MASTER OF SCIENCE
IN
ELECTRICAL ENGINEERING

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

A METHOD OF INCREASING THE KINEMATIC BOUNDARY OF AIR-TO-AIR MISSILES USING AN OPTIMAL CONTROL APPROACH
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Current missile guidance laws are generally based on one of several forms of proportional navigation (PN). While PN laws are robust, analytically tractable, and computationally simple, they are only optimal in a narrow operating regime. Consequently, they may not optimize engagement range, time to intercept, or endgame kinetic energy. The advent of miniaturized high speed computers has made it possible to compute optimal trajectories for missiles using command mid-course guidance as well as autonomous onboard guidance. This thesis employs a simplified six degree of freedom (6DOF) flight model and a full aerodynamic 6DOF flight model to analyze the performance of both PN and optimal guidance laws in a realistic simulation environment which accounts for the effects of drag and control system time constants on the missile's performance. Analysis of the missile's kinematic boundary is used as the basis of comparison. This analysis is immediately recognizable to the warfighter as an engagement envelope. The guidance laws are tested against non-maneuvering and maneuvering aircraft targets and against a

simulation of a cruise missile threat. An application of the 6DOF model for a theater ballistic missile interceptor is presented.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Missile Guidance Laws, Proportional Navigation, Optimal Control, Kinematic Boundary

INDOOR PROPAGATION SIMULATION SOFTWARE

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Computer simulation can be used to predict the signal strength in complex indoor environments. Signal propagation prediction is essential for determining the coverage of WLANs (Wireless Local Area Networks). Increasing use of WLANs within infrastructures that have been built prior to the installation of the wireless networks requires measurements, semi-empirical models, or computer simulations to determine the number and location of access points for optimum coverage. In cases where the infrastructure has yet to be built (as in a new class of ships) the simulation may be the only option for WLAN coverage prediction. In such a case blueprints may be used in conjunction with the computer indoor propagation simulation software in order to predict the best places to install the access points. The indoor propagation simulation software differs from the outdoor propagation software used for the cellular networks because of the differences in the characteristics of indoor and outdoor propagation channels.

This thesis explains the characteristics and structure of a Wireless Local Area Network and presents the computer simulation results the 2.4 GHz wireless signal propagation inside an enclosed space. A building at the Naval Postgraduate School, where some previous physical measurements have been conducted, was selected for the indoor propagation simulation.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Simulation of Signal Propagation, Wireless Local Area Network

DYNAMICS OF PRIVATE NETWORK-TO-NETWORK INTERFACE (PNNI) ROUTING IN ATM VULNERABILITY ASSESSMENT

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To reduce the number of successful attacks against the U.S. Government's computer networks, resources must be invested not only into implementing known fixes and security measures, but also into the identification and correction of vulnerabilities before adversaries can exploit them. This thesis establishes a procedure for observing and analyzing the Private Network–to–Network Interface (PNNI) Routing Protocol. This protocol is responsible for deciding which route network traffic will take, assuming that multiple routes exist, in an autonomous system. Measurements of line utilization, cell delay and interarrival rate of the PNNI channel are taken into account for characterizing a normal PNNI exchange. Finally, potential vulnerabilities related to PNNI dynamics are discussed.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Asynchronous Transfer Mode, ATM, PNNI, Network Vulnerabilities, Exploits, Routing Protocol, Cell Injection, AX/4000, Internetworking, High Speed Computer Networks

ULTRA-WIDEBAND, LOW PROFILE, VERTICALLY POLARIZED ANTENNA DESIGNS FOR MILITARY APPLICATIONS

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The emerging need to operate ultra-wideband communication and electronic warfare systems in tactical environments will require efficient, omni-directional broadband antennas. In the case of the Grumman EA-6B, the candidate antenna should ideally operate from 30-500 MHz with a voltage standing-wave ratio (VSWR) less than three across the entire band. Additionally, it must be vertically polarized, it must be constrained in size, and it must have minimal aerodynamic effects while offering structural stability. In this thesis, an antenna was designed that is capable of operating in the frequency range of 72-500+ MHz, a 70 MHz improvement over the existing configuration. The antenna performance was optimized for its design restrictions and takes advantage of dielectric loading to minimize antenna size relative to the operating wavelengths. The antenna was designed and its performance predicted using Ansoft's High Frequency Structure Simulator (HFSS). HFSS is based on the finite element method (FEM). As well, it assigns material properties to a structure enabling more realistic antenna designs to be simulated. Several aerodynamic versions of the base design were modeled and simulated and a comparison of their performance is presented. As well, alternative antenna applications other than the Grumman EA-6B were suggested.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronic Warfare, Surface/Under Surface Vehicles-Ships and Watercraft, Ground Vehicles, Modeling and Simulation

KEYWORDS: Ultra-Wideband Antenna, Omni-Directional, Low Profile, Vertically Polarized, Ansoft High Frequency Structure Simulator (HFSS), Dielectric Loading

PERMANENT-MAGNET SYNCHRONOUS MACHINE CONTROL STRATEGIES FOR ELECTRIC DRIVE

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The United States Navy has committed to employing an Integrated Power System (IPS) on DD-21, the next generation land-attack destroyer. The IPS is embodied by two revolutionary concepts: the DC Zonal Electric Distribution System and the Electric Drive. Electric Drive propulsion offers numerous advantages over conventional drives including reduced overall weight, size, and maintenance requirements, improved flexibility of arrangement, and enhanced fault tolerance and controllability.

Since solid-state power converters drive the propulsion motor, it will be infinitely controllable throughout its speed range. This offers the capability to achieve a smooth torque on the ship's propeller. Of key interest is an algorithm to control the current and voltage wave-shapes of the propulsion motor. This thesis develops an algorithm based on field-oriented vector control that will be applied to a proof-of-concept 30 horsepower permanent-magnet synchronous machine currently under study. Two supervisory control architectures are analyzed consisting of two inner current loops and one outer speed loop. The selection of the controller gains is documented and validation simulation studies are presented. The thesis also outlines a hardware-in-the-loop testing strategy to be implemented with the dSPACE DS1103 Controller Board, a hardware and software package designed for real-time digital controller evaluation.

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

KEYWORDS: Permanent-Magnet Synchronous Machine, Vector Control, Hardware-in-the-Loop, Electric Drive, Integrated Power System

AN EXTENDED KALMAN FILTER FOR QUATERNION-BASED ATTITUDE ESTIMATION

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This thesis develops an extended Kalman filter for real-time estimation of rigid body motion attitude. The filter represents rotations using quaternions rather than Euler angles, which eliminates the long-standing problem of singularities associated with those angles. The process model converts angular rates into quaternion rates, which are in turn integrated to obtain quaternions. Gauss-Newton iteration is utilized to find the quaternion that best relates the values of linear accelerations and earth magnetic field in the body coordinate frame and the earth coordinate frame. The quaternion obtained from the optimization algorithm is used as part of the observations for the Kalman filter. As a result, measurement equations become linear. The computational requirements related to the extended Kalman filter developed using this approach are significantly reduced, making it possible to estimate attitude in real-time. Extensive static and dynamic simulation of the filter using Matlab proved it to be robust. Test cases included the presence of large initial errors as well as high noise levels. In all cases the filter was able to converge and accurately track attitude.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Sensors, Modeling and Simulation

KEYWORDS: Inertial Navigation, Extended Kalman Filter, Quaternion

A 3D SPATIAL CHANNEL MODEL FOR CELLULAR RADIO

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This thesis provides closed form expressions for the angular distribution in azimuth and elevation planes for a geometrically based single bounce spheroid model. The geometry of the spheroid is defined by the semi-major axis *a* and the semi-minor axis *b*. The other parameter of interest in the model is the distance *D* between the base station and the mobile station. The latter is assumed to be at the center of the spheroid. The mobile station is assumed to be the transmitter, while the base station is the receiver. This thesis investigates the effects of the above parameters on the angular distribution of the received waves. Important parameters such as the R.M.S. angle spread in azimuth and elevation plane are calculated from the P.D.F. expressions derived. The behavior of these R.M.S. angle spreads versus the ratio *a/D* or *b/D* respectively is also investigated.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Battlespace Environments

KEYWORDS: Spatial Channel Model, Joint TOA/AOA PDF, AOA Marginal PDF in Azimuth Plane, AOA Marginal PDF in Elevation Plane, R.M.S. Angle Spread

DIGITAL COMMUNICATIONS JAMMING
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The objective of this thesis is to obtain a computer-based prediction of noise and jamming (barrage, pulsed and tone) effects on the probability-of-error for coherently detected BFSK, BPSK, QPSK, and noncoherently detected BFSK communication systems. To accomplish this, several models were developed using MATLAB Communications Toolbox and Simulink.

As observed from the simulation results, different types of jamming affect each digital modulation technique differently. We determined that in attempting to disrupt digital communications, it is often advantageous to concentrate the jamming energy in short pulses. Pulsed jamming can cause a substantial increase in the bit error rate relative to the rate caused by continuous jamming with the same average power. By comparing the effects of different jammer types used in the simulation, we observed that AM-modulated jammers caused more damage to digital communication systems than FM-modulated jammers.

The performance of the models has been verified by comparing the simulation results and the theoretical results for the bit error probability for the case of a signal in the presence of AWGN. The experimental results approach to the theoretical results after one million transmitted symbols. The difference in bit-error-rate was found to be between 0.64% and 1.25%, thus, the theoretical and numerical values of bit-error-rate are in reasonable agreement.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: MATLAB Communications Toolbox, Simulink, Jamming, Bit-Error Rate, BFSK, BPSK, and QPSK

SIMULATION AND PERFORMANCE ANALYSIS OF THE ZONE ROUTING PROTOCOL FOR TACTICAL MOBILE AD HOC NETWORKS
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This thesis presents a simulation and analysis of the Zone Routing Protocol (ZRP) for mobile ad hoc network (MANET) environments using the OPNET simulation tool. ZRP is being suggested for possible implementation in the Joint Tactical Radio System (JTRS) for the United States military. Utilizing a ZRP OPNET model that was developed at Cornell University, the analysis focuses on key performance parameters that include overhead generation, network adaptation, efficiency, and routing zone optimization. The ZRP model's traffic monitoring has been enhanced for this work to identify the engineering tradeoffs between efficiency and performance. The results of this thesis provide valuable insight into the analysis and performance with varying zone routing radius, node velocity, and node density. Critical MANET environmental and simulation parameters required for JTRS implementation into the military battlespace have been studied.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: MANET, PROTOCOL, BRP, DMR, IARP, IERP, JTRS, OPNET, ZRP

DESIGN OF AN ULTRA-WIDEBAND DIRECTIONAL ANTENNA FOR A GIVEN SET OF DIMENSION CONSTRAINTS

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This research encompasses the preliminary and detailed design phases of a directional high-power UHF antenna that fits within a restrictive cylinder. The antenna design was limited to a free-space situation.

In the preliminary design phase, various antenna configurations were evaluated through simulation using the Numerical Electromagnetics Code (GNEC) to determine the optimum design. The optimization process was divided into consecutive steps. The best antenna from one step was further developed in the next step, and so on, until the final preliminary design, the RATTLE-1 antenna, was obtained. The Antenna Comparison Technique (ACT), a procedure that compares normalized grades evaluated for each antenna, was used to choose the optimum antenna configuration.

The detailed design phase concentrated on solving the impedance matching problem between the antenna and the transmission line. The final solution entailed the use of a tapered coaxial line balun. The performance of the RATTLE-1 integrated balun was evaluated through simulations using the High-Frequency Structure Simulator (HFSS) and prototype measurements.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Antenna Simulation, Antenna Optimization, Conical Spiral Antenna, Broadband UHF Antennas, Tapered Coaxial Line Balun