# Physics Of Offshore Buried Mine Detection and Classification

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## LONG-TERM GOAL

A better understanding of the science and engineering of buried mine detection leading to safe, standoff detection technologies.

## OBJECTIVES

A unified model of acoustic penetration of ocean sediments for a wide variety of sediment types, from gravel through sand, silt and clay and combinations thereof, and a model of signal attenuation and reverberation due to multiple scattering by sediment grains.

## APPROACH

The approach is divided into two parts, dealing with the propagation and scattering, respectively.
(1) Propagation: In progressing towards a unified model of acoustic penetration of ocean sediments for a wide variety of sediment types, the key unknowns are frame moduli and permeability. One approach is to collect acoustic measurement s from various sediment types, along with geophysical measurements and establishing relationships between them, in the context of Biot's theory for wave propagation in porous media. In this effort, collaboration with other laboratories, including the Naval Research Laboratory, GESMA, in France, and the NATO research center, SACLANTCEN, will be mutually beneficial. Through collaboration, a sediment database may be accumulated from a wide variety of measurements.

(2) Scattering: Acoustic interaction with sediment grains is expected to be a multiple scattering process. One approach is to model the medium as a finely layered structure, in which the layering is used to approximate the local variations in porosity at the grain size level.

## WORK COMPLETED

With regard to the development of propagation modeling, a process of inverting the grain and frame moduli from acoustic measurements was developed. Using an inversion of Biot's theory, based on the formulation by Stoll (1989), operative values of grain bulk modulus and the frame bulk and shear moduli of water-saturated sand may be extracted from measurements of compressional and shear wave speeds and reflection loss at normal incidence. The inversion process is nonlinear, but in practice it is well behaved and converges quite rapidly to unique values. The term grain bulk modulus, as defined in

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the formulation by Stoll, is not necessarily identical to the bulk modulus of the grain material, as is often assumed.

With regard to scattering, it was postulated that a laminar sand bed may be modeled as an ensemble of randomly layered Biot medium. The thickness of each layer was approximately half a grain diameter. The porosity variations in the vertical direction were matched to the mean and standard deviation of that of a structure of packed spherical grains. The effect of lateral variations in porosity was simulated by performing a coherent ensemble average of the acoustic output from several realizations of the randomly layered medium. The medium parameters were chosen to represent water-saturated sand. Specifically, the sand bed was modeled as bounded by a homogeneous water halfspace above, and a homogeneous poroelastic halfspace of equivalent average porosity below. Reflected and transmitted signals were computed using code developed in the previous project and debugged and enhanced in the present project. Coherent and random components of the reflected signal were calculated. The coherent parts were directly related to the reflected and the transmitted waves.

## RESULTS

Inversion results, using reflection loss at normal incidence and fast compressional and shear wave speeds pointed to a grain bulk modulus that is considerably lower than that of quartz crystals. For quartz sand, this is inconsistent with previous assumptions and requires further research.

Modeling results showed significant differences between the modeled sand bed and an equivalent uniform Biot medium. In the modeled sand bed, the fast wave attenuation was found to be anisotropic, and a propagating slow wave was excited at most incident angles, except at normal incidence, which may explain the apparent failure to detect the slow wave of certain experiments .

## IMPACT/APPLICATION

The propagation studies are of general application to sediment acoustic modeling. There is an inconsistency in current models in the predicted values of compressional and shear wave speeds and normal incidence reflection loss. Current models, including the fluid, elastic solid, and poro-elastic (Stoll) models may be adjusted to match one or two, but not all three measurements. The problem is a systemic and underlies all existing sediment acoustic models currently in use. The results of this study will lead to an understanding of the underlying processes, a new model that is consistent with all three acoustic measurements, and thereby provide an insight to the relationships between acoustic and geophysical properties, and the physics of buried mine detection.

The scattering studies will provide a candidate model for scattering from granular sediments, which will include the effects of multiple scattering due to sound wave interaction with the grains. This model will fill the gap that currently exists between low frequency scattering by structural features, and high frequency geometric scattering when the wave length is smaller than the grains.

## TRANSITIONS

Both results are transitionable to existing mine hunting sonar performance prediction models. The popular propagation model OASES, in version 2.1, includes the facility to model poro-elastic layers and is capable of utlilizing the results of the propagation study. Elements of the scattering study have already been transitioned into the bottom scattering model BOGGART.

Environmental data from UUV systems and Purple Star, N00014-96-C-6025, in which an algorithm was for bottom classification, using an echo-sounding sonar, was successfully demonstrated, was based on models developed in this, and preceding projects.

The specifications of the sediment classification function of the Remote Minehunting system (RMS), designated AN/WLD-1(V)1, was based on the model developed in this, and preceding projects.

## RELATED PROJECTS

1 ñ Broad-band High-frequency Sound Interaction With The Seafloor. This project will provide much needed in-situ experimental data.

2 ñ Projects related to the application of the Biot model to sediment acoustics, such as Sediment Acoustics (Stoll), and Range Dependent Media (Stephens), will benefit from the findings in this project.

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