using Quadrature Phase-Shift Keying (QPSK) modulation techniques.

2. Literature Review

Digital underwater communications are becoming increasingly important, with numerous applications emerging in environmental monitoring, exploration of the oceans, and military missions. Until the mid-nineties, the research was focused on hardware and on communication transmitters and receivers for the transmission of raw bits. In network terminology, this is known as the physical Layer. A breakthrough was achieved in the mid-nineties by Stojanovic*et al.*, which showed that phase coherent Communication is feasible by integrating a phase-locked loop into a decision-feedback equalizer. Such a receiver can be applied to a single hydrophone, although robust operation at high data rates, say generally requires the presence of a (vertical) Hydrophone array for reception. Indeed, multichannel adaptive equalizers have proven to be versatile and powerful tools. If the use of a receive array is impractical, as in multi nodes networks, then frequency-shift keying (FSK) is often used as a fairly robust modulation for single receiver systems. Underwater sensor networks have been proposed recently to support time-critical aquatic applications such as submarine tracking and harbor monitoring [1, 2]. Unlike traditional tethered sensors, a large number of underwater mobile sensor nodes are dropped in the venue of interest to form a Sensor Equipped Aquatic (SEA) swarm that moves as a group with the water current [3, 4].In the underwater positioning scheme of [7], a master anchor sends a beacon signal periodically, and other anchors transmit their packets in a given order after the reception of the beacon from the previous anchor. The localization algorithm in [8] addresses the problem of joint node discovery and collaborative localization without the aid of GPS. The algorithm starts with a few anchors as primary seed nodes, and as it progresses, suitable sensor nodes are converted to seed nodes to help in discovering more sensor nodes. The algorithm works by broadcasting command packets which the nodes use for time of light measurements. The authors evaluate the performance of the algorithm in terms of the average network set-up time and coverage. However, physical factors such as packet loss due to fading or shadowing and collisions are not included, and it is not established whether this algorithm is optimal for localization. Lloret [9] compares a proposed communication system with other existing systems. Although the proposal supports short communication distances, it provides high data transfer rates. It can be used for precision monitoring in applications such as contaminated ecosystems or for device communications at high depth. The authors have proposed a cheap and efficient way for underwater communications using IEEE 802.11 devices at 2.4GHz transmission. Llor et. al. [10] presents the various parameters used for underwater communication. The paper discusses the transmission distance and frequency. Furthermore, the authors investigate the multipath loss. Finally, the paper addresses the modulation and demodulation of the signal for underwater communication.

2.1Current commercial solutions

Table 1 presents an overview over some of the commercial underwater communication systems currently available. It can be seen that the only solution that uses electromagnetic (EM) waves has by far the highest data rate. But at the same time this is the solution with the shortest range 10m. If we compare the acoustic devices among themselves, a strong dependency between range and maximum possible data rate can be identified. A shorter range in general leads to a higher possible data rate. The last device Develogic HAM.NODE is only usable for vertical acoustic communications. This device could hardly be compared with the other ones so this is completely different acoustic channel.

Table -1 Commercial solution for underwater communications.

Name	Data rate	Range	power consumption	Method Used
Wireless Fibre Sea tooth	100 kb/s	10m	4.56-15.8w	EM
EvoLogics S2C R 48/78	28 kb/s	1km	500mw-2.5w	Acoustic
LinkQuest UWM1000	19.2kb/s	350m	.75w-1w	Acoustic
AquaComm Modem	480b/s	10km	25.2mw-252mw	Acoustic
CDL DATUM	480b/s	2km	1w-3.5w	Acoustic
Teledyne Benthos OEM	360b/s	2km	OEM	Acoustic
Develogic HAM. NODE	7kb/s	-	3w-500w	Acoustic

3. Presented Work

The simulation system is illustrated in figure below. It consists of a bit source, transmitter, channel, receiver and a bit sink. The bit source generates the random binary sequence that is to be transmitted by the transmitter. Typically a random bit source is employed in simulations and this is the case in our simulation as well. The transmitter converts the bits into QPSK symbols, applies pulse shaping and up-conversion is done to the desired carrier frequency.

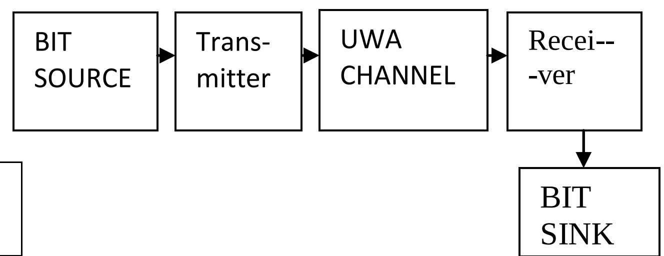

Fig. 1: The Simulation system considered

The output from the transmitter is fed through the underwater acoustic channel. The receiver block takes the output from the channel, estimates phase and timing offset, and demodulates the received QPSK symbols into information bits which are fed to the bit sink. Here, the bit sink counts the number of errors that occurred to gather the statistics used for investigating the performance of the system.

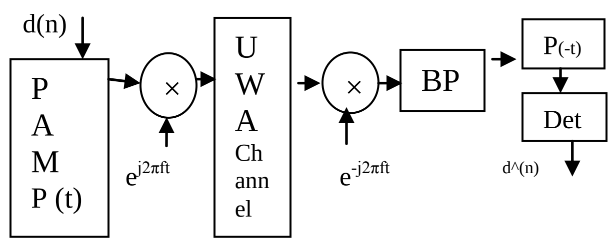

Fig. 2: Underwater Acoustic simulation system.

The communication system considered is shown in Fig.1. This is a typical set up which can represent any kind of system using Quadrature amplitude modulation (QAM). This QPSK system is used in our investigations. A brief overview of the system now follows. At the transmitting side, the sequence of symbols d (n) is converted to a continuous-time baseband signal $S_{bb}(t)$ by a pulse amplitude modulator (PAM). Note that d(n) takes the values from discrete set of complex valued symbols. Up conversion is performed by multiplying with $e^{j2\pi f_c t}$, resulting in a band pass signal S(t), being transmitted over the channel. In order to remove the carrier, the received signal r(t) is processed by a down converter which outputs the corresponding baseband equivalent signal $r_{bb}(t)$. The down converter is followed by a low pass and then by a matched filter. The detector gives the estimates of the transmitted symbols. Baseband representation is useful in order to be able to simulate the system using, for example, Mat-lab, where only time discrete signals can be represented. Figure 3 represents the base band equivalent system.

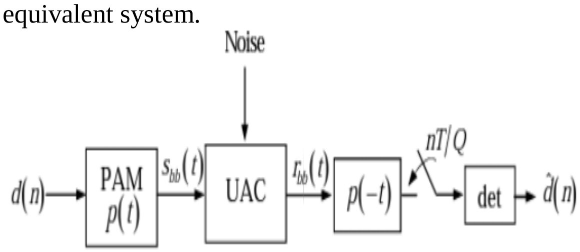

Fig. 3: The baseband equivalent system

In order to gain the high order data transmission at low bit error rate to the receiver. We have separated the transmitter and receiver at 1000m.then a continuous time base system is taken and QPSK modulation technique is used. We have shown example of case 1 only in our results at different depths of transmitter and receiver along with various horizontal distances. The simulation result shows the losses and bit error rate in direct and multipath propagation.

4. Methodology

We are using a continuous Time Baseband system for finding the bit error rate for direct path and multi path in under water communication channel. Our program is written in C language, implemented in Mat-lab. It is divided into three parts i.e., Transmitter, channel and Receiver, as shown in flowchart below.

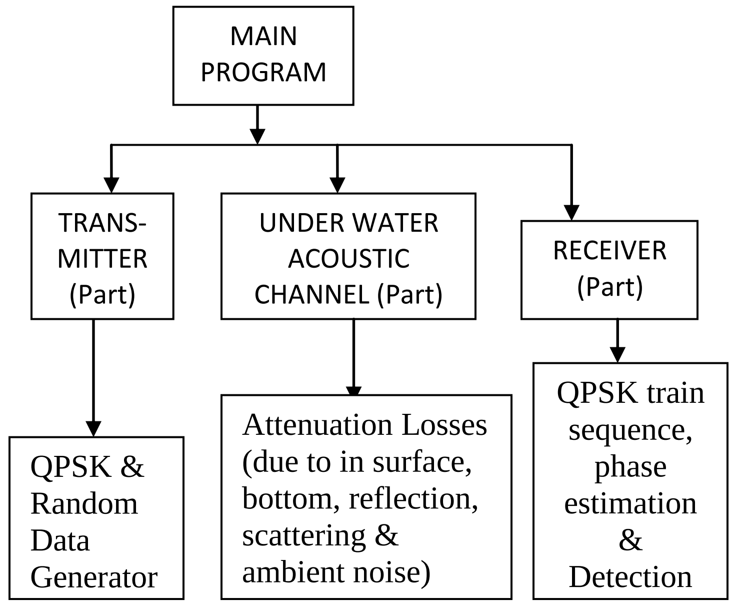

Fig.4: Flow Chart

5. Result

The major impact in an underwater acoustic channel would be its multi-path propagation. Always our desired goal is to achieve high data rates from transmitter to receiver at low BER. The physical positioning of a transmitter and receiver in an underwater acoustic channel of depth *D* and infinite length is also in consideration. At shorter distances the multi-path reaches the receiver at a much longer time compared to the direct path.

A number of figures given below present the simulation results for a particular environmental scenario varying the receiver location. These figures explain the impact of distances, (indirectly its grazing angles which play a major role) on time delays of multi-path propagation for the following environmental scenario. Here, the wind speed and bottom type are not included as we are representing only the time delay concept without any transmission loss phenomenon included.

Environmental Scenario Case 1:-

Depth=40m
Source location r s=0m; z s=10m;
Receiver locations r r =500m; z r=20m
Salinity S=30; Temp=14; PH=6; V w=10; b t=1;

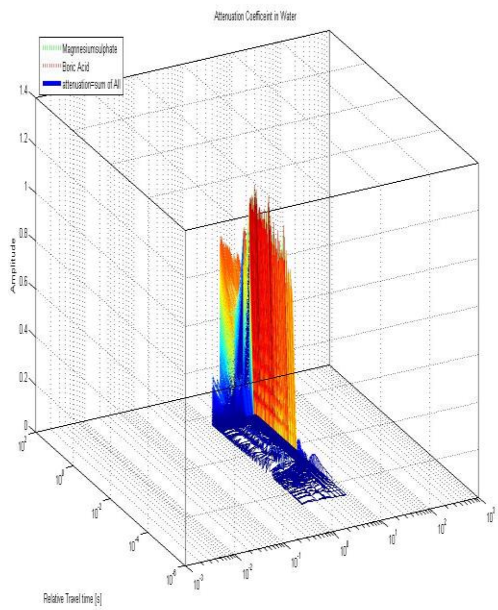

Fig. 5: Simulation results using Multipath.

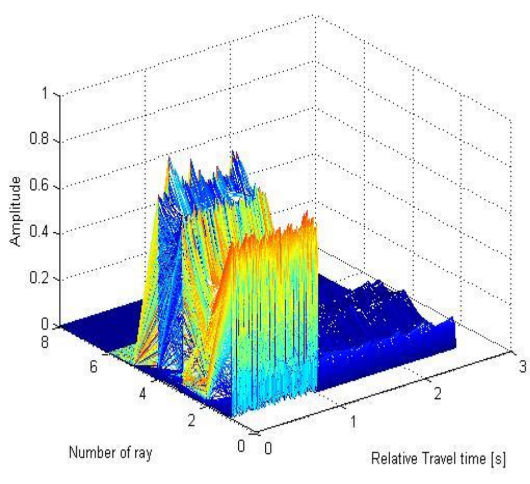

Fig. 6: Simulation results direct path.

The relative times of all the rays comparing to direct and the grazing angles for case 1 are provided in the following.
By changing the receiver position we get the following data in multipath:-

a) $(r_{R_1}, z_{R_1}) = (10, 20)$
T = [0 20.8207 20.8207 47.0817 47.0817 73.6106 73.6106 100.2081]
Angles = [0 75.9638 75.9638 82.8750 82.8750 85.2364 85.2364 86.4237]

b) $(r_{R_2}, z_{R_2}) = (100, 20)$
T = [0 5.1355 5.1355 18.7083 18.7083 37.4700 37.4700 59.1197]
Angles = [0 21.8014 21.8014 38.6598 38.6598 50.1944 50.1944 57.9946]

C) $(r_{R_3}, z_{R_3}) = (500, 20)$
T = [0 1.0650 1.0650 4.2397 4.2397 9.4656 9.4656 16.6508]
Angles = [0 4.5739 4.5739 9.0903 9.0903 13.4957 13.4957 17.7447]

d) $(r_{\downarrow}(R_{\downarrow}4), z_{\downarrow}(R_{\downarrow}4)) = (1000, 20)$
T = [0 0.5331 0.5331 2.1299 2.1299 4.7828 4.7828 8.4794]
Angles = [0 2.2906 2.2906 4.5739 4.5739 6.8428 6.8428 9.0903]

There is a huge difference in relative travel times for very shorter distances of 10 m, case (a), compared to a desirable range of 1000 m, case (d). This can be understood when we observe the corresponding grazing angles for each case. In case (a), the grazing angles are very high due to shorter distances where, as in case (d) you observe very low grazing angles. Another observation is the same, relative travel times and grazing angles for rays hitting surface or bottom, surface-bottom-surface or bottom-surface-bottom, etc. This is due to the location of both transmitter and receiver at exactly half of channels depth.

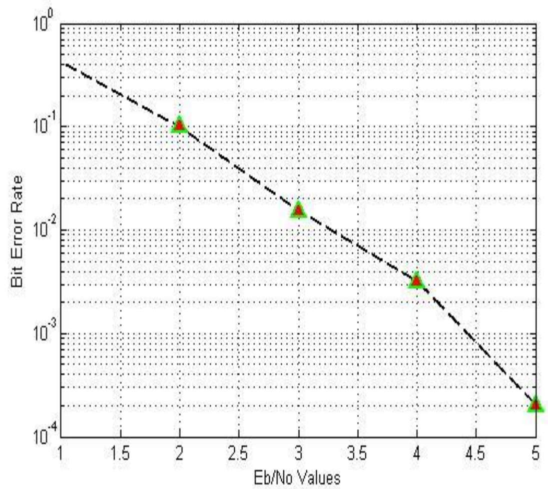

Fig.7: Bit error rate using multi path

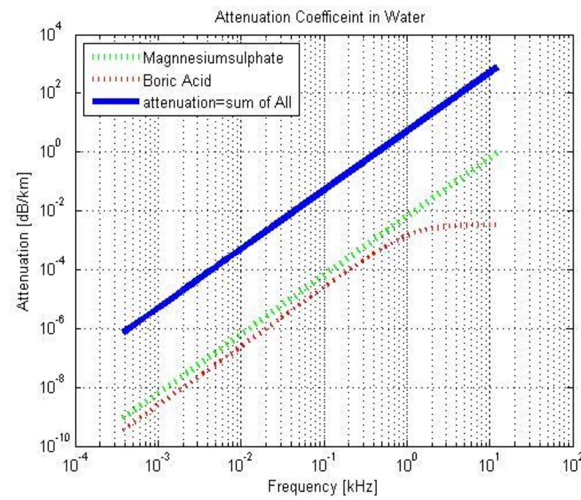

Fig.9: Attenuation coefficient diagram in water

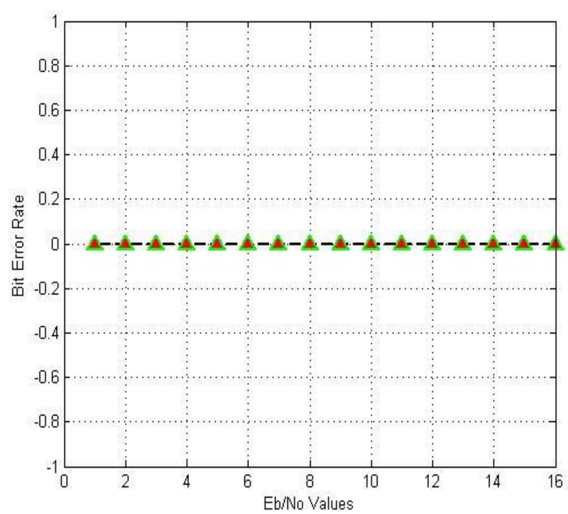

Fig.8: Bit error rate using Direct path

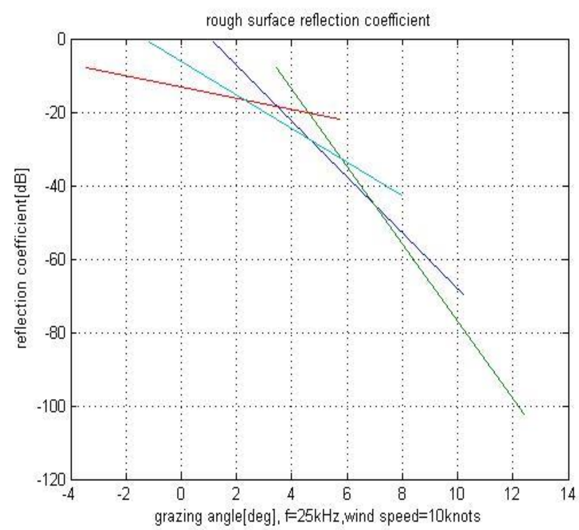

Fig. 10: reflection coefficient diagram in water

The following simulation results are exclusively presented to show the impact of transmission loss (including time delays) on multipath propagation at various vertical depths of transmitter and receiver along with various horizontal distances. All our simulation results are presented considering a 1000m separation between the transmitter and receiver.

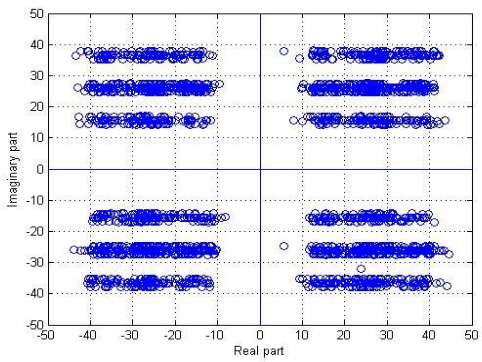

Fig.11: constellation diagram for direct-path case1

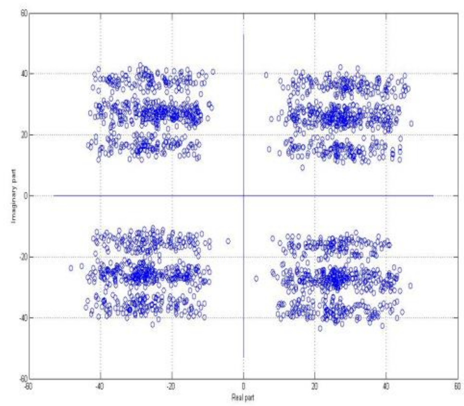

Fig.12- Constellation diagram for multi-path case 1

6. CONCLUSION

In this paper, we presented the direct and multi-path propagation in underwater acoustic channel and all the channel effects. In underwater acoustic channel the noise is in two forms, one is the ambient noise and the other is the multipath itself. We have showed the Bit Error Ratio for only direct path and multi-path for various environmental conditions. The results obtained from the system shows that the presented work is effective enough for under water channel communication.

7. References

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