MASTER OF SCIENCE
IN
ELECTRICAL ENGINEERING

EXAMINATION OF TIME-REVERSAL ACOUSTICS IN SHALLOW WATER AND APPLICATIONS TO UNDERWATER COMMUNICATIONS

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Time-varying multipath propagation is considered the most important difficulty in shallow underwater acoustic (UWA) communications. To compensate for the time variability of the channel, the receiver must use an adaptive algorithm for adjusting its parameters. At high symbol rates, intersymbol interference caused by multipath propagation requires large adaptive filters, increasing the computational complexity at the receiver end.

This thesis presents a time-reversal acoustic technique (implemented with a phase-conjugated array or PCA) that generates a spatio-temporal focus of acoustic energy at the receiver location which reduces distortions introduced by channel propagation (including multipath), allowing the use of low-complexity receivers. Numerical analysis shows that for different PCA geometries (element spacing and aperture sizes), the PCA focus footprint does not appear to significantly change its dimensions. Furthermore, the aperture size plays a more significant role than the number of array elements in a PC array design.

Specific examples of novel UWA communication systems utilizing time-reversal focusing are introduced. Current simulation results suggest the potential for high data transfer rates compared to existing noncoherent UWA communication systems.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Other (Underwater Acoustic Communications)

KEYWORDS: Time-Reversal Acoustics, Underwater Acoustic Communications

FUZZY CLUSTERING MEANS ALGORITHM FOR TRACK FUSION IN U.S. COAST GUARD VESSEL TRAFFIC SERVICE SYSTEMS

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This thesis presents a fuzzy association based data fusion algorithm for U.S. Coast Guard Vessel Traffic Service (VTS) systems to reduce the number of redundant target tracks displayed to vessel traffic operators. The proposed algorithm uses the Fuzzy Clustering Means (FCM) algorithm to reduce the number of target tracks and associate tracks by determining the degree of membership for each target track. The algorithm uses current sensor data and the known sensor resolutions for measurement-to-measurement association and the selection of the most accurate sensor for tracking fused targets. Actual vessel traffic data collected from U.S. Coast Guard VTS systems are used for simulation and analysis of the algorithm. The results

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exhibit successful fusion of correlated tracks and selection of the most accurate sensor resulting in a reduced number of tracks displayed to the VTS operator.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Vessel Traffic Services, VTS, Redundant Observations, Data Fusion, Fuzzy Logic, Fuzzy Clustering Means

DEVELOPMENT OF SOFTWARE MODULES FOR CALCULATION OF SOUND PRESSURE LEVELS IN BROADBAND AND SWATH ACOUSTIC SIGNALS

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This work is part of an ongoing effort to integrate the separate BEARTRAP post mission analysis tools into a system residing in a Microsoft Windows NT environment. This new integrated system will contain software modules designed to replace the array of diverse processing systems currently being used for BEARTRAP post mission analysis. This thesis develops the modules responsible for broadband and swath sound pressure level acoustical processing along with a graphical interface for display and analysis of results. The Broadband module identifies segments of broadband acoustical contact, pre-processes and filters the data to one tenth or one fiftieth decade frequency bands across the frequency spectrum, and performs sound pressure level calculations within the identified frequency bands. The Swath module identifies segments of swath acoustical contact, pre-processes and filters to the 3-dB bandwidth of the data, and performs sound pressure level calculations over the 3-dB bandwidth. Both modules display their output with a spreadsheet format text display, a graphical representation of the associated sonogram, and a polar plot of sound pressure level intensity versus aspect angle. This work describes the development, integration, and testing of these modules for the BEARTRAP Post Mission Processing System 2000 (S2K) using Microsoft Visual C++ as the implementation language.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Sensors

KEYWORDS: Acoustics, BEARTRAP, DSP, Broadband, Swath, Sound Pressure Level

USING MARTES TO IDENTIFY GSM AND *IS-95* CO-CHANNEL INTERFERENCE SIGNALS MODELED WITH HP-ADS

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One goal of Information Operations is information superiority in both information warfare and information-based warfare. Active Signals Intelligence is one tool used to support this goal. This research used Hewlett-Packard's Advanced Design System (HPADS) to develop simple models of the Global System for Mobile Communications and Interim Standard *95* type signals. The approach was to first model the two communication systems with various levels of co-channel interference, determine a methodology for exporting the data in a way that could be imported into MARTES, which is a Unix-based cryptologic software package, and then determine the capability of MARTES to identify signal types. This information was evaluated to determine the usefulness of the software for signal generation and processing in the Cryptologic Research Laboratory. The benefit of the study will be supporting Active Signals Intelligence by providing information used to determine the best methods to exploit, collect, and process communication signals generated using the wireless communication standards in use throughout the world.

MARTES did a remarkable job of identifying the modeled signals in the presence of co-channel interference. Both HP-ADS and MARTES would be useful tools in the Cryptologic Research Laboratory.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: MARTES, HP-ADS, Advanced Design System, Global System for Mobile Communications, GSM, Interim Standard 95, IS-95, Power Spectral Density, Spread Spectrum, Cryptologic, Active SIGINT, Information Operations, Co-Channel Interference, Signal to Interference Ratio

CHARACTERIZATION OF SEMICONDUCTOR DEVICES FOR RADIATION EFFECTS STUDIES

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Radiation effects pose a serious problem for space-based electronic integrated circuits. This is especially true for high frequency (>1 GHz) data communications applications. Gallium Arsenide (GaAs) devices are inherently immune to total dose radiation exposure; however, they are extremely sensitive to single event upsets (SEUs). This research through device characterization helps prove that the addition of a low-temperature grown (LTG), Beryllium (Be) doped layer beneath a complementary GaAs (CGaAsTM) device should reduce SEU sensitivity and possibly improve performance.

DoD KEY TECHNOLOGY AREA: Other (Electronics, GaAs, Radiation Hardened)

KEYWORDS: Electronics, GaAs, Radiation Hardened

DESIGN CRITERIA FOR DC LINK FILTERS IN A SYNCHRONOUS GENERATOR-PHASE CONTROLLED RECTIFIER-FILTER-LOAD SYSTEM

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Power electronics have advanced to the point that they can be considered for use in large, high power dc electrical distribution systems. The proposed Navy DC Zonal Electrical Distribution System (DC ZEDS) being designed for the new DD-21 utilizes a rectified ac generator output which is filtered and stepped to usable voltages by local dc-dc converters. One characteristic of the high-bandwidth converters is a negative input impedance, which when coupled with an LC input filter, can lead to system instabilities. This thesis examines various stability criteria for determining parameters of the dc link filter. Comparisons between a simplified system model, a model using subsystem impedances and an Advanced Continuous Simulation Language (ACSL) model of a reduced-order system are made. Simulations were conducted to verify the validity of the stability criteria. The ACSL model provides an extremely useful tool in evaluating the response of various system parameters to changes in design values. The design criteria examined in this thesis can be ultimately used to provide design specifications to future vendors.

DoD KEY TECHNOLOGY AREAS: Electronics, Modeling and Simulation.

KEYWORDS: Stability Analysis, dc-dc Converter, dc Link Filter, Synchronous Generator, Phase Controlled Rectifier

VALIDATION/EVALUATION OF POLARIZATION VERSION OF SEARAD MODEL

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Until recently no standard atmospheric propagation codes included the effects of polarization. Recently a research grade upgrade to MODTRAN (Zeisse, Nrad) has allowed the polarized case. This upgrade, called SEARAD, calculates the infrared polarization of sea surface radiance. Data available in the EOPACE data base were used for a direct comparison of the code prediction to the measurements. The data consist of polarized and unpolarized images of the R/V POINT SUR in the Long Wave Infrared (LWIR), taken with the AGA 780 camera during an experiment conducted in San Diego Bay in April 1996. Meteorological, geographical, and external ship temperature data were recorded along with the images. The analysis of the EOPACE data was conducted by using IDL (Interactive Data Language) analysis programs and included 34 sets of images. The sea pixels were extracted from the images, and correlated with meteorological, and geographical data to provide input to the SEARAD code. The comparison of the experimental data with the SEARAD predictions yielded an average error of 1.57 $Wm^{-2}sr^{-1}$ in unpolarized sea radiance, which is within approximately 5% of the experimental radiance, and an average 0.51 absolute difference between the predicted and experimental degree percentage of polarization.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Infrared Sensors)

KEYWORDS: Infrared Radiation, Radiance, Degree of Polarization, Atmospheric Propagation Codes

MODELED DETECTION AND RECOGNITION RANGE FOR A POLARIZATION FILTERED FLIR SENSOR

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A model has been developed to evaluate the influence of polarization filtering on the detection and identification range of a thermal sensor. The scenarios evaluated were based on environmental parameters and ship temperatures recorded during the EOPACE measurement series in San Diego Bay in 1996. These scenarios represent a FLIR sensor on a platform in level flight at 100 m or 1000 m approaching a ship target represented as a gray body at the recorded ship hot-spot temperature. The polarized version of the SEARAD sea radiance code was used to provide sea background radiance and propagation characteristics for both ship target and background. Apparent Temperature Difference was calculated versus range for horizontally polarized and unpolarized imaging. Maximum range was determined for both cases by comparison to a generic Minimum Resolvable Temperature function representing a typical LWIR Common Module FLIR. Preliminary results for the polarized case predict greater apparent temperature difference at ranges to around 10 kilometers. Unresolved apparent anomalies in the computed results suggest that target temperatures are under-estimated. Empirical correction of the zero range temperature difference suggests polarized identification ranges of the order of 25 to 30 km. Improvements to the modeling are proposed.

DoD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation

KEYWORDS: Forward Looking Infrared (FLIR), Apparent Temperature Difference, Common Module FLIR, Minimum Resolvable Temperature Difference (MRTD), SEARAD

LOW BAND VHF ANTENNA DESIGN FOR THE GRUMMAN EA-6B AIRCRAFT

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The overall effectiveness of an aircraft antenna depends on its inherent radiating pattern, its efficiency, and the effects of its host platform. Coupling between the antenna and aircraft skin affects antenna input impedance while shadowing, reflection, refraction, and diffraction by the aircraft structures affect the antenna radiation pattern. Placement of the antenna on the aircraft is critical to optimizing these effects. This thesis determines optimum antenna locations on an EA-6B aircraft by analyzing its characteristic modes using a modified method of moments (MoM) code. With the optimum antenna locations determined, a survey of several broadband antenna designs is conducted. The candidate antenna must operate from 20-100 MHz with a voltage standing-wave ratio (VSWR) less than four across the band. It must be vertically polarized and must have minimal aerodynamic effects. Input impedance and radiation patterns are determined for the candidate antennas using the well-known GNEC method of moments code. Ultimately, a new antenna design provides the best overall performance.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronic Warfare, Modeling and Simulation

KEYWORDS: Antennas, Numerical Electromagnetics Code (NEC), Method of Moments, Characteristic Modes, Aircraft Modeling, Conical Monopole

ELECTRICALLY PROPELLED HANG GLIDER FOR SMALL UNIT BATTLEFIELD MOBILITY

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On the high speed, info-centric, dispersed battlefield of the future, information dominance will require increased small unit battlefield mobility. The trend of the future will be towards smaller units responsible for scouting, securing, and shaping the battlefield prior to a larger, heavier force being injected at the crucial time and place to decisively engage the enemy. This light scouting, shaping force has a need for some type of vehicle to provide battlefield mobility, insert, extract, escape and evasion, and re-supply. This thesis explores the possibility of using an electrically powered hang glider for small unit battlefield mobility. This platform is not envisioned to replace other means of insertion such as helicopter, rubber boat, etc. This platform is envisioned to provide mobility for these small units once they have been inserted, especially over terrain that is difficult for foot mobility. This thesis discusses the research concept used to conduct the vehicle design. A proposal for an optimal system design using commercially available components is given along with a description of the capabilities and limitations of the platform.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications, Other (Information Dominance)

KEYWORDS: Information Dominance, Reconnaissance, Battle Field Mobility, Aerial Vehicle, Motorized Hang Glider

PERFORMANCE ANALYSIS OF THE ADVANCED AMPHIBIOUS ASSAULT VEHICLE PERSONNEL VARIANT (AAAV-P) VETRONICS COMMUNICATIONS SYSTEM HIGH SPEED DATA BUS

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The United States Marine Corps Advanced Amphibious Assault Vehicle Personnel Variant (AAAV-P) is a critical weapon system that supports the Naval Operational Maneuver from the Sea (OMFTS) concept. The AAAV-P will provide the Marine Corps with the ability to project naval power ashore in support of strategic objectives. The Marine Corps is relying on the AAAV-P to exploit the sea and land terrain in order to attain surprise and be able to rapidly take advantage of weak points in enemy littoral defenses. The first prototype of the AAAV-P will be completed in June 1999. Successful operation of the AAAV-P is heavily dependent upon the Vetronics System communications network residing within the vehicle. The Vetronics System supports three networks: a High Speed Data Bus, a Utility Bus, and a Powertrain Bus. This thesis develops a model of the High Speed Data Bus, which is considered the main data bus within the AAAV-P. The simulation results of the model are analyzed to determine if the High Speed Data Bus is properly designed to handle the anticipated communications traffic that will traverse the network. The network performance capability is evaluated under various scenarios.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Electronics, Surface/Under Surface Vehicles - Ships and Watereraft, Ground Vehicles, Modeling and Simulation

KEYWORDS: Electronics, Data and Computer Communications, Network Modeling and Simulation, OPNET

DEVELOPMENT OF A DIGITAL DIRECTIONAL FREQUENCY ANALYSIS AND RECORDING DEMULTIPLEXER AND BEARING TRACKER MODULE

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This work is part of an ongoing effort to integrate the separate BEARTRAP post mission analysis tools into a system residing in a Microsoft Windows environment. This new integrated system will contain software modules designed to replace the array of diverse processing systems currently being used for BEARTRAP post mission analysis. This thesis develops the module responsible for implementing and testing a combined digital demultiplexer and arctangent bearing estimator algorithm used to retrieve acoustic and directional signals from Directional Frequency Analysis and Recording (DIFAR) sonobuoy signals and perform target bearing estimation. The primary objective of the module is to provide the necessary framework for testing several independently developed DIFAR digital demultiplexers to assess their performance and suitability for inclusion in a consolidated post mission analysis application. This document describes the multiplexing technique used in DIFAR sonobuoys, the mathematical basis of demultiplexing a DIFAR signal, the implementation of a digital demultiplexing and bearing estimation algorithm, and the development of a stand-alone Microsoft Windows application used to display bearing information resulting from DIFAR digital demultiplexing.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Sensors

KEYWORDS: DIFAR, Demultiplex, Beartrap

DESIGN AND PROTOTYPE DEVELOPMENT OF A WIRELESS POWER TRANSMISSION SYSTEM FOR A MICRO AIR VEHICLE (MAV)

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Microwave radiation at 1.0 GHz and 1.3 GHz is used to demonstrate remote powering of a micro air vehicle (MAV). Several prototype microwave rectifier systems were fabricated in microstrip using EEsof® computer-aided engineering (CAE) software to assist in their design. Radio frequency (RF) parameters of the rectifiers were measured on a vector network analyzer. RF-to-DC conversion efficiency was measured for several designs and with various circuit loads consisting of lumped elements and DC motors. A peak RF-to-DC conversion efficiency of 33 percent was achieved. MAV antenna designs were investigated by simulating 68 geometries using the GNEC® numerical electromagetics computer program. Two prototype MAVs were assembled, each consisting of microwave rectifier, antenna, and a miniature DC motor. It was demonstrated that a 1.8-Watt, 1.3-GHz microwave signal could power the DC motor at free space distance of 30 inches from transmitting antenna to prototype MAV. Greater operating distances are proposed by using higher transmitting power and antenna gain.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles, Sensors

KEYWORDS: MAV, Remotely Piloted Vehicle, Surveillance, Wireless Power Transfer, Microwave

MINIATURIZATION OF A MICROCONTROLLER FOR THE TACTILE SITUATIONAL AWARENESS SYSTEM

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Loss of Situational Awareness (SA) is a leading cause of pilot-related mishaps, resulting in numerous fatalities and costing the Department of Defense an estimated $300 million annually in destroyed aircraft. Loss of SA can occur when a pilot incorrectly perceives the attitude, altitude, or motion of their aircraft. As one solution to the SA problem, the Naval Aerospace Medical Research Laboratory has developed the Tactile Situational Awareness System (TSAS). The primary objective of TSAS is to enhance pilot performance and reduce SA-related aircrew/aircraft losses by providing continuous non-visual information using the normally-underutilized sensory channel of touch. Using vibrotactile stimulators, TSAS applies information taken from the aircraft's instruments to the pilot's torso. Prototypes have been built and flight-tested with positive results. However, the current implementation of TSAS is a research system that is not compatible with the crowded cockpits of modern aircraft. This thesis presents a design of a miniature microcontroller for the TSAS that is compatible with tactical environments. This new microcontroller system incorporates the functionality of the research TSAS into a palm-sized device.

DoD KEY TECHNOLOGY AREAS: Biomedical, Computing and Software, Electronics, Human Systems Interface

KEYWORDS: Electronics, Embedded Computing, Microcontroller, Tactile Situational Awareness System, TSAS