MASTER OF SCIENCE
IN
ENGINEERING ACOUSTICS

ACOUSTIC TRANSIENT TDOA ESTIMATION AND DISCRIMINATION

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This thesis examines acoustic transient discrimination and Time Difference of Arrival (TDOA) estimation for the purposes of estimating the position of a submarine in a sonabuoy field. Transient discrimination, for this thesis, is the process of telling different transients apart. Two algorithms are evaluated. One method is based on higher order statistics while the other is based on signal subspace techniques. Extensive simulations using synthetic transients were conducted to establish the performance of each algorithm in terms of discrimination and TDOA estimation. It was found that the bispectral algorithm gave better TDOA estimation at low SNRs while the subspace algorithm gave better TDOA estimation at high SNRs. For discrimination, it was found that the subspace algorithm gave consistant false alarm rates at all SNRs while the false alarm rate for the bispectral algorithm grew with increasing SNR.

DoD KEY TECHNOLOGY AREAS: Sensors, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Transient, TDOA, Discrimination, Bispectrum, Subspace

CONSTRUCTION AND QUANTIFICATION OF A TOROIDAL BUBBLE APPARATUS

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A toroidal bubble is a vortex ring with a gas core in a liquid. Current interest in toroidal bubbles is partially due to the discovery that small toroidal bubbles can occur in the cavitation collapse of a spherical bubble near the surface of a solid. This can occur near a propeller blade, causing both damage and acoustic emission. Another motivation is that dolphins generate a rich variety of large vortex bubbles. The objectives of this thesis are the construction of an apparatus that generates large toroidal bubbles in a tank of water, and the establishment of the parameter space in which toroidal bubbles occur. The apparatus employs a variable electrical input, interchangeable solenoid valve, interchangeable needle valve, and pressurized nitrogen gas. The tank is an acrylic cylinder with diameter one foot and height four feet. It is observed that whether or not a toroidal bubble forms is highly stochastic. This is studied by varying several parameters of the apparatus. Preliminary results of possible acoustic emission are presented. Future work with the apparatus is discussed, including digital photography of toroidal bubble formation and the effect of ensonification on the motion.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Toroidal Bubble, Vortex Ring, Acoustic Emission, Fluid Dynamics

ANALYSIS OF THE WATERHAMMER CONCEPT AS A MINE COUNTERMEASURE SYSTEM

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The purpose of this thesis is to provide an analysis of the Waterhammer concept design. Waterhammer is a device intended to generate repetitive shock waves to clear a path through the very shallow water region for amphibious operations. These repetitive shock waves are intended to destroy obstructions and mines alike.

This thesis analyzes the energy budget of the deflagration processes and the basic principles of shock waves and acoustic saturation. When the source amplitude is increased to very high levels, acoustic saturation sets in, a state in which the amplitude of the received signal approaches a limiting value, independent of the source amplitude. Acoustic saturation thus will set physical constraints in the design of Waterhammer. Furthermore, as the pulse propagates in the shallow water environment, reflections from the water's surface and bottom floor will spread the energy in the water column thus reducing the energy density. These combined effects can affect the intended performance of Waterhammer. The results of the analysis in this thesis lead to the conclusion that Waterhammer may not be viable in its present concept design.

DoD KEY TECHNOLOGY AREAS: Conventional Weapons, Surface/Under Surface Vehicles-Ships and Watercraft, Manufacturing Science and Technology (MS&T)

KEYWORDS: Waterhammer Performance, Acoustic Saturation Limits, Nonlinear Effect in Water Due to Very High Source Levels

PARABOLIC EQUATION MODELING OF BOTTOM INTERFACE AND VOLUME REVERBERATION IN SHALLOW WATER

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A reverberation model based on the parabolic approximation is developed that includes sediment interface and volume perturbations. A multiple forward/single backscatter approximation is made, and the structure of the solution is found to depend on the two-way propagation with a scattering strength scaling dependent on the local properties of the perturbation. The model is implemented for continuous wave (CW) signals to predict mean reverberation pressure levels and for broadband pulse signals to generate complex reverberation structures in the time-domain. The spatial correlation and statistical properties of these predicted signals are then analyzed in an attempt to extract information on the underlying characteristics of the perturbation. Preliminary analysis suggests that reverberation due to the volume perturbations decorrelates more rapidly over depth than the reverberation due to interface fluctuations, although the differences appear small. Additionally, the statistical character of the reverberation structure due to the interface appears as a relatively flat spectrum, while the spectrum of the volume reverberation tends to appear colored. Attempts to correlate these characteristics with the structure of the perturbations is ongoing.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Shallow-Water Sound Propagation, Reverberation, Bottom Interface, Bottom Volume, Spatial Perturbations, Sound Speed Perturbations, Peak Correlations, Time/temporal Series, Range Series, MMPE, MMPEREV

DESIGN AND COST-BENEFIT ANALYSIS OF A MINI THERMO-ACOUSTIC REFRIGERATOR DRIVER

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A miniature thermoacoustic refrigerator is being developed for the purpose of cooling integrated circuits below their failure temperature when used in hot environments. This thesis describes the development of an electrically powered acoustic driver that powers the thermoacoustic refrigerator. The driver utilizes a flexural tri-laminar piezoelectric disk to generate one to two Watts of acoustic power at 4 kHz in 15 bar of He-Kr gas mixture.

This thesis also provides a cost analysis of the Mini TAR and a comparison with other cooling methods in terms of cost and benefits. It estimates the unit cost of a Mini TAR and compares it with other existing microchip coolers in terms of cost and benefits.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronics

KEYWORDS: Thermoacoustics, Refrigeration, Acoustic Driver, Piezoelectric Driver, Cost and Benefit Analysis