MASTER OF SCIENCE
IN
ENGINEERING ACOUSTICS

MASTER OF SCIENCE IN ENGINEERING ACOUSTICS

AN INVESTIGATION OF SURFACE WAVES USING A TWO-AXIS SOURCE-RECEIVER COMBINATION

Anthony J. Anglin-Lieutenant, United States Navy
B.S., United States Naval Academy, 1990
Master of Science in Engineering Acoustics-June 1996
Advisors: Anthony A. Atchley, Department of Physics
Donald L. Walters, Department of Physics

The goals of this thesis are: 1) to design and test a two-axis surface wave source and two axis surface wave receiver, and 2) investigate surface waves to detect buried objects in water saturated sand. Results of measurements confirm the ability to generate particle motions in water saturated sand consistent with surface wave excitation. However, limitations in the size of the test tank prohibit a thorough investigation of the ability of the source and receiver to selectively excite and detect surface waves.

OPTIMAL DIGITAL DETECTION OF ACOUSTIC SIGNALS IN COLORED NOISE

Martin Cloutier-Captain, Canadian Armed Forces
B.Eng., Royal Military College of Canada, 1986
Master of Science in Engineering Acoustics-December-1995
Master of Science in Electrical Engineering-December 1995
Advisors: Ralph Hippenstiel, Department of Electrical and Computer Engineering
Roberto Cristi, Department of Electrical and Computer Engineering

The thesis addresses optimal methods for the detection of acoustic signals, corrupted by colored noise. In achieving this we provide a study of the characteristics of ambient noise in the ocean and the digital techniques which can be used in the process of detecting known acoustic signals which are corrupted by that noise. Various techniques are studied, in particular the use of matrix decomposition techniques applied to the correlation matrix or to a data matrix, and the matched filter for colored noise. Other methods such as the inverse filter, the differential operator, and the adaptive prediction-error filter will also be looked at for their whitening properties. The theoretical foundations of those techniques are presented as well as the application of each method to the problem. Simulations are conducted for each technique in order to provide quantified performance measurements supporting the use of each method.

DETECTION AND IDENTIFICATION OF CYCLOSTATIONARY SIGNALS

Evandro L. da Costa-Lieutenant Commander, Brazilian Navy
B.S., Instituto Militar de Engenharia, 1980
Master of Science in Electrical Engineering-March 1996
Master of Science in Engineering Acoustics-March 1996
Advisors: Ralph Hippenstiel, Department of Electrical and Computer Engineering
Roberto Cristi, Department of Electrical and Computer Engineering

Propeller noise can be modeled as an amplitude modulated (AM) signal. Cyclic Spectral Analysis has been used successfully to detect the presence of analog and digitally modulated signals in communication systems. It can also identify the type of modulation. Programs for Signal Processing based on compiled languages such as FORTRAN or C are not user friendly and MATLAB based programs have become the *de facto* language and tools for signal processing engineers worldwide.

This thesis describes the implementation in MATLAB of two fast methods of computing the Spectral Correlation Density (SCD) Function estimate, the FFT Accumulation Method (FAM) and the Strip Spectral Correlation Algorithm (SSCA), to perform Cyclic Analysis. Both methods are based on the Fast Fourier Transform (FFT) algorithm. The results are presented and areas of possible enhancement for propeller noise detection and identification are discussed.

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BOTTOM BACKSCATTER MAPPING: THE EFFECT OF SECONDARY MULTIPATH INTERACTIONS

Erick Brian Cushman-Lieutenant, United States Navy
B.S.C.E., Tulane University, 1989
Master of Science in Engineering Acoustics-December 1995
Master of Science in Physics-December 1995
Advisor: Kevin B. Smith, Department of Physics

It has been shown that good correlation exists between large-scale, high level signal returns of bottom acoustic reverberation and bathymetric ridge structures. The ultimate goal of this type of analysis would be the removal of propagation effects resulting in a large-scale mapping of scattering strengths. Furthermore, analysis with a quasi-CW propagation model suggests a strong correlation between the small-scale fluctuations in the reverberation signal and the bottom acoustic ensonification, thereby suggesting that uncertainties in the predictions of forward propagation may limit the resolution of such mapping. By employing broadband modeling techniques, a valid representation of the complete time domain forward propagation is provided. Diffuse secondary bottom interactions appear to affect the resolution of the primary, direct-path interaction at ranges beyond a few water depths. Analysis of data recorded by near-bottom vertical line arrays (VLA's) confirms the existence of these secondary, multipath interactions in the forward propagation. The exact, two-way travel times from all bottom interactions are modeled and the influence of the secondary interactions is quantified. Possible ramifications for general sonar system performance are discussed.

THE INFLUENCE OF PHYSICAL SYSTEM PARAMETERS ON THE PERFORMANCE OF ADAPTIVE FILTERS FOR SYSTEM IDENTIFICATION OF MECHANICAL SYSTEMS

Michael R. Dargel-Lieutenant, United States Navy
B.S.M.E., Norwich University, 1990
Master of Science in Engineering Acoustics-September 1996
Advisors: Robert M. Keolian, Department of Physics
Roberto Cristi, Department of Electrical and Computer Engineering

Recursive and non-recursive least mean square adaptive filters were used to predict the output of various mechanical systems for a given input. The effects of quality factor (Q), dispersion and transmission time on adaptive filter performance were investigated. Optimal filter delay times and tap weight vector lengths were determined.

ANTI-HELICOPTER MINE SYSTEMS

Enrique Garcia-Lieutenant, United States Navy
B.S., California State University, Los Angeles, 1985
Master of Science in Engineering Acoustics-September 1996
Advisors: Donald L. Walters, Department of Physics
James V. Sanders, Department of Physics

The development and production of acoustically-cued Anti-Helicopter Mines (AHM) poses a serious threat to low flying helicopters throughout the world. The AHM determines if air approaching helicopter will come within its lethal range. When it does, an IR sensor is energized to provide a firing solution for air explosive charge aimed in tile same direction as the IR sensor. The AHM's can perform this mission autonomously using passive sensors only. These features and the relatively low cost of the mines could lead to large scale production and exportation of AHM's. This thesis explores this concept with an emphasis on the acoustic principles applied to make these mines effective. The results from an AHM proof of concept evaluation conducted by Sandia National Laboratories in 1993 are studied to validate the operational capabilities of AHM systems. The results proved that AHM systems are effective and require serious consideration in future deployments of helicopters in hostile environment.

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TRANSIENT PHENOMENA IN THERMOACOUSTIC PRIME MOVERS

Ching-Kai Meng-Lieutenant Commander, Republic of China Navy
B.S., Chinese Naval Academy, 1985
Master of Science in Engineering Acoustics-June 1996
Advisors: Anthony A. Atchley, Department of Physics
Robert M. Keolian, Department of Physics

The purpose of this thesis is to investigate the evolution of the acoustic pressure waveform and temperature change across the heat exchangers as functions of time in a thermoacoustic prime mover. Measurements are reported for both nitrogen and helium gas under different mean pressures and initial temperature differences. Aspects of this thesis included the design and construction of the prime mover and implementation of a computer controlled data acquisition system. The goal is to form a set of data with which to test transient, nonlinear theories of thermoacoustics. The main conclusion is that models will have to take into account the performance of heat exchangers to accurately model the initial build up of the oscillations.

VIBRATION MEASUREMENTS ON THE PHALANX ELECTRO-OPTICAL STABILIZATION SYSTEM

James E. Schmidt-Lieutenant Commander, United States Navy
B.A., John Carroll University, 1985
Master of Science in Engineering Acoustics-September 1996
Advisor: Steven R. Baker, Department of Physics
Second Reader: Robert M. Keolian, Department of Physics

The installation of the new PHALANX Surface Mode (PSUM) upgrade will enable the PHALANX to handle a wider range of threats, such as a small boat approaching the ship. The objective of the research described in this thesis was to measure the vibration of a prototype forward looking infrared (FLIR) camera stabilizer system during live-fire tests to evaluate its performance. Uniaxial, triaxial, and angular accelerometers were mounted at 19 different locations on the stabilizer and on the camera. Acceleration data were collected during eight live fire tests conducted at a Navy range, and the results analyzed. The power spectral densities (PSD) of the input linear accelerations at key locations on the stabilizer were calculated. The azimuth and elevation angular displacements of the FLIR camera mount were also calculated. The azimuth and elevation angular displacement of the plane of the stabilizer pedestal mounting points were also calculated. Recommendations are made for follow-on studies.

EFFECTS OF SHALLOW WATER BOTTOM INTERFACE ROUGHNESS AND VOLUME FLUCTUATIONS ON BROADBAND PULSE RESOLUTION

Mei-Chun Yuan-Lieutenant Commander, Republic of China Navy
B.S., Chung Cheng Institute of Technology, 1987
Master of Science in Engineering Acoustics-June 1996
Advisor: Kevin B. Smith, Department of Physics
Second Reader: Anthony A. Atchley, Department of Physics

Typical acoustic propagation in shallow water environments is dominated by bottom-interacting paths. The effects of rough bottom interfaces and sediment volume fluctuations are investigated using model simulations. A numerical study of low-frequency (~200 Hz) broadband pulse propagation is presented and several characterizations of bottom factors are examined. In particular, the variations of the interface rms roughness and a volume fluctuation strength constant on the time resolution of the broadband pulse are investigated. It is shown that interface roughness is the dominant factor in the degradation of pulse resolution.