Using Varying Channel Impulse Response to Determine Water Pollution

Sadia Ahmed

Department of Electrical Engineering
University of South Florida
Email: ahmed3@mail.usf.edu

***Abstract*—Water occupies three forth of earth's surface. Although human habitats reside on land, there is no denying of the vital connection between land and water. The future sustainability of human species on this planet depends on wise utilization of all available resources, including that provided by the vast water world. Therefore, it is imperative to explore, understand, define, and protect this massive, varying, and in many areas unexplored water domain. With the exponential growth in urbanization all over the world, water seems to be the common dumping ground of industrial waste. In addition, water is indirectly polluted in many ways in our everyday lives. Therefore, it is of vital importance to monitor water pollution levels effectively and regularly. It is a well known fact that sound wave propagation through water changes considerably in time, frequency, and in spatial domains. Any changes in the water channel and its parameters directly affect the propagation of the acoustic signal through it. Therefore, changes in acoustic channel impulse response (CIR) and acoustic signal level can be a valued indicator of water pollution. This paper presents preliminary laboratory results of the effects of two water contaminants, namely, motor oil and liquid detergent and shows how they change the water channel and in turn changes resulting acoustic CIR and signal level. The differences in CIR and signal level between clean water and that with pollutants can be utilized to monitor water pollution and its level effectively.**

I. Introduction

The rapid growth of world population and an equally high urbanization rate placed earth's water resources in great danger. Many enclosed water resources on land, rivers, and the oceans are regularly polluted with different pollutants from our daily domestic living and from heavy industrialization. It is imperative to identify these pollutants and their quantities effectively in order to protect the natural water resources. This paper presents an initial observation of the acoustic channel impulse response (CIR) in the presence of two water pollutants, namely, motor oil and liquid household detergent. Although a very few literature exists on detecting pollutants in sediments at the bottom using acoustic signal, to the best of the author's knowledge currently there doesn't exist any literature on detection of water pollutants using acoustic signal. Thus this paper proposes a novel approach to water pollutant detection.

The rest of the paper is organized as follows. Section II presents an analysis of the CIR, Section III presents the measurement set up and results, and Section IV presents the concluding remarks.

II. Analysis

A frequency selective and time varying channel can be expressed as [1],

$$h(t,\tau_{REF}) = \sum_{l=0}^{L-1} \alpha_l(t,\tau_{REF})\delta(\tau_{REF}-\tau_l(t)), \qquad (1)$$

where $\alpha_l(t,\tau)$ and $\tau_l(t)$ represent time varying attenuation coefficient and time varying tap delay of the lth delay bin respectively. Both parameters are function of time and depend on the scatterers arriving within the lth bin. The variable L represents the total number of multipaths or delay bins and δ represents the Dirac Delta function. In discrete domain (1) can be expressed as,

$$h(n,nT_s) = \sum_{l=0}^{L-1} \alpha_l(n,nTs)\delta(nT_s-\tau_l(n)), \qquad (2)$$

where variable T_s denotes the sampling period, nT_s represents the time corresponding to the nth sample. The channel impulse $h(n)$ is a complex quantity. It can be assumed that the real and imaginary components of $h(n)$ are independent and identically distributed (i.i.d.) and follow Gaussian distribution. Under such condition, the modulus of $h(n)$ or $|h(n)|$ will follow Rayleigh distribution [1]. In a time invariant channel (2) becomes $h(n) = \sum_{l=0}^{L-1}\alpha_l\delta(n-\tau_l)$. In this paper, CIR is generated and measured in time invariant and frequency selective UAC channels.

If only path loss is considered, each multipath will go through path loss given by [2],

$$TL_i = 20\log R_i + \beta R_i, \qquad (3)$$

where β is the water absorption coefficient with units of dB/Km and is a function of temperature, T, pressure, P, and salinity, S [2]. In this ideal scenario, the amplitude of each path derived from (3) can be expressed as, $A_i = 10^{\frac{TL_i}{10}}$.. Therefore, the received path amplitude levels in the CIR indicate the path loss encountered in the channel, which in turn is an indicator of water channel parameters and water pollutants. Different types of pollutants may affect the sound velocity and the water medium in such away that the arrival of paths and path delays may alter in the CIR in addition to path amplitudes.

III. CIR Measurement

This section presents the setup and results of UAC channel CIR measurement carried out at an indoor laboratory at the

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University of South Florida, St. Petersburg, FL campus. The two subsections below present the measurement setup and the measurement results.

A. Measurement Setup

The measurement is conducted in a small indoor container. The container inner dimension is of length 25inches, width 16inches, and water surface to bottom depth of 10inches. The container is made up of plastic material and filled with 65 liters of water. The water salinity is roughly 30 salinity units. Two RESON transducers are used to transmit and receive the signal while a signal generator generates the transmitted signal and an oscilloscope is used to record the transmitted and received signals. The transducers are 18 degrees conical directional transducers with operating resonant frequency of 200 KHz, operating bandwidth of 40 KHz, and with maximum power level of 50 Watt or 47 dB. The voltage and frequency range of the signal generator is 32V peak to peak and 50MHz respectively. The range of the oscilloscope is 100V per division with probe on the Y axis and 100μsec per division on the X axis. The transducers are placed 12 inch apart from each other and at 1 inch depth from the surface of the water. For the mixture of water and motor oil, 946 mL of motor oil is mixed with the water. For the water, oil, and detergent mixture, two standard cups of detergent is added. Figures 1, 2, 3, 4, and 5 illustrate the container, the transducers, salinity instrument, signal generator, and oscilloscope. The transducer transmits signal at 200kHz with peak to peak voltage of 10V.

B. Measurement Results and CIR Comparison

Figures 6, 7, and 8 illustrate the transmitted and received signal snapshots from the oscilloscope in clean sea water, clean water with mixed motor oil, and clean water with mixed motor oil and liquid detergent. The input or transmitted channel on the oscilloscope is calibrated with 2V per division on the Y axis and the output or received channel is calibrated with 20mV per division on the Y axis. The CIR in the clean sea water is almost as same as the CIR in the water and oil mixure. This is primarily due to the fact that after oil is stirred into the water, the oil makes a thin layer at the surface. The transducers are transmitting and receiving 1 inch below the surface. Therefore, the acoustic signal doesn't pass through the oil layer and is unaffected by the oil layer. The detergent mixture, however, mixes with the water better allowing the acoustic signal propagate through the mixture. The CIR amplitudes for the water, oil, and detergent mixture is lower compared to clean water CIR. In addition, the two transducers are placed only 12 inches apart making the acoustic propagation path a short one. As a result, the CIR in the three different mediums vary slightly from each other.

IV. CONCLUSION

This paper presents initial laboratory experiment results of using acoustic signal CIR to determine presence of water pollutants. In the future, this experiment will be conducted in a larger tank environment with variation of range, depth, water conditions, and water pollutants.

Fig. 1: Measurement Container

Fig. 2: Transducers

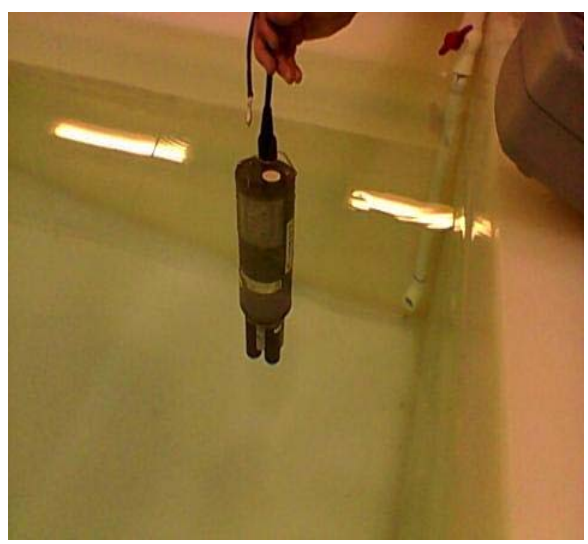

Fig. 3: Salinity Measuring Instrument

Fig. 4: Signal Generator

Fig. 5: Oscilloscope

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[2] X. Lurton, *An Introduction to Underwater Acoustics: Principles and Applications*. Springer, UK, 1996.

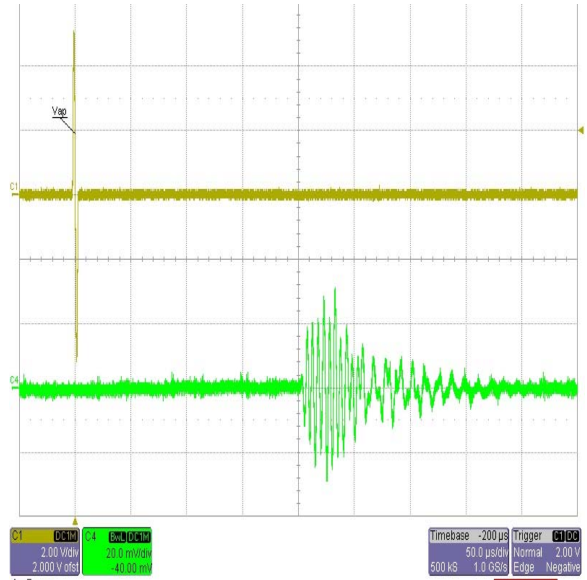

Fig. 6: Received CIR in Clean Sea Water

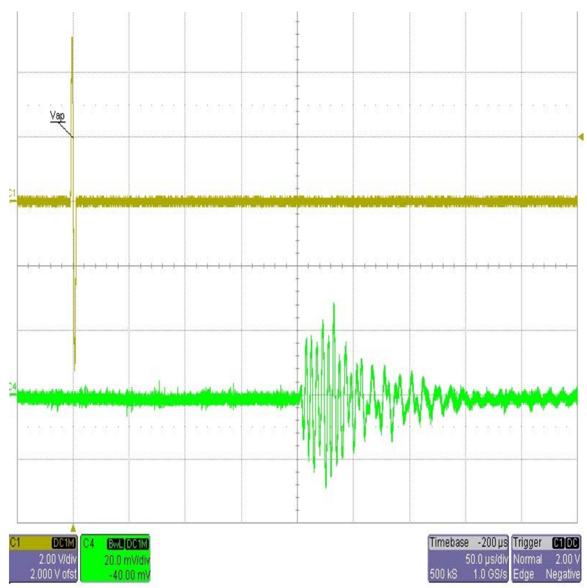

Fig. 7: Received CIR in Sea Water and Motor Oil Mixture

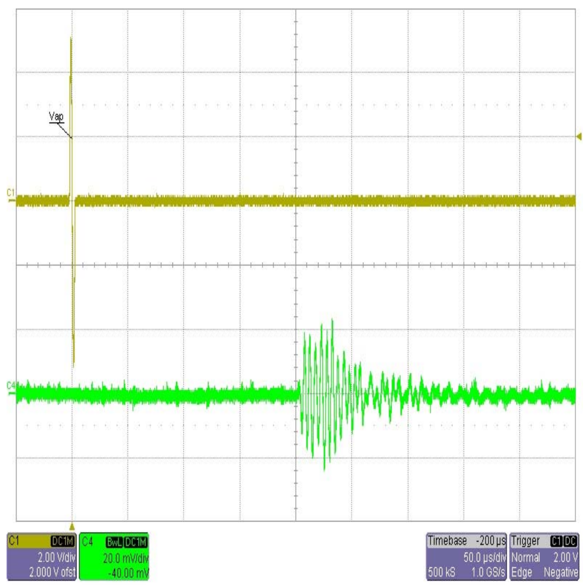

Fig. 8: Received CIR in Sea Water, Motor Oil, and Liquid Detergent Mixture