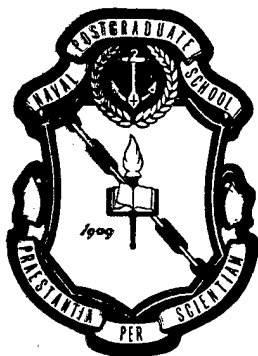**Naval Postgraduate School**
Monterey, California 93943-5138

SUMMARY
OF
RESEARCH
1995

Department of Electrical and Computer Engineering

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Chairman

DTIC QUALITY INSPECTED 4

Jeffrey B. Knorr
Associate Chair for Research

19961016 163

Prepared for: Naval Postgraduate School
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NAVAL POSTGRADUATE SCHOOL
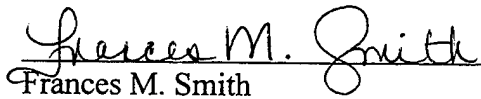### Monterey, California

Rear Admiral M.J. Evans
Superintendent

R. Elster
Provost

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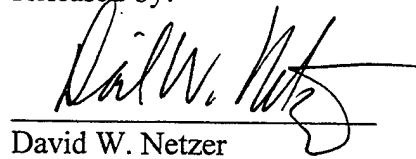
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13. ABSTRACT (Maximum 200 words.)

This report contains **55** summaries of research projects in the Department of Electrical and Computer Engineering which were carried out under funding of the Naval Postgraduate School Research Program. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports.

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THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to provide advanced professional studies at the graduate level for military officers and defense officials from all services and other nations. The School's focus is to increase the combat effectiveness of the armed forces of the United States by providing quality education which supports the unique needs of the defense establishment.
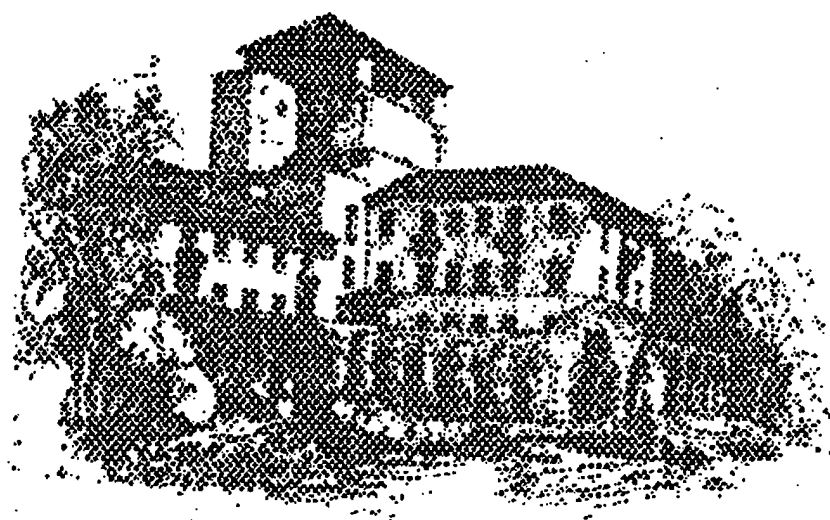
Introduction

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.

- Keep faculty on the leading edge of advances in defense-related science, technology, managment and policy to ensure that the latest information is incorporated into NPS courses and curricula.

- Apply faculty and student knowledge to enhance Navy/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

The overall research program at NPS has two funded components:

- The Direct Funded Research (DFR) Program provides internal funding from the School's operating budget to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.

- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The two research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

All research projects, both reimbursable and direct funded, support the School's research mission:

- To develop an overall research investment strategy that ensures a high quality, creative learning experience for NPS graduate students.

- To encourage faculty and student pursuit of new discoveries and applications which enhance the long term effectiveness of the armed forces.

- To stimulate interactions between NPS faculty and a wide variety of potential research sponsors (Government, Universities, Private Industry).

- To publicize (both internally and externally) significant achievements of the NPS research program and market NPS research capabilities.

- To foster synergy and force multiplication with Navy/DoD commands and laboratories to increase the potential for successful research and development programs

The Department seeks to provide NPS students with the highest quality and most DoD-relevant graduate education available in electrical and computer engineering. This discipline spans a broad swath of leading-edge technology which impacts most facets of DoD's warfighting capability, ranging from secure voice and computer communication networks to advanced electronic warfare systems to the guidance of precision strike weapons. Eight MSEE degree tracks cover these areas and others with degrees which are fully ABET-accredited. A distance learning program is being offered leading to the MSEE in approximately 12 quarters.

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ELECTRICAL AND COMPUTER ENGINEERING

The research program of the Department of Electrical and Computer Engineering (ECE) is very broad, reflecting the variety of skills and interests of the faculty in providing technical advances and solutions to important problems for the Navy and the Department of Defense. DoD research in ECE is strongly coupled to instruction, both in bringing the most recent advances into the classroom and in providing highly relevant and unique thesis topics for officer students to investigate with faculty guidance.

Research in the Department of Electrical and Computer Engineering is supported by an internally funded research program called the Direct Funded Research (DFR) Program, and an externally funded research program called the Reimbursable Research (RR) Program. The DFR program includes a Research Initiation Program (RIP) for new faculty and also provides funding for new initiatives, meritorious projects, cost sharing, and a postdoctoral program. The Reimbursable Research Program includes those projects which are externally supported by a wide range of government agencies, and by private industry through Cooperative Research and Development Agreements (CRADAs).

In FY 1995, ECE Department reimbursable research totaled $4.2M. A total of 16.1 faculty research work years were executed, representing 45% of the Department's faculty labor. The Reimbursable Program supported 13.4 faculty work years, or 83% of the total research effort. The department's research work led to 15 journal papers, 46 conference presentations, 33 conference papers, 3 books and chapters, 22 technical reports, and 1 patent application. These publications are listed following the Research Project Summaries.

Research projects in the department can be grouped into the following specialty areas: Communications; Computer Engineering; Electromagnetics; Electronics and Power Systems; Infra-red and Electro-optics; Radar, Surveillance, and Information Warfare; Signal Processing; Systems and Control; and Underwater Acoustics. Following this introduction, is a listing of 1995 research project titles and principal investigators, by specialty area. Although some projects involve more than one area, they are listed in only one.

Complete Project Summaries appear following the specialty area listing. These Summaries appear in alphebetical order, according to the principal investigator's surname. Publications, presentations, and theses associated with each project are listed. The student thesis involvement in faculty research is evidence of the strong interaction between the department's teaching and research programs.

Communications

ANALYSIS OF HIGH CAPACITY DIRECT DETECTION LIGHTWAVE NETWORKS
T.T. Ha, Professor

FEATURE EXTRACTION FROM DIGITAL COMMUNICATION SIGNALS USING WAVELET TRANSFORMS
R. Hippenstiel, Associate Professor
M. Fargues, Associate Professor

COORDINATED WIRELESS CONTROL IN COMMON USER NETWORKS
C-H. Lee, Professor

COMMON DATA LINK'S INTERFACE TO THE GLOBAL NETWORK ARCHITECURE
P.H. Moose, Associate Professor

Computer Engineering

COMPUTER-AIDED LOGIC DESIGN DECISION DIAGRAMS
J.T. Butler, Professor

ELECTRICAL AND COMPUTER ENGINEERING

COMPUTER-AIDED LOGIC DESIGN MULTIPLE-VALUED LOGIC DESIGN
J.T. Butler, Professor

RADIATION-IMMUNE, HIGH-SPEED, LOW-POWER, GALLIUM ARSENIDE, DIGITAL INTEGRATED CIRCUITS
D.J. Fouts, Assistant Professor

READ PREDICTION CACHE MEMORIES FOR EMBEDDED MICROPROCESSOR SYSTEMS
D.J. Fouts, Assistant Professor

SOFTWARE ANALYSIS AND ELECTRICAL TESTING
C-H. Lee, Professor

Electromagnetics

SIGNAL-TO-NOISE ENHANCEMENT PROGRAM (SNEP) RESEARCH AND SUPPORT
R.W. Adler, Senior Lecturer
W.R. Vincent

ENHANCEMENTS FOR THE RF MISSION PLANNER
R.W. Adler, Senior Lecturer

SYSTEM MODELING AND ANALYSIS CENTER SUPPORT FOR ANTENNA PERFORMANCE EVALUATION
R.W. Adler, Senior Lecturer

DEVELOPMENT OF A TIME DOMAIN ELECTROMAGNETICS CODE FOR VEHICULAR ANTENNA RADIATION AND RADHAZ ASSESSMENT
R.W. Adler, Senior Lecturer
J.E. Lebaric, Visiting Associate Professor

PROPAGATION MODELING OVER ROUGH SEA
R. Janaswamy, Associate Professor

COMPUTATIONAL ELECTROMAGNETIC METHODS FOR COMPLEX BODIES
R. Janaswamy, Associate Professor

NEAR-FIELD MEASUREMENTS OF SHIPBOARD HF ANTENNAS
D.C. Jenn, Associate Professor

SYNTHESIS OF RADAR CROSS SECTION FOR DOUBLY CURVED SURFACES
D.C. Jenn, Associate Professor

EM SCATTERING FROM A TUBULAR CYLINDER OF ANISOTROPIC SURFACE IMPEDANCES
H-M. Lee, Associate Professor

ULTRA-WIDEBAND IMPULSE ANTENNA DESIGN
M.A. Morgan, Professor
R.C. Robertson, Associate Professor

ELECTRICAL AND COMPUTER ENGINEERING

IMPULSE ANTENNA DESIGN AND EVALUATION
M.A. Morgan, Professor
R.C. Robertson, Associate Professor

ULTRA-WIDEBAND IMPULSE SIGNAL PROPAGATION
R.C. Robertson, Associate Professor
M.A. Morgan, Professor
R. Janaswamy, Associate Professor

Electronics and Power Systems

DEVELOPMENT OF SIMULINK MODEL FOR UAV ELECTRIC PROPULSION SYSTEM
R.W. Adler, Senior Lecturer
J.E. Lebaric, Visiting Associate Professor

CONVERTER DESIGN, ANALYSIS, AND PROTOTYPE FOR FUTURE NAVY SURFACE SHIPS
R.W. Ashton, Assistant Professor

A LIBRARY OF DETAILED AND REDUCED-ORDER POWER SYSTEM COMPUTER-BASED COMPONENT
MODELS
J.G. Ciezki, Assistant Professor

EVALUATION OF ENVIRONMENTAL REQUIREMENTS
J.G. Ciezki, Assistant Professor

Infra-red and Electro-optics

HIGH RESOLUTION DIRECT DIGITIZATION AND OPTICAL TELEMETRY OF ANTENNA SIGNALS
P.E. Pace, Associate Professor

EXTENDING THE VISIBILITY MRTD MODEL TO SECOND GENERATION THERMAL IMAGING SYSTEMS
R.J. Pieper, Associate Professor

DUAL BASELINE TRIANGULATION
R.J. Pieper, Associate Professor
A. Cooper, Professor

Radar, Surveillance, and Information Warfare

STEP FREQUENCY RADAR RESEARCH
G.S. Gill, Visiting Associate Professor

SUPERRESOLUTION IMAGING OF RADAR TARGETS
G.S. Gill, Visiting Associate Professor

MISSILE CLOSURE SIMULATION AND ANALYSIS TO SUPPORT TESTING MISSILE APPROACH WARNING
SYSTEMS
R.G. Hutchins, Associate Professor

ELECTRICAL AND COMPUTER ENGINEERING

RESEARCH IN DATA COMPRESSION TECHNIQUES
M. Tummala, Associate Professor

MULTI-SENSOR DATA FUSION FOR THE VTS SYSTEM
M. Tummala, Associate Professor

MODELING AND ANALYSIS OF AIRCRAFT ELECTROMAGNETIC TRANSIENT WAVEFORMS
M. Tummala, Associate Professor

RESEARCH IN SIGNAL PROFESSING FOR DIGITAL COMMUNICATIONS
M. Tummala, Associate Professor

Systems and Control

COORDINATION OF MOBILE MANIPULATORS
X. Yun, Associate Professor

CISE RESEARCH INSTRUMENTATION EXPERIMENTAL STUDY OF MULTIPLE COOPERATIVE MOBILE MANIPULATORS
X. Yun, Associate Professor

DEVELOPMENT OF COOPERATIVE CONTROL ALGORITHMS FOR MULTI-ROBOT SYSTEM
X. Yun, Associate Professor

Underwater Acoustics

SENSOR BASED NAVIGATION FOR AUTONOMOUS UNDERWATER VEHICLES
R. Cristi, Associate Professor

SONAR SIGNAL MODELING
C.W. Therrien, Professor

RECURSIVE RAY ACOUSTICS FOR THREE-DIMENSIONAL SPEEDS OF SOUND
L.J. Ziomek, Professor

ELECTRICAL AND COMPUTER ENGINEERING

Electrical and Computer Engineering Laboratories

The Electrical and Computer Engineering Department has excellent laboratory facilities in Microwaves and Antennas, Radar, Electronic Warfare, Optical Electronics, Transient Electromagnetics, Sonar Signal Processing, Control Systems, Power Systems, Image Processing, Very-Large-Scale Integration Design, Digital Systems, and computer laboratories using high-speed microcomputers, UNIX-based workstations and distributed servers.

A wide array of computer facilities and software is available to support such areas as digital signal processing, control simulations, digital circuit simulation, digital system design, electromagnetics, power electronics and distribution, and image processing. There are also extensive service facilities including a calibration laboratory with a continuous program of calibration and maintenance for laboratory instruments. The department operates a secure computing and simulation laboratory, and has access to simulation and computing facilities in the Sensitive Compartmented Information Facility (SCIF). A Worldwide SCI computer network is available in the SCIF.

Status as a Naval facility also enables the department to utilize a number of modern systems as adjuncts to the laboratory. These include radar, telemetry, sonar, countermeasures, and navigational systems.

FY95 REIMBURSABLE PROGRAM
Department of Electrical and Computer Engineering

K Dollars

[Line graph: "Reimbursable Funds Available by Fiscal Year" showing K Dollars on Y-axis (0 to 5,000) and months OCT through SEP on X-axis. Three data series: FY93 AVAILABLE, FY94 AVAILABLE, FY95 AVAIL.]

☆ FY93 AVAILABLE ✳ FY94 AVAILABLE ✦ FY95 AVAIL
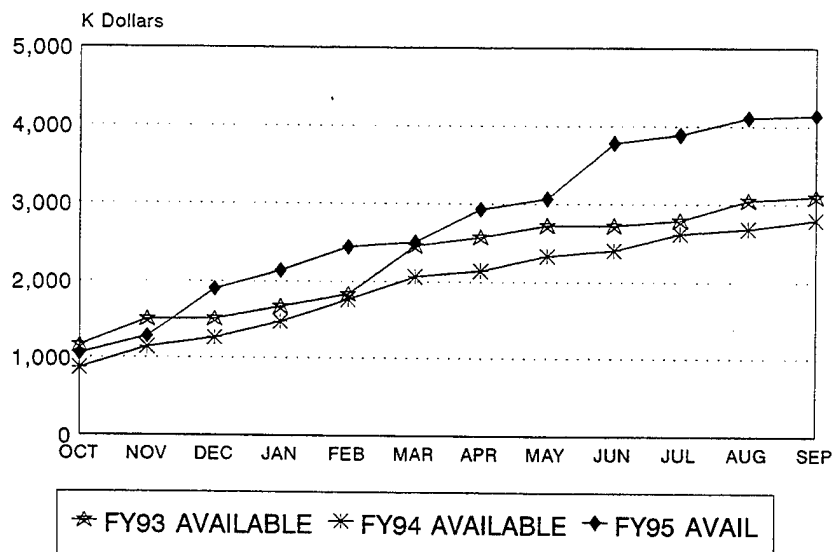
Figure 1. Reimbursable Funds Available by Fiscal Year.
This graph shows the amount of reimbursable funding available to the department. Dollar amounts include research and academic reimbursable activities, as well as funding from Cooperative Research and Development Agreements.

[Pie chart showing FY95 Reimbursable Sponsor Profile with the following segments: NAVY 78%, ARMY 5%, CRDA 1%, AIR FORCE 8%, OTHER 2%, NSF 5%, DEFENSE 1%]
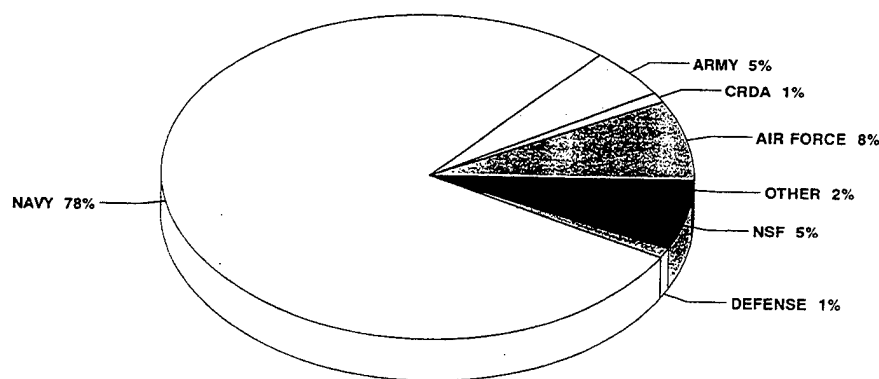
Figure 2. FY95 Reimbursable Sponsor Profile.

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ELECTRICAL AND COMPUTER ENGINEERING

SIGNAL-TO-NOISE ENHANCEMENT PROGRAM (SNEP)
RESEARCH AND SUPPORT
Richard W. Adler, Senior Lecturer
Wilbur R. Vincent, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Security Group

OBJECTIVE: Continued research and development in techniques to improve the signal-to-noise ratio at Navy receiving sites worldwide.

SUMMARY: Development of techniques and methodology for identifying and locating radio noise sources at NSG sites worldwide continued. Support was provided to NSG via review of pre-survey planning documentation, mitigation plans and authoring "Quick-Look" and final site-survey reports. Students and NSG site personnel were trained as part of the NSG support. A 2 1/2 day HF Technical Review of Factors that Affect Performance of Naval Receiving Sites was organized and was held in Washington DC in February.

PUBLICATIONS:

Vincent, W.R. and Adler, R.W., "EMI Survey at Detachments K, J and L," USA INSCOM Supplementary Report #MSA9409S, January 12, 1995. (SECRET)

Vincent, W.R., "SNEP Team Quick-Look Report, NSGA, Hanza, Okinawa, CDAA Site," NSG Technical Report, March 1995.

Vincent, W.R., "SNEP Team Technical Report, NSGA, Hanza, Okinawa CDAA Site," NSG Technical Report, April 1995.

Vincent, W.R., "SNEP Team Quick-Look Report, NSGD, Sabana Seca, PR, CDAA Site," NSG Technical Report, April 1995.

Vincent, W.R., "SNEP Team Technical Report, Sabana Seca, PR, CDAA Site," NSG Technical Report, May 1995.

Adler, R.W. and Vincent, W.R., "The Primary Encroachment Problem, Overhead Power Lines," NSA 3rd Annual EMC Conference Proceedings, June 1995.

Vincent, W.R. and Adler,R.W., "Evaluating the Impact of EMI on the Operation of Receiving Sites," NSA 3rd Annual EMC Conference Proceedings, June 1995.

Vincent, W.R. and Adler, R.W., "The Intra-site EMI Problem," NSA 3rd Annual EMC Conference Proceedings, June 1995.

Vincent, W.R., "SNEP Team Quick-Look Report, NSGD, Winter Harbor, ME, CDAA Site," NSG Technical Report, June 1995 .

Vincent, W.R., "SNEP Team Technical Report, Winter Harbor, ME, CDAA Site," NSG Technical Report, July 1995.

Vincent, W.R., "SNEP Team Quick-Look Report, NSGD, Rota, Spain, CDAA Site," NSG Technical Report, August 1995.

Vincent, W.R., "SNEP Team Technical Report at the Rota, Spain CDAA Site," NSG Technical Report, September 1995.

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Vincent, W.R., "SNEP Team Quick-Look Report, NSGD, Sabana Seca, PR, CDAA Site," NSG Technical Report, September 1995.

Vincent, W.R., "SNEP Team Technical Report, Sabana Seca, PR, CDAA Site," NSG Technical Report, October 1995.

Vincent, W.R., "SNEP Team Quick-Look Report, NSGA, Kunia, HI, Regional Operational Site," NSG Technical Report, November 1995.

Vincent, W.R., "SNEP Team Technical Report, NSGA, Kunia, HI, Regional Operational Site," NSG Technical Report, November 1995.

Vincent, W.R., Perry, R.M., Shillcock, S.S., and Adler, R.W., "Radio Interference from Fluorescent Lights Using Energy Efficient Electronic Ballasts," Naval Postgraduate School Technical Report, NPS-EC-95-011, August 1995.

Vincent, W.R. and Adler, R.W., "Technical Aspects of Grounds at Naval Receiving and Data Processing Facilities," NSG Technical Memorandum #SNEP 950830, August 1995.

CONFERENCE PRESENTATIONS:

Adler, R.W., "The Fallacy of Using MOV's to Suppress Power Transients," Workshop on Factors Affecting the Performance of Naval Receiving Sites, Vienna, VA, February 1995.

Adler, R.W., "Mitigation of Digital Motor-Controller Radio Interference," Workshop on Factors Affecting the Performance of Naval Receiving Sites, Vienna, VA, February 1995.

Adler, R.W., "The Results of Current Injection Tests at a CDAA Site," Workshop on Factors Affecting the Performance of Naval Receiving Sites, Vienna, VA, February 1995.

Adler, R.W., "Using the Numerical Electromagnetics Code to Predict the Effects of Noise Currents Injected onto the Radial Wire Ground System of a Conical Monopole Antenna," Workshop on Factors Affecting the Performance of Naval Receiving Sites, Vienna, VA, February 1995.

Adler, R.W., "Power-Line Noise -- The Myths and the Facts: Understanding the Fundamentals," The Dayton Amateur Radio Convention, May 1995.

THESIS DIRECTED:

Hodge, J., "A Comparison Between Power Line Noise Level Field Measurements and Man-Made Radio Noise Prediction Curves in the High Frequency Radio Band," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: Electromagnetic environmental effects, communication systems, man-made noise, antennas

ELECTRICAL AND COMPUTER ENGINEERING

ENHANCEMENTS FOR THE RF MISSION PLANNER
Richard W. Adler, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor: Naval Information Warfare Activity

OBJECTIVE: The goal of this eighth year of a continuing project was to conduct numerical analysis and experimental research in support of the Navy's requirement to site VLF through UHF communication antenna systems and support equipment in non-ideal locations. The effort this year was to support the propagation prediction models of the Radio Frequency Mission Planner (RFMP). In particular, the RFMP provides the warfighter an estimate of the probability of successfully receiving radio signals from 20 to 1500 Mhz. The ionosphere does support 20 to 150 MHz in both the equatorial and the polar regions of the earth. The propagation models used in RFMP are tropospheric models only. Hence in the high- and low-latitude regions, RFMP will miss ionospheric paths and not predict some long-distance links. NPS is developing a rule-set to add to the tropospheric models for those conditions under which Auroral E (Polar) and Transequatorial F layer paths can exist.

SUMMARY: An inexpensive equatorial propagation experiment has been completed to gather data for the rule set. The path mode is being correlated with observed electron content. The data obtained is being analyzed to provide a verification of propagation modes and existing prediction programs. A set of numerical models of various antennas of interest for RFMP has been developed.

THESES DIRECTED:

Karapinar, E., "Modification and Verification of an Antenna Design for PANSAT Using NEC," Master's Thesis, June 1995.

Kline, T.S., "Broadband HF and VHF Antenna Design with Terrain Modeling," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: Electromagnetic environmental effects, communication systems, man-made noise, antennas, radiowave propagation

SYSTEM MODELING AND ANALYSIS CENTER SUPPORT FOR ANTENNA PERFORMANCE EVALUATION
Richard W. Adler, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor: Naval Information Warfare Activity

OBJECTIVE: The System Modeling and Analysis Center (SMAC) is tasked to provide personnel and modeling tools to support all Tri-Service communication systems performance predictions for the warfighter. NPS is supporting this requirement by providing user-friendly numerical modeling tools. The first deliverable will be in 1996, a Windows graphical I/O interface for the NEC-MOM antenna code. Training will be provided on-site to the SMAC personnel in the form of a short course in conjunction with the Applied Research Lab of Penn State.

KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: Electromagnetic environmental effects, antennas

ELECTRICAL AND COMPUTER ENGINEERING

DEVELOPMENT OF SIMULINK MODEL FOR UAV ELECTRIC PROPULSION SYSTEM

Richard W. Adler, Senior Lecturer
Jovan E. Lebaric, Visiting Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Research Laboratory

OBJECTIVE: A SIMULINK model of a UAV electric propulsion system is needed. The simulation will allow determination of if both the propulsion system performance will be sufficient and the battery will be able to supply the required energy for the intended missions.

SUMMARY: The simulation developed requires inputs of propeller torque and RPM as functions of time. The electric propulsion model using SIMULINK can be used by NRL to determine the minimum time a mission would take for the battery/motor resources, the flight regime to maximize range or time over target and the "minimum expenditure of energy" mission.

DOD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles, Modeling and Simulation

KEYWORDS: UAV, model, electric propulsion

DEVELOPMENT OF A TIME DOMAIN ELECTROMAGNETICS CODE FOR VEHICULAR ANTENNA RADIATION AND RADHAZ ASSESSMENT

Richard W. Adler, Senior Lecturer
Jovan E. Lebaric, Visiting Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Explosive Ordinance Disposal Technology Division

OBJECTIVE: EOD requires the ability to predict internal and external EM fields radiated by vehicular antennas, from 20 to 1000 MHz. To assess RADHAZ potential, the effects of the passengers must be simulated using lossy dielectric loading.

SUMMARY: A proprietary absorbing volume technique has been coupled to a Method of Moments wire solution to meet the requirements. MATLAB is the programming environment for the PC-based code which features a user-friendly I/O interface.

DOD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: Electromagnetic environmental effects, communication systems, antennas, radiowave propagation

CONVERTER DESIGN, ANALYSIS AND PROTOTYPE FOR
FUTURE NAVY SURFACE SHIPS
Robert W. Ashton, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center, Annapolis Detachment

OBJECTIVE: The object of this continuing project is to provide Naval Surface Warfare Center (NSWC) with six working 100kW DC-to-DC converters. This will be accomplished through the design and construction of the power portion of the converter by Power Paragon, Inc. (PPI) of Anaheim, CA in coordination with the design and construction of the controller by NPS.

SUMMARY: Through the use of previous thesis work by Mark Colby at NPS, a pseudo multiloop control scheme was chosen. This investigator designed, built and tested an analog multiloop controller which was used with a 10kW power section of a converter that was available during a six week venture at NSWC. After being satisfied with the overall results of the testing and a computer modeling effort, it was decided to make the controller more 'universal'. The multiloop control scheme was coded in SIMULINK by MATLAB converted to C and down loaded to a DSP controller from dSpace. After proof-of-concept by Gene Blalock, another thesis student at NPS, an autonomous DSP card was chosen during a second six week venture at NSWC. Coding was then written for the new DSP card, an SBC31 by Innovative Integration. Parallel simulation work utilizing the finished design of the power section by PPI was accomplished to determine converter stability and optimize control loop gains. One of three in-house prototype 4kW DC-to-DC power sections was built and tested. The prototype IGBT power portions will be used for hardware validation of computer simulations. Issues like stability when paralleling with and without negative resistance loads will be validated. This continuing project expects to deliver two completed controllers that operate in both analog and digital mode to PPI in April. The controllers will be connected to two 100kW power portions at PPI, tested and shipped to NSWC for further evaluation.

THESIS DIRECTED:

Blalock, G., "Comparative Assessment of a Competitive Design Pulse Width Modulated Three Phase Inverter Module in a Static Electronic Reversible Power Supply for Shipboard Power Distribution Systems," Master's Thesis, March 1995.

DOD KEY TECHNOLOGY AREAS: Other (Power System Enhancement), Computing and Software

KEYWORDS: Power system, DC distribution, zonal architecture, stability

COMPUTER-AIDED LOGIC DESIGN DECISION DIAGRAMS
John T. Butler, Professor
Department of Electrical and Computer Engineering
Sponsor: Unfunded

OBJECTIVE: This project is intended to provide the means to develop digital design which provides customer-specific characteristics that are both cost-effective and efficient. A current example of the latter is the development of planar circuits, circuits that have no crossings.

SUMMARY: The Characterization of Functions with Planar Decision Diagrams: A significant source of delay in digital circuits now are crossings, which must be realized by at least two levels in VLSI circuits connected by vias between levels. Indeed, in FPGAs (field programmable gate arrays), most of the delay occurs in interconnecting devices rather than the devices themselves. Necessary conditions for planarity in decision diagrams of certain functions have been shown. Last year, the first (as far as we know) paper on this subject was published. This year, this was extended

by completely characterizing symmetric functions with planar decision diagrams. Such functions are an important set of functions being an indispensable part of arithmetic circuits.

The Development of Decision Diagrams to Represent Multi-Output Logic Circuits: This year, ways were demonstrated efficiently representing multi-output functions and showed the relative benefits of each. This is important because decision diagrams are part of almost all contemporary CAD tools, and there is a significant need for efficient representation.

PUBLICATION:

Sasao, T. and Butler, J.T., "Planar Multiple-Valued Decision Diagrams," Proceedings of the 25th International Symposium on Multiple-Valued Logic, pp. 28-35, May 1995.

PRESENTATION:

Butler, J.T., "Planar Multiple-Valued Decision Diagrams," 25th International Symposium on Multiple-Valued Logic, May 1995.

OTHER:

Sasao, T. and Butler, J.T., "Planar Decision Diagrams for Multiple-Valued," accepted by Multiple-Valued Logic: An International Journal.

Butler, J.T., Herscovici, D.A., Sasao, T., and Barton, R., "Average and Worst Case Number of Nodes in Decision Nodes of Symmetric Functions," accepted by IEEE Transactions on Computers.

Butler, J.T. and Sasao, T., "Average Number of Nodes in Binary Decision Diagrams of Fibonacci Functions," accepted by The Fibonacci Quarterly.

Sasao, T. and Butler, J.T., "A Method to Represent Multiple-Output Switching Functions by Using Multi-Valued Decision Diagrams," conditionally accepted by the Proceedings of the 26th International Symposium on Multiple-Valued Logic, May 1996.

Butler, J.T., Nowlin, J.L., and Sasao, T., "Planarity of ROMDDs of Multiple-Valued Symmetric Functions," conditionally accepted by the Proceedings of the 26th International Symposium on Multiple-Valued Logic, May 1996.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computers, logic design, computer-aided design tools

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COMPUTER-AIDED LOGIC DESIGN
MULTIPLE-VALUED LOGIC DESIGN
John T. Butler, Professor
Department of Electrical and Computer Engineering
Sponsor: Unfunded

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OBJECTIVE: This project is intended to develop logic design techniques for multiple-valued logic circuits. Such circuits offer compactness and high-speed. Technologies for which multiple-valued logic have application include CCD (charge-coupled devices) and RTTs (resonant-tunneling transistors).

ELECTRICAL AND COMPUTER ENGINEERING

SUMMARY: Design Methods for Multiple-Valued Systems. During this reporting period, work begun earlier on the cost-table technique for multiple-valued logic was completed. In this technique, designs are made by composing compact and efficient designs from a table of such designs using specific composing operations [1]. Further, work was completed on the design of multiple-valued PLAs (programmable logic arrays) using the "heat-quench" method, involving simulated annealing [2].

The Analysis of Redundant Number Systems. This year, two classes of proposed multiple-valued number systems were analyzed and showed for the first time the relative redundancy. In a redundant number system, two or more tuples may represent the same number. While it may be viewed as a disadvantage, there are important advantages of such number systems. Redundancy allows of "almost carryless" (and thus fast) arithmetic operations (e.g., addition). Redundant number systems are important for error correction and detection codes are an essential part of CD ROMs. The relative redundancy of two proposed number systems was shown. The work is reported in a submitted manuscript [3].

CONFERENCE PRESENTATIONS:

Butler, J.T., "Multiple-Valued Logic Design," Osaka University, Japan, June 1995.

Butler, J.T., "Multiple-Valued Logic Design," Tohoku University, Japan, August 1995.

OTHER:

[1] Schueller, K.A. and Butler, J.T., "Complexity Analysis of Cost-Table Approach to the Design of Multiple-Valued Logic Circuits," accepted by IEEE Transactions on Computers.

[2] Dueck, G.W. and Butler, J.T., "Heat-Quency Algorithm for the Minimization of Multiple-Valued Programmable Arrays," accepted by Computers and Electrical Engineering.

[3] Butler, J.T. and Sasao, "On the Proportion of Digits in Redundant Number Systems," preprint.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computers, logic design, computer-aided design tools

A LIBRARY OF DETAILED AND REDUCED-ORDER POWER SYSTEM COMPUTER-BASED COMPONENT MODELS

John G. Ciezki, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: The goal of this research is to implement a comprehensive library of digital computer models of the components and topologies common to electromechanical drives, power electronic converters, and power distribution networks. The detailed and reduced-order modeling and simulation of these systems is an important and developing area of research utilized in both defense and civilian endeavors. In particular, the Naval Surface Warfare Center is presently developing an Integrated Power System based on DC Zonal Electric Distribution for the surface ship of the next century. In this effort, it is vital to have design issues thoroughly investigated with accurate digital models prior to intensive hardware investment. With this requirement considered, research efforts at NPS have concentrated on establishing a set of analysis tools which may be readily applied to studies such as fault analysis, system stability, power quality, control integrity, system reconfiguration, and control synthesis. Implicit to this effort is the development and validation of a set of reduced-order models which may be conveniently used in-house by interested customers who are seeking alternatives to time-intensive detailed simulations.

ELECTRICAL AND COMPUTER ENGINEERING

SUMMARY: As originally intended, the simulation library (a collection of model definitions written in the Advanced Continuous Simulation Language) contains a range of standard and non-standard component representations which are commonly used in power system configurations. The library has been organized into a number of categories including AC to DC conversion devices, DC to AC conversion devices, Current Source Inverters, Induction Machines, Synchronous Machines, DC Machines, Brushless DC Machines, Stepper Motors, Transformers, Electric Loads, Electric Sources, Mechanical Loads, Turbines, Resonant Converters, DC to DC converters, Inverter Controls, Vector Controls, Manipulators, Ship Dynamics, and Magnetic Relays. Within each category are detailed, reduced-order, and specialty models. The library contains several alternative component models to facilitate the solution of special topological problems such as stiffly-connected networks. In addition, the library serves as a repository for interconnected systems with which to add to or modify. Also, various control algorithms and analysis tools have been encapsulated in MATLAB files and are available for use with or on interconnected systems.

DOD KEY TECHNOLOGY AREA: Electronics

KEYWORDS: Electromechanical drives, power electronic converters, simulation, reduced-order modeling

EVALUATION OF ENVIRONMENTAL REQUIREMENTS
John G. Ciezki, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Command, Control and Ocean Surveillance Center,
Research and Development Division

OBJECTIVE: The objective of this proposed work is to evaluate the MIL-STDs for the protection against ambient and battle conditions for racks, cabinets, enclosures, and other components to be procured under the next phase of the Tactical Advanced Computer procurement. The areas to be investigated will include the MIL-STDS pertaining to shock and vibration effects, temperature and humidity effects, and electromagnetic effects.

SUMMARY: The Department of Defense and the Department of the Navy are engaged in a serious effort to assess the need for invoking MIL-SPECS as requirements in all procurements. In the case of the procurement of tactical advanced computers an effort is underway to examine the implications of using commercial standards in certain areas. This would allow the possibility of procurring commercial off-the-shelf (COTS) components as part of the next Tactical Advanced Computer procurement. A careful evaluation of the implications of commercial standards in lieu of MIL-SPECS must be made so that military effectiveness of the hardware procured is not compromised. The MIL-STDS will be reviewed by the following criteria: application area, ship class, battle conditions. The criteria will then be contrasted with the ship environment and characteristics. The potential for COTS will then be identified and the level of effort required to incorporate them into systems will be assessed. Finally, standards for the application of COTS will be proposed.

DOD KEY TECHNOLOGY AREA: Electronics

KEYWORDS: Electromagnetic fields

ELECTRICAL AND COMPUTER ENGINEERING

SENSOR BASED NAVIGATION FOR AUTONOMOUS UNDERWATER VEHICLES
Roberto Cristi, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The main goal of this project is to develop a technique to localize an underwater vehicle with respect to known landmarks. It uses information from sonar a high frequency, high resolution profiling sonar, and linear acceleration in the inertial reference frame.

SUMMARY: During the current year we developed a technique for localizing an underwater vehicle with respect to known features of the working environment. Its main feature is the use of a high resolution profiling sonar, which provides range and bearing information. This sensor is integrated with the measurement of linear acceleration in three dimensions to yield a recursive, real time, estimate of the vhicle location and instant velocity. Also the effects of an unknown current can be estimated, provided there is sufficient information in the vehicle surroundings.

An additional feature of the technique is the ability of detecting and localizing features which are not accounted in the map of the environment, resident in the memory of the vehicle. This information can be used in different ways, either by updating the map itself or by passing the information to a different level of software (for example, to the controller for obstacle avoidance maneuvers).

At the same time we are also investigating the possibility of using Synthetic Aperture Sonar (SAS) techniques in order to obtain high resolution imaging of the environment. This part of the work is not funded yet, but it will be proposed as part of the continuation of the project.

PUBLICATION:

Cristi, R., Caccia, M., Veruggio, G., and Healey, A.J., "A Sonar Based Approach to AUV Localization," Proceedings of 1995 Symposium on Control Applications in Marine Systems (CAMS'95), Trondheim, Norway, May 1995.

CONFERENCE PRESENTATION:

Cristi, R., Caccia, M., Veruggio, G., and Healey, A.J., "A Sonar Based Approach to AUV Localization," 1995 Symposium on Control Applications in Marine Systems (CAMS'95), Trondheim, Norway, May 1995.

THESES DIRECTED:

Conovitch, K.D., "Sensor Based Navigation and Localization Methods for Autonomous Underwater Vehicles," Master's Thesis, June 1995.

Welter, J.D., "Investigation of High Resolution Synthetic Aperture Sonar for Imaging and Classification," Master's Thesis, December 1995 (advisor Professor D.L. Walters, coadvisor Professor R. Cristi).

OTHER:

Cristi, R., Caccia, M., and Veruggio, G., "Motion Estimation and Modeling of the Environment for Underwater Vehicles," Proceedings of the IARP 1996, Toulone, France, to appear April 1996.

DOD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles

KEYWORDS: Estimation, control, modeling

ELECTRICAL AND COMPUTER ENGINEERING

SPEECH PROCESSING USING ONE- AND TWO-DIMENSIONAL
SIGNAL PROCESSING TECHNIQUES
Monique P. Fargues, Associate Professor
Department Electrical and Computer Engineering
Sponsors: Naval Command, Control and Ocean Surveillance Center and Naval Postgraduate School

OBJECTIVE: The goal of this project is to investigate the use of speech processing and modeling techniques to detect foreign accents in spoken American English. This is a follow-up study to work begun during fiscal year 1995.

SUMMARY: Most research done in the study of foreign accents use subjective assessment of the speech quality, as listeners are usually able to detect easily the presence of a given accent. Therefore, such studies depend to a large extent on the listeners chosen and their consistency over time. As a result, there is a for more objective schemes which are listener independent.

A previous study conducted at the Naval Postgraduate School investigated the feasibility to differentiating non-native (foreign) speakers of American English from native speakers of American English. The identification process used the stationary spectral information contained in short monosyllabic English words. The study focused on one group of non-native speakers of English for a proof of concept, with the understanding that the study could be extended to speakers of other origins. This preliminary study used AR modeling and spectral distance measures for the native-versus-foreign classification task. Results were encouraging, as they showed that it may be possible to differentiate native from non-native speakers of American English by using the stationary spectral information contained in the first two formant locations.

The 1996 fiscal year effort was focused on the application of the Two-Dimensional Cepstrum (TDC) transform as a tool for speech processing. The TDC can be regarded as an extension of the one-dimensional cepstrum as it carries both instantaneous and transitional information contained in speech. The first part of the study focused on the relationship between the one- and two-dimensional cepstrum transform. The second part of the study considered the application of the TDC to speaker identification problems. Results showed that the TDC is robust to noise degradations. They also indicated that the TDC performances are sensitive to large variations in word length.

PUBLICATION:

Fargues, M.P. and Dewey, J.K., "Speech Recognition of Foreign Accent," Signal and Image Processing, SIP-95, Las Vegas, NV, November 1995.

THESIS DIRECTED:

Lelakis, L., "Speaker Identification Using the Two-Dimensional Cepstrum Transform," Master's Thesis, March 1995.

DOD KEY TECHNOLOGY AREAS: Electronics, Computing and Software

KEYWORDS: Speech processing, cepstrum

ELECTRICAL AND COMPUTER ENGINEERING

DETECTION AND CLASSIFICATION OF TRANSIENT SIGNALS
USING WAVELET
Monique P. Fargues, Associate Professor
Department of Electrical and Computer Engineering
Sponsors: Naval Underwater Warfare Center - New London Detachment
and Naval Sea Systems Command

OBJECTIVE: The goal of this project is to investigate the application of the Wavelet Transform to classification of underwater signals.

SUMMARY: This study investigated the application of orthogonal and non-orthogonal Wavelet -based procedures as feature extraction tools to classify several classes of underwater signals consisting of sperm whale, killer whale, pilot whale, humpback whale, gray whale, and underwater earthquake. A two-hidden-layers back-propagation neural network was used for the classification procedure. Results showed that the non-orthogonal undecimated A-trous implementation with multiple voices lead to the highest classification rate of 96.7%.

PUBLICATION:

Fargues, M.P. and Bennet, R., "Comparing Wavelet Transforms and AR Modeling as Feature Extraction Tools for Underwater Signal Classification," Proceedings of the 29th Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, November 1995.

DOD KEY TECHNOLOGY AREAS: Electronics, Computing and Software

KEYWORDS: Signal classification, wavelet transform

RADIATION-IMMUNE, HIGH-SPEED, LOW-POWER, GALLIUM ARSENIDE, DIGITAL
INTEGRATED CIRCUITS
Douglas J. Fouts, Assistant Professor
Department of Electrical and Computer Engineering
Sponsors: Space and Naval Warfare Systems Command and National Security Agency

OBJECTIVE: To develop a low-cost method for fabricating high-speed, low-power, gallium arsenide, field effect transistor, digital integrated circuits that are immune to radiation-induced single-event upsets.

SUMMARY: Buried, low-temperature grown, gallium arsenide (GaAs) buffer layers are being investigated for use in GaAs wafers for digital integrated circuit (IC) fabrication processes. The effects of the buffer layer on transistor characteristics, circuit operation, and sensitivity to single event upsets are being characterized. Simulations indicate that the single event error rate can be reduced by approximately six orders of magnitude, without any decrease in speed or increase in power consumption. The proposed modified wafer will be compatible with existing commercial wafer growth and IC fabrication processes. The results of this research will make it possible to turn any off-the-shelf or custom GaAs digital IC design into a radiation-hardened IC by fabricating the IC on a special wafer, avoiding the high costs associated with redesigning an IC for radiation tolerance and the required changes to the fabrication process.

PUBLICATIONS:

Fouts, D.J., Weatherford, T.R., McMorrow, D., Wolfe, K., Van Dyk, S.E., and Campbell, A.B., "Single Event Upsets in Gallium Arsenide Pseudo-Complementary MESFET Logic," IEEE Transactions on Nuclear Science, Vol. 42, No. 6, December 1995.

Fouts, D.J., Weatherford, T.R., McMorrow, D., Wolfe, K., Van Dyk, S.E., and Campbell, A.B., "Single Event Upsets in Gallium Arsenide Pseudo-Complementary MESFET Logic," 32nd Annual International Nuclear and Space Radiation Effects Conference, Madison, WI, July 1995.

CONFERENCE PRESENTATION:

Fouts, D.J., Weatherford, T.R., McMorrow, D., Wolfe, K., Van Dyk, S.E., and Campbell, A.B., "Single Event Upsets in Gallium Arsenide Pseudo-Complementary MESFET Logic," 32nd Annual International Nuclear and Space Radiation Effects Conference, Madison, WI, July 1995.

THESES DIRECTED:

Van Dyk, S.E., "Single Event Upsets and Noise Margin Enhancement of Gallium Arsenide Pseudo-Complimentary MESFET Logic," Master's Thesis, June 1995.

Madsen, A.K., "Reducing Single-Event Upsets in Bulk CMOS Digital ICs Using Guard Rings," Master's Thesis, September 1995.

Andreasen, P, "Testing Hardware, Methods, and Results for a High-Speed, Gallium Arsenide, Dynamic Memory," Master's Thesis, December 1995.

OTHER:

Fouts, D.J., McMorrow, D., and Van Dyk, S., "Synchronized SEU Testing of Ring Oscillators Using Pulsed Lasers," IEEE Transactions on Nuclear Sciences, submitted.

Wight, R.L., Fouts, D.J., and Weatherford, T.R., "A Technology Independent ASIC for Measuring the Dependence of SEUs on Operating Frequency," 33rd Annual International Nuclear and Space Radiation Effects Conference, Indian Wells, CA, submitted and forthcoming July 1996.

DOD KEY TECHNOLOGY AREAS: Electronics, Computing and Software, Command, Control and Communications, Electronic Warfare, Materials, Processes and Structures

KEYWORDS: Radiation-hardened electronics, space-qualified electronics, gallium arsenide integrated circuits, high-speed logic

READ PREDICTION CACHE MEMORIES FOR EMBEDDED MICROPROCESSOR SYSTEMS
Douglas J. Fouts, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To develop an alternative to off-chip primary and second-level cache memories for spacecraft, weapon systems, and other embedded high-performance microprocessor applications.

SUMMARY: Off-chip primary and second-level cache memories for high-performance microprocessor systems require large arrays of high-speed static RAM ICs, which greatly increases the power consumption, weight, physical size, and cooling requirements of the microprocessor system. By using address prediction techniques, a significantly smaller cache can provide the same performance, with significantly reduced power consumption, weight, physical size, and cooling requirements. Single-chip VLSI implementations of read prediction caches are possible, which can reduce design time and improve system reliability.

ELECTRICAL AND COMPUTER ENGINEERING

THESES DIRECTED:

Aguilar, M.E., "Testing of the Read Predictive Buffer Chip, Design and Implementation of the Predictive Read Cache Chip," Master's Thesis, March 1995.

Miller, R., "Simulation and Performance of a Read Predictive Cache Memory," Master's Thesis, June 1995.

OTHER:

Fouts, D.J., Nowicki, G.J., and, Aguilar, M.E., "A CMOS Read Prediction Buffer IC for Embedded Microprocessor Systems," IEEE Transactions on VLSI Systems, submitted.

DOD KEY TECHNOLOGY AREAS: Computing and Software, Command, Control and Communications

KEYWORDS: Embedded computing, portable computing, high-performance microprocessors

STEP FREQUENCY RADAR RESEARCH
G. S. Gill, Visiting Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Command, Control and Ocean Surveillance Center,
Research and Development Division

OBJECTIVE: The objective of this multi-year research is to investigate the waveform design and signal processing issues of step frequency radar as applied to naval applications.

SUMMARY: Step frequency offers special advantages for detection of moving targets embedded in clutter as it can achieve large effective bandwidth (to reduce clutter) without increasing the sampling rate. As a result there is interest in building and testing radars based on this waveform for timely detection of low RCS, low flying, missiles. Traditional coherent signal processing of radar returns from a moving target due to step frequency waveform causes the signals to smear in range, resulting in loss of range resolution and signal to noise ratio. However, compensation of signals can be devised to counter these effects. In this continuing multi-year effort the exact compensation term was derived from fundamentals. Two implementations of the compensation were devised and were investigated for computational efficiency and other effects. In first implementation compensation is performed in time domain. In the second implementation compensation is implemented by circular convolution to reduce the overall number of signal processing steps. However, it turned out that first scheme is significantly faster than the second implementation even though the second implementation has fewer steps. Judicious use of weighting has also improved the performance over the previous efforts. Design of optimal waveforms for the above mentioned application is continuing. The results of this research are being employed in radar implementation.

PUBLICATION:

Gill, G.S., "Step Frequency Waveform Design and Processing for Detection of Moving Targets in Clutter," Proceedings of the IEEE International Radar Conference, pp. 573-578, 1995.

CONFERENCE PRESENTATION:

Gill, G.S., "Step Frequency Waveform Design and Processing for Detection of Moving Targets in Clutter," IEEE International Radar Conference, Washington, DC, May 1995.

OTHER:

Gill, G.S., and Huang, J.C., "Ambiguity Function Analysis of Step Frequency Radars," submitted to the International Radar Conference in China and the SPIE Conference at Denver, CO.

THESIS DIRECTED:

Ma, Y-B, "Velocity Compensation in the Stepped Frequency Radar," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Step frequency, signal processing, velocity compensation

SUPERRESOLUTION IMAGING OF RADAR TARGETS
G.S. Gill, Visiting Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The purpose of this research is to develop, implement, and test superresolution algorithms for synthetic aperture radar (SAR) and inverse synthetic aperture radar (ISAR).

SUMMARY: Recently there has been significant interest in using superresolution signal processing to enhance the range profiles and SAR/ISAR images of targets and to improve the classification accuracy at longer ranges. In normal radar cross-range resolution is proportional to real antenna beamwidth and range to the spot to be mapped. Resolution obtained from the real beam mapping can be of the order of a mile, which is not of any practical use other than recognizing gross geographical features. This problem is solved in SAR where the cross-range resolution is improved by synthesizing a long synthetic array. In side-looking mode the length of the array is limited by real antenna size and in spotlight mode it is limited by time on target (or dwell). However, both the parameters cannot be stretched to the limit to achieve arbitrarily fine cross-range resolution. The factors which ultimately limit the cross-range resolution are such as frequency and phase stability of the radar equipment, errors caused by propagation of electromagnetic waves through the atmosphere, quadratic and higher order errors caused by motion, and the limited accuracy of motion compensation. Thus, any further improvement in the cross-range resolution can be gained by techniques such as superresolution. Superresolution techniques increase the resolution by additional signal processing instead of stretching the radar parameters. With 2-D SAR/ISAR superresolution technique it is possible to increase the cross-resolution as well as (slant) range resolution by a factor of 3 to 5. Recent developments in spectral analysis promise improved frequency resolution among other things and that is the reason for the name 'superresolution'. Resolving point scatters in cross-range in a SAR system is similar to estimating the frequency of closely spaced superimposed sinusoids. The increased frequency resolution capability of new techniques will improve the resolution and thus the image quality of SAR/ISAR systems. In this effort we plan to implement superresolution algorithms for synthetic aperture radar (SAR) and inverse synthetic aperture radar (ISAR). The algorithms will be tested on the available data. This is a multi-year effort and we plan to perform work in 1996.

DOD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Radar, signal processing, synthetic aperture, inverse synthetic aperture

ELECTRICAL AND COMPUTER ENGINEERING

ANALYSIS OF HIGH CAPACITY DIRECT DETECTION LIGHTWAVE NETWORKS
Tri T. Ha, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: The objective of this project is to evaluate the capacity of multi-channel direct detection lightwave networks with and without optical amplifiers.

SUMMARY: Optical FDMA networks using Fabry-Perot filter as the channel demultiplexer were analyzed. The intersymbol interference effect, the adjacent channel interference effect, and the receiver thermal noise were taken into account. Error-correction codes were included in the analysis. Bit error probabilities and power penalty/coding gain were evaluated. For optical FDMA networks with optical amplifiers, the amplifier noise was included in the analysis.

THESIS DIRECTED:

Studer, J.A., "A Time-Domain Approach to Sensitivity Analysis of Direct Detection Optical FDMA Networks with OOK Modulation," Master's Thesis, March 1995.

OTHER:

Studer, J.A., Ha, T.T., and Borchardt, R.L., "A Time-Domain Analysis of Direct Detection Dense WDM Networks," accepted for publication in 1996 in the Journal of Optical Communications.

Ha, T.T. and Powers, J.P., "Optical FDMA Networks: A Discrete-Time Approach," MILCOM96, invited paper.

DOD KEY TECHNOLOGY AREA: Other (Networks)

KEYWORDS: Optical FDMA, Fabry-Perot, optical amplifier

FEATURE EXTRACTION FROM DIGITAL COMMUNICATION SIGNALS USING WAVELET TRANSFORMS
Ralph Hippenstiel, Associate Professor
Monique P. Fargues, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The goal of this project was to investigate Wavelet based processing techniques as applied to digital communication signal detection and classification and to recommend potentially useful basis functions.

SUMMARY: Research was conducted to evaluate the feasibility of applying wavelet transforms and methods based on proportional bandwidth processing to transient feature extraction. Classical wavelets and signal related basis functions were used to extract the switching instants from BPSK, QPSK, FSK, ASK and AMQPSK signals in the presence of additive Gaussian white noise. Results show that using the magnitude of one output scale, the transient times can be detected above a certain signal to noise ratio level. This level depends on the type of signal and wavelet, as well as on the acceptable number of mistakes. Additional work, using several scales and a properly trained neural network, should demonstrate automated selection of the modulation type.

PUBLICATION:

Hippenstiel, R. and Fargues, M., "Feature Extraction from Digital Communication Signals using Wavelet Transforms;" Naval Postgraduate School Technical Report, NPS-EC-95-001, February 1995.

THESIS DIRECTED:

Pitta, A. J., "Transient Detection Using Wavelets," Master's Thesis, March 1995.

DOD KEY TECHNOLOGY AREA: Electronics

KEYWORDS: Communication intercept, wavelets, detection, demodulation, parameter identification

WAVELET BASED TRANSMITTER IDENTIFICATION
Ralph Hippenstiel, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Unfunded

OBJECTIVE: The goal of this project was to investigate wavelet based processing techniques as they allow automated transmitter identification.

SUMMARY: Research was conducted to evaluate the feasibility of using a wavelet based approach to identify the transmitter of electronic communication system. The dominant terms allowing identification were found in the characteristic turn on signature of a given transmitter. The study included an assessment as to how sensitive the wavelet based approach is to noise. Future work should be focused on an automatic threshold selection, a robust template selection, improved ways to associate the scale outputs and robust ways to use several scale outputs simultaneously.

PUBLICATION:

Hippenstiel, R., "Wavelet Based Approach to Transmitter Identification;" Naval Postgraduate School Technical Report, NPS-EC-95-014, December 1995.

THESIS DIRECTED:

Payal, Y., "Identification of Push-to-Talk Transmitters Using Wavelets," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREA: Electronics

KEYWORDS: Communication intercept, wavelets, detection, demodulation, parameter identification

MISSILE CLOSURE SIMULATION AND ANALYSIS TO SUPPORT
TESTING MISSILE APPROACH WARNING SYSTEMS
Robert G. Hutchins, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Air Warfare Center - Weapons Divsion

OBJECTIVE: NAWCWD is undertaking a study of simulation methodologies to support testing of missile approach warning systems (MAWS). The Naval Postgraduate School (NPS) has been tasked to assist in this effort along two paths:

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first by acting as the focal point for missile fly-out simulations and studies, and second to assist in the RF portion of the MAWS study by developing and implementing real-time algorithms to assist a ground-mounted, stationary RF seeker to perceive a more realistic view of incoming targets through the use of simulation enhancements. The first path is the more critical for the research and time frame covered in this proposal, and emphasis is to be placed on RF missile seekers at the present time. Also, these more realistic missile fly-out simulations (being acquired by NPS to simulate specific classified threat missile systems) will be used to validate and extend the missile end-game studies begun by NPS last summer. This study will address: a characterization of missile fly-out trajectories and end-game behavior for selected threat missiles, based on government-furnished ESAMS missile fly-out simulation code, a comparison of these trajectories with the results obtained last summer, and a more thorough investigation of end-game trajectories and other phenomena of importance for RF seeker simulation during end-game. Work on the ground-mounted RF seeker simulations and upgrades will proceed as time permits.

SUMMARY: The Naval Air Warfare Center, Weapons Division (NAWCWD), is involved in a large tri-service effort to develop testing procedures for assessing aircraft response mechanisms to threat surface-to-air missile systems (SAMS). To this end, realistic sensors, sensor simulators, missile fly-out geometries and end-game intercept geometries for a wide band of sensor types and missile types must be assessed. Last year's research, completed last summer and reported in "Missile Closure and End-Game Characterization: Final Report for FY 1995," 23 September 1995, was an analysis of missile end-game behavior to assess the time frame during which a decoy deployed by an attacking aircraft can successfully thwart a closing SAM missile by drawing off its seeker. This effort used generic missile fly-out code developed by me at NPS, and focused on the behavior of RF missiles and decoys on a very limited set of scenarios. Hence, the results were limited in scope and realism. To rectify these shortcomings, the enhanced surface-to-air missile simulation (SURVIAC) at Wright-Patterson AFB was obtained. This code is classified at the SECRET level and allows future testing and validation using government-recognized code for specific threat missile systems. Hence, NPS is in a position this year to perform a wide class of realistic missile fly-out studies. This year's research effort is using a new ESAMS code to validate the results obtained last year and extend these results to a wider list of scenarios, missile attack geometries, and specific threat missile systems. The ESAMS code has been hosted on a classified SUN workstation in Spanagel Hall, and scenario testing is ongoing at this time.

The RF seeker enhancement activity centers around a functional SAM RF illuminator/sensor system that has been established on one of the ranges at China Lake, CA. In contrast to an actual SAM system, both the illuminator and the missile sensor are located at fixed sites on the ground. Hence, an aircraft can fly in the vicinity of this sytstem and be illuminated in a realistic fashion, and those illuminations can be received by theground-mounted missile sensor. However, the sensor observations are not realistic because they do not include the target aspect, Doppler, and Doppler-sensitive background clutter that would be observed by a real missile sensor during actual fly-out. The purpose of this project is to provide a combination of simulation and real data in real time to make the encounter more realistic from the standpoint of testing alternative MAWS technologies. The thrust of the effort this year is to examine the issues surrounding the construction of this hybrid simulation system. Because of the primacy of the missile fly-out and end-game studies, this activity will be secondary and will be conducted as time and funds permit.

DOD KEY TECHNOLOGY AREAS: Sensors, Electronic Warfare, Modeling and Simulation

KEYWORDS: Sensors, integration, missile guidance, real-time simulation

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**EVALUATION AND EXTENSIONS OF THE PROBABILISTIC
MULTI-HYPOTHESIS TRACKING ALGORITHM TO CLUTTERED ENVIRONMENTS**
Robert G. Hutchins, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Undersea Warfare Center, Newport Detachment

OBJECTIVE: Dr. Roy Streit and colleagues at the Naval Undersea Warfare Center, Newport Division, have developed a probabilistic multi-hypothesis tracking (PMHT) algorithm that simplifies multi-hypothesis tracking and thus extends the applicability of these techniques to a broader range of problems. Analysis and testing to date have not included three key areas: a comparison with a traditional MHT algorithm, the study of cluttered environments, or the use of attribute data in measurement-to-track association. The purpose of the research effort directed by me at NPS is four-fold: to test and validate this new algorithm by comparing it with a traditional MHT algorithm using standardized test scenarios, to study comparative algorithm performance in the presence of clutter, to enhance system performance by revising clutter initiation procedures, and to initiate a study of attribute-augmented measurement-to-track association procedures for potential inclusion in the new algorithm at a later date. Also of interest is the study of scenarios where target P_D is less than unity. The ultimate goal is to develop a workable set of algorithms that is practical and that will achieve reasonable performance in the presence of clutter.

SUMMARY: Traditional multiple hypothesis tracking algorithms seek to enumerate all possible combinations of measurement-to-track data associations, maintaining a goodness of fit score to each association. A consistent set of measurement-to-track data associations over time is a single hypothesis, and the likelihood (or "goodness") of a single hypothesis is computed from the goodness of fit scores of all associations contained in the hypothesis. Because computers have finite memories and the combinatorial possibilities of assigning even a few time sets of measurements to different possible combinations of tracks quickly becomes astronomical, all possible hypotheses cannot be maintained over time. Hence, only the most likely subset of hypothesis is maintained over time, and tracks, associations and hythesis themselves are increased and pruned over the course of an engagement to maintain an acceptable memory load on the computer. This process places a high maintenance overhead burden on the computer processing algorithms. Hence, multiple hypothesis algorithms have been limited in their applications to large computer systems and platforms capable of carrying such large systems (i.e., fixed ground sites, ships and submarines).

Dr. Roy Streit and colleagues at the Naval Undersea Warfare Center have developed a new approach to multiple hypothesis target tracking that features a probabilistic approach to the measurement-to-track assignment problem. Conceptually, the system of measurements and tracks is decomposed into two parts: a continuous part that encompasses the target motion and measurement process under the assumption that the measurement-to-track associations are known, and a discrete part that encompasses the measurement-to-track assignment problem itself. The discrete portion of the system, the measurement-to-track assignment problem, is solved using a maximum *a posteriori* (MAP) estimation method. The MAP measurement-to-track probability estimates are then used to solve the continuous portion of the system. This concept is called the probabilistic multi-hypothesis tracking (PMHT) algorithm. Hence, this algorithm circumvents the need for enumeration of measurement-to-track assignments (hard assignments), as well as pruning.

This new algorithm is still under development and extensions to critical practical areas is ongoing. Two areas of particular interest are performance in clutter and performance when the probability of detection (P_D) is less than one. Also, comparative performance analyses for the new algorithm versus a traditional multi-hypothesis algorithm have yet to be published.

The thrust of the effort at NPS is to test the PMHT against a more traditional MHT algorithm, subjecting them both to cluttered environments, and assess the strengths and weaknesses of each. This work is in progress. In addition, recommendations for improving the algorithm performance in clutter will be made. Time permitting, the $P_D < 1$ problem will be studied. Also, attribute-augmented data association will be considered this summer, time permitting.

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THESES DIRECTED:

Roque, J.P.C., "Sensors and Control in the Underwater Intercept and Docking Problems," Master's Thesis, June 1995.

Allred, L.K., "Correlation and Kalman Filter Tracking Solutions for the NRL NIPEX Algorithm," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation

KEYWORDS: Sensors, data association, target tracking

PROPAGATION MODELING OVER ROUGH SEA
Ramakrishna Janaswamy, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: U.S. Navy/American Society for Engineering Education (ASEE) Summer Faculty Research

OBJECTIVE: To rigorously incorporate wind-driven sea surface roughness into the parabolic equation.

SUMMARY: Previous attempts to include wind-driven surface roughness in the prediction of fields by the parabolic equation involved heuristic post-processing of data obtained for a smooth surface. These tend to be problem specific and make the application to generic problems very difficult. In this project, a rigorous formulation of rough earth parabolic equation for the prediction of propagation loss in a ducting environment was developed. The formulation was based on casting the transform equations of the split-step algorithm in terms of incident and reflected plane waves and using the rough surface reduction factor directly in the spectral domain. A complete redefinition of the Fourier transform pair has to be made to make it consistent. Several examples were considered showing favorable comparisons with waveguide and other models for wind speeds ranging up to 20 m/s.

PUBLICATION:

Janaswamy, R., "A Rigorous Way of Incorporating Sea Surface Roughness into the Parabolic Equation," Naval Postgraduate School Technical Report, NPS-EC-95-008, September 1995.

OTHER:

Janaswamy, R., Hitney, H, Barrios, A., and Anderson, K., "A Rough Surface Split-Step Parabolic Equation Method for Radiowave Propagation," 1996 National Radio Science Meeting, Boulder, CO, forthcoming January 1996.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Radiowave propagation, surface roughness, parabolic equation

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COMPUTATIONAL ELECTROMAGNETIC METHODS
FOR COMPLEX BODIES
Ramakrishna Janaswamy, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Unfunded

OBJECTIVE: To explore efficient numerical methods for handling complex electromagnetic problems.

SUMMARY: Partial differential equation methods of solving time-domain Maxwell's equations have become very popular over the recent years due to their ability to handle various material characteristics and complex shapes. In this project, a new unstaggered, colocated finite difference scheme to solve time-domain Maxwell's equations in curvilinear coordinates was developed. All components of the electric and magnetic fields were defined at the same spatial point and a combination of one-sided, forward- and backward-difference (FD/BD) operators were used for the spatial derivatives to produce the same order of accuracy as a staggered, central differencing scheme. In the temporal variable, the usual leapfrog integration was used. The computational domain was bounded at the far end by a curvilinear, perfectly matched layer (PML). The PML region was terminated with a first-order Engquist-Majda type absorbing boundary condition. Comparison was shown with results available in the literature for Te_z scattering by conducting cylinders. Equations were also presented for the 3D case.

CONFERENCE PRESENTATIONS:

Janaswamy, R. and Liu, Y., "An Unstaggered Colocated Scheme for Solving Maxwell's Equations in Curvilinear Coordinates,'" presented at the 1995 Joint IEEE/URSI International Meeting, Newport Beach, CA.

Janaswamy, R. and Liu, Y., "An Optimized Finite Difference Scheme for Time Domain Maxwell's Equations," presented at the 1995 Joint IEEE/URSI International Meeting, Newport Beach, CA.

OTHER:

Janaswamy, R. and Liu, Y., "An Unstaggered, Unlocated Finite Difference Scheme for Solving Time-Domain Maxwell's Equations in Curvilinear Coordinates," submitted to the IEEE Transactions on Antennas and Propagation.

DOD KEY TECHNOLOGY AREA: Other (Design Automation)

KEYWORDS: Computational electromagnetics, finite differences, curvilinear coordinates

NEAR-FIELD MEASUREMENTS OF SHIPBOARD HF ANTENNAS
David C. Jenn, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this research is to investigate possible methods of calibration of shipboard DF systems, or at least developing a means of determining whether a need to calibrate exists.

SUMMARY: High frequency direction finding (HFDF) systems are subject to a lengthy and expensive calibration process once they are installed onboard a ship. The primary purpose of the calibration is to generate a database of antenna responses for a predetermined set of frequencies and angles. In the past, when a topside change was made to a ship, the DF system was generally recalibrated even though there has been no well-defined measurable criteria for the need to recalibrate. This research has developed a "need to calibrate indicator" based on a numerical electromagnetics code computer simulation of DF systems on a DD963 class ship. A test procedure has been written and demonstration of the test is planned.

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CONFERENCE PRESENTATION:

Jenn, D.C., "SPAWAR PMW-178 Baseline Review," Washington, DC, 5-7 September 1995.

DOD KEY TECHNOLOGY AREAS: Electronic Warfare, Modeling and Simulation

KEYWORDS: Direction finding, numerical electromagnetics

SYNTHESIS OF RADAR CROSS SECTION FOR DOUBLY CURVED SURFACES
David C. Jenn, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: The objective was to derive synthesis formulas for the surface impedance of a target given that it must have a specified radar cross section (RCS).

SUMMARY: RCS synthesis formulas were derived for the general problem of a target of known shape with a plane wave incident. Two approaches were considered. The first was rigorous, and required solving for both the current and surface impedance of the body. The second was an approximate approach whereby the current was estimated and only the surface impedance determined. The synthesis equations were verified using a thin resistive strip as the target.

PUBLICATIONS:

Jenn, D.C. and Lee, S., "Inband Scattering From Arrays With Series Feed Networks," IEEE Transactions on Antennas and Propagation, Vol. AP-43, No. 8, July 1995.

Jenn, D.C., Morgan, M.A., and Pogorzelski, R., "Characteristics of Approximate Numerical Modeling Techniques Applied to Resonance-Sized Reflectors," Electromagnetics, Vol. 15, No. 1, January-February 1995 (invited).

THESES DIRECTED:

Waddell, R., "Radar Cross Section Synthesis of Doubly Curved Surfaces," Master's Thesis, September 1995.

Waddell, J., "Scattering From Rough Plates," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREAS: Electronic Warfare, Modeling and Simulation

KEYWORDS: Radar cross section, rough surface scattering

SURVEILLANCE SYSTEM STUDIES
Jeffrey B. Knorr, Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this project is to investigate the feasibility of computer simulation of a high frequency, shipboard direction finding system. This project was initiated in 1994 and continued in 1995.

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SUMMARY: A direction finding (DF) system simulation consisting of a computational electro-magnetic (EM) module, a signal processing module, and a display graphics module was constructed. EM computations were carried out to determine DF antenna responses at several frequencies for two configurations of a Spruance Class destroyer. A measurement program was carried out to collect experimental data using identically configured scale models of the ship. Numerical results were compared with experimental results and found to agree quite well for the frequencies studied.

CONFERENCE PRESENTATIONS:

Knorr, J.B., "Surveillance System Studies," RDT&E Division, Naval Command Control and Ocean Surveillance Center, San Diego, CA, 17 October 1995.

Knorr, J.B., "Surveillance System Studies," SPAWAR PMW-178 Baseline Review, Washington, DC, 6 September 1995.

THESIS DIRECTED:

Robey, S., "Graphical Software for Outboard Simulation," Master's Thesis, September 1995.

OTHER:

Knorr, J.B. and Jenn, D.C., "A Numerical and Experimental Investigation of a Semi-Loop Antenna on a Metal Box," Proceedings of the 12th Annual Review of Progress in Computational Electromagnetics, to appear March 1996.

Knorr, J.B., "A Numerical and Experimental Investigation of a Shipboard DF Antenna Array," Proceedings of the 12th Annual Review of Progress in Computational Electromagnetics, to appear March 1996.

DOD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control and Communications, Electronic Warfare, Modeling and Simulation

KEYWORDS: Direction finding, DF, modeling and simulation, computational electromagnetics, CEM

COORDINATED WIRELESS CONTROL IN COMMON USER NETWORKS
Chin-Hwa Lee, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Command, Control and Ocean Surveillance Center,
Research and Development Division

OBJECTIVE: The objective of this project is to develop and demonstrate the RF power management applied to narrow band transceivers in either end-to-end or networking situations. In a RF power management system signals are radiated with just enough power to establish a reliable link and no more. Additional power usually will cause interference to other systems as mentioned before. Since no unnecessary power is radiated in the air, this approach will also enhance the LPD/LPI characteristics of the links.

SUMMARY: Preliminary experiments were conducted in FY95. Two UHF amateur packet radios are used to establish an end-to-end link. The radio uses FSK with 100 KHz bandwidth at 430.55 MHz frequency. Instrumentation to measure BER over fixed position for long period of time (7 days) was set up. Co-channel interference due to other amateur users are quite large in this situation. The baseline results from these experiments should help to observe the power control experiment planned for FY96. The RF power will be varied to maintain a required BER in this experiment either for quiet environment or in the presence of cochannel interference. Analysis is planned to correlate the measured signal strength with the predicted signal strength. This will answer the question about how much margin reduction is possible according to the classical wave propagation model.

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PUBLICATION:

Lee, C.-H., "Variable Data Rate for Low Orbiting Satellite (LEOS) Communication," Proceedings of 1995 MILCOMM Conference, November 1995.

CONFERENCE PRESENTATION:

Lee, C.-H., "Variable Data Rate for Low Orbiting Satellite (LEOS) Communication," 1995 MILCOMM Conference, San Diego, CA, November 1995.

DOD KEY TECHNOLOGY AREA: Command, Control and Communications

KEYWORDS: Wireless technology, personal communication services, line-of-sight communication, RF power control

ADVANCED PHASED ARRAY ANTENNA TECHNOLOGIES
Chin-Hwa Lee, Professor
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Intelligence

OBJECTIVE: Analysis of the advanced phased array antenna technologies in emerging systems.

SUMMARY: Conduct a technical analysis of each technology to include technology description, application of the technology to radar system describing its role and function in the system. Other technologies which would affect active array antenna capabilities would also be included. Technologies of interest include, but are not limited to transmitter/receiver (T/R) modules, system integration, detecting and tracking algorithm, power management, hardware production.

PUBLICATION:

Lee, C. H., "Foreign APAR Survey and Analysis," Naval Postgraduate School Technical Report, NPS-EC-95-016, June 1995.

DOD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: Microwave circuit, active phase array, T/R module

SOFTWARE ANALYSIS AND ELECTRICAL TESTING
Chin-Hwa Lee, Professor
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Intelligence

OBJECTIVE: This research will develop a design methodology for unknown device testing. Current attention is concentrated on modification of the Genrad 125 software and on the usage of LEARN function.

SUMMARY: Continue writing and modifying GENRAD 125 VLSI tester software and documenting all procedures. Continue to use the tester's LEARN function for device exploitation and program modification. Provide a complete technical report to be used as the basis of an ONI FMEMR.

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MULTI-SENSOR INTEGRATION FOR LOW ALTITUDE DETECTION
Hung-Mou Lee, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Program Executive Office, Theater Air Defense

OBJECTIVE: Examine the short range, low altitude detection mechanism of each sensor integrated under the Ship Self Defense System. Determine the performance of the integrated system against low altitude targets in the littoral region.

SUMMARY: During this second year of the research project, efforts were devoted to designing a proper methodology to model radar returns in the littoral region. Available AN/SPS-49 (MPU) parameters were utilized in a simulation. Millisecond spikes of high Doppler echoes from stationary extended targets were observed. It is speculated that these are the so-called sea-spikes. Further studies are required to identify such problems and to evaluate the performances of specific radar systems.

ELECTROMAGNETICS SCATTERING FROM A TUBULAR CYLINDER OF ANISOTROPIC SURFACE IMPEDANCES
Hung-Mou Lee, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Department of Energy - Sandia National Lab

OBJECTIVE: To investigate the effects of impedance coating on the scattering of electromagnetic waves by a body in the resonant region. To develop accurate computer codes as a reference standard. This is a continuation of work initiated in FY93.

SUMMARY: The electromagnetic scattering from a zero-thickness, perfectly conducting, circular, tubular cylinder of finite length with different anisotropic coatings on its inside and outside surfaces is investigated. The induced electric and magnetic surface current densities and the far field are obtained. Analytical expressions of the double series expansion coefficients of the kernels of the integral-differential equations of this problem are found and utilized in the

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computation to assure that extremely accurate numerical results can be obtained. These results will be used as a standard for validating numerical electromagnetic computation codes.

CONFERENCE PRESENTATION:

Lee, H-M, "Axial Scattering of a Coated Tubular Cylinder," Program and Abstracts, National Radio Science Meeting, Newport Beach, CA, June 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Other (Low Observables)

KEYWORDS: Radar cross section

ADVANCED SIGNAL PROCESSING TECHNIQUES
Hershel H. Loomis, Jr., Professor
Raymond Bernstein, Visiting Instructor
Department of Electrical and Computer Engineering
Sponsor: Secretary of the Air Force

OBJECTIVE: To investigate advanced signal processing algorithms and architectures for the detection and characterization of broadband communications signals in noise and interference.

SUMMARY: The principle accomplishment this year has been in the realization, and experimental verification of algorithms for the detection and characterization and emitter location of cyclostationary signals, such as Phase Shift Keyed (PSK) signals. This work has resulted in one journal publication, one technical report, and one Ph. D. Dissertation. In addition, two MSEE theses are in progress.

PUBLICATIONS:

Roberts, R.S. and Loomis, H.H., Jr., "Parallel Computational Structures for a Class of Cyclic Spectral Analysis Algorithms," Journal of VLSI Signal Processing, vol. 10, pp 25-40, 1995.

Bernstein, R.F., Jr., and Loomis, H.H. Jr., "Fast Fourier Transform and Spectral Correlation Timing Tests," Naval Postgraduate School Technical Report, NPS-EC-95-017, July 1995.

THESIS DIRECTED:

Bernstein, R.F., Jr., "A Pipelined Vector Processor and Memory Architecture for Cyclostationary Processing," Ph.D. Dissertation, December 1995.

DOD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Cyclic spectral analysis, signal detection, emitter geolocation

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OCEAN SURVEILLANCE METHODS
Hershel H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering
T. C. Betterton, Naval Space Technology Chair
Sponsor: Office of Naval Research

OBJECTIVE: This project is concerned with the investigation of the effectiveness of certain ocean surveillance sensors and platforms and of the synergism among several sensors in multisource tracking.

SUMMARY: Research was conducted into chokepoint shipping analysis. National Systems contribution to the "cloud-track" research project of P. Durkee, NPS, were analyzed. As ONR sponsored workshop on Specific Emitter Indentification (SEI) was held at NPS in June of 1995. The details of the project are classified.

CONFERENCE PRESENTATIONS:

Loomis, H.H., Jr., "Target Emitter Utilization Study," ONR Workshop on Specific Emitter Identification, Naval Postgraduate School, 8 June 1995.

Loomis, H.H., Jr. and Betterton, T.C., "Ocean Surveillance Collection Study," ONR Code 321, 7 August 1995 and Chief of Naval Research, 26 September 1995.

OTHER:

Betterton, T.C. and Loomis, H.H., Jr., Co-Chairs, ONR Workshop on Specific Emitter Identification, Naval Postgraduate School, 7-8 June 1995.

DOD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Ocean Surveillance

PROJECT GUSTY ORIOLE
Herschel H. Loomis, Jr., Professor
Raymond Bernstein, Visiting Instructor
Department of Electrical and Computer Engineering
Sponsor: Secretary of the Air Force

OBJECTIVE: To conduct research into computer algorithms and architectures for the processing of tactical information. To provide support for the course Space Systems 3001, Military Applications of Space.

SUMMARY: Investigations were conducted on the following: algorithms and architectures of systems for the production, distribution and analysis of tactical information; architectures of spaceborne computer systems; and operational problems concerned with the employment of tactical information for decision making and targeting. Several military satellite facilities were visited to gather information in support of SS3001. A proposal, jointly prepared with Prof. Terry Alfriend, for a small satellite design study were visited. The proposal has been funded.

THESES DIRECTED:

Sitton, J., "Geolocation Using Cooperative, Disparate Sensors,", Master's Thesis, June 1995.

Humphries, T.H., "Geolocation Workbench Development System," Master's Thesis, September 1995.

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Campbell, R., "Geolocation Workbench," Master's Thesis, December 1995.

Jones, G., "Design and Implementation of a Geolocation Software Workbench," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Military space applications, tactical support

COMMON DATA LINK'S INTERFACE
TO THE GLOBAL NETWORK ARCHITECTURE
Paul H. Moose, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Defense Aerial Reconnaissance Office

OBJECTIVE: The objective of this project is to develop a signal level simulation of the CDL to assist in the evaluation of candidate network protocols to interface CDL to local area and to wide area DoD data networks.

SUMMARY: A MATLAB simulation model of CDL has been developed by linking a number of previously created and newly created m-files that simulate the functions within the CDL surface communications element and the CDL platform communication element. Approximately 31 subroutines were created. They include multiplexers/demultiplexers, convolutional coders/Viterbi decoders, interleavers/de-interleavers, and modulators/demodulators. These are linked together with appropriate arguments to simulate the CDL command link transmitter and receiver, the CDL low rate return link transmitter and receiver, and the CDL high rate return link. The simulation was validated using an AWGN channel. A transmission convergence sublayer for interfacing CDL to ATM devices has been designed and simulated in MATLAB as well. These simulations will not be used to evaluate the effects of jamming and other interference on the throughput rate of CDL when transferring data in via ATM and comparison of that to the currently used synchronous transfer mode of operation.

PUBLICATION:

Moose, P.H., "Simulation of the Common Data Link Using MATLAB," Naval Postgraduate School Technical Report, NPS-EC-95-010, July 1995.

DOD KEY TECHNOLOGY AREAS: Command, Control and Communications, Other (Networking)

KEYWORDS: MATLAB simulation, network interface, ATM

RADAR SIGNATURE CANCELLATION - IMPLEMENTATION
AND EFFECTIVENESS
Michael A. Morgan, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School - Institute for Joint Warfare Analysis

OBJECTIVE: A distributed, active cancellation approach is being investigated for possible use in bistatic radar cross section of military platforms.

SUMMARY: Implementation approaches and combat effectiveness for a powerful new radar signature cancellation approach are being analyzed for use on military platforms. The technique employs distributed active canceler modules

to achieve deep signature reduction in all directions, even against future bistatic radars and impulse radars. This approach can be applied to air and ground vehicles, fixed installations, as well as surface ship combatants. Analysis is being conducted through modeling and simulation of the combat effectiveness of radar signature reduction vs. frequency range for number and placement of canceler modules on tactical aircraft in selected engagement scenarios.

OTHER:

Morgan, M.A., "Active Reduction of Bistatic Radar Scattering," in preparation for IEEE Transactions on Antennas and Propagation.

DOD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Active cancellation, signature reduction, impulse radar

ULTRA-WIDEBAND IMPULSE ANTENNA DESIGN
Michael A. Morgan, Professor
R. Clark Robertson, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: U.S. Army Communications-Electronics Command, Signals Warfare Directorate

OBJECTIVE: The goals of this project were to perform engineering designs, develop validation procedures, and to construct and test highly efficient, small-sized prototypical ultra-wideband impulse receiving antennas.

SUMMARY: A Method-of-Moments numerical model was developed as an aid to the design process. This numerical model was employed extensively to search for optimum geometrical dimensions and resistive tapers to achieve the challenging 10MHz operation criterion, given the antenna size constraint.

Several prototype TEM horns were then fabricated and performance evaluations were conducted using two procedures. Preliminary tests were performed in an anechoic chamber, using identical transmitting and receiving antennas, with a low-power dc-50 GHz step-waveform source and a 50 GHz bandwidth sampling oscilloscope receiver. Open region tests were then conducted in a desert environment using a higher power impulse source radiating from a 10 foot diameter reflector with a conical TEM feed.

OTHER:

Morgan, M.A. and Robertson, R.C., "Impulse Receiving Antenna Design and Measurement," Abstracts of URSI Radio Science Meeting, to appear July 1996.

Morgan, M.A. and Robertson, R.C., "Optimized TEM Horn Impulse Receiving Antenna," Abstracts of Ultra-Wideband, Short Pulse EM 3 Conference, to appear May 1996.

Morgan, M.A. and Robertson, R.C., "Optimized TEM Horn Impulse Receiving Antenna," in Ultra-Wideband, Short-Pulse Electromagnetics 3, L. Carin and L.B. Felsen, eds., Plenum Press, New York, to appear 1996.

Morgan, M.A. and Robertson, R.C., "Impulse Receiving Antenna Design and Measurement," URSI Radio Science Meeting, Baltimore, MD, forthcoming 21-26 July 1996.

Morgan, M.A. and Robertson, R.C., "Optimized TEM Horn Impulse Receiving Antenna," 3rd International Conference on Ultra-Wideband, Short-Pulse Electromagnetics, Albuquerque, NM, forthcoming 27-31 May 1996.

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IMPULSE ANTENNA DESIGN AND EVALUATION
Michael A. Morgan, Professor
R. Clark Robertson, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: United States Air Force

OBJECTIVE: Goals of this project were to design, construct, test and deliver two efficiently optimized, small-sized ultra-wideband impulse receiving antennas for special mission use.

SUMMARY: Prototype antennas were fabricated and performance evaluations were conducted in an anechoic chamber, using identical transmitting and receiving antennas, with a low-power dc-50 GHz step-waveform source and a 50 GHz bandwidth sampling oscilloscope receiver.

ALGORITHMS FOR ASSESSING THE EFFECTIVENESS OF SHIPBOARD COUNTERMEASURES AGAINST ANTI-SHIP MISSILE PLATFORMS
Phillip E. Pace, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Research Laboratory

OBJECTIVE: The objective of this project is to quantitatively predict the effectiveness of shipboard electronic attack (EA) systems against anti-ship cruise missile (ASCM) simulators through computer models trained from laboratory and captive-carry field test data. (CONTINUING PROJECT)

SUMMARY: A simulator correlation processor (SCP) trained from closed-loop anechoic chamber missile simulator results (1 Hz bavdwidth) has been constructed in software. These models give high-confidence effectiveness calculations (miss distance) and are independent of the type of EA activity being utilized. A preprocessor has also been constructed which predicts the ASCM dynamics from the simulator captive-carry seeker angles and range gate voltages. After the captive-carry experimental results are preprocessed, they are transitioned into the SCP where a fly out is generated to calculate the corresponding effectiveness (miss distance). The complete set of software models and algorithms have been integrated into an easy-to-use graphical user interface which simplifies the use in the P-3 captive-carry field test environment. The operation of the complete on-board P-3 captive carry correlation software (P3C3 Ver 1.0) has been flight tested successfully with only minor problems being identified. The P3C3 software provides the ability to send quantitative feedback to the shipboard self-protection system operators in near real-time.

PUBLICATIONS:

Pace, P.E., Nishimura, B.H., Cooper, C.R., and Surratt, R.E., "Correlation of Anti-Ship Cruise Missile Simulator Experiments for High-Confidence ECM Effectiveness Calculations," Proceedings of the 1995 Joint Western Mountain Region EW Technical Symposium, San Antonio, TX, pp. 23-40, 23-26 April 1995.

ELECTRICAL AND COMPUTER ENGINEERING

Pace, P.E. and Cooper, C.R., "Correlation Environment for Determining the Effectiveness of Shipboard Electronic Countermeasures Against Anti-Ship Cruise Missile Simulators (U)," Naval Postgraduate School Technical Report, NPS-EC-95-002, February 1995. (SECRET/NOFORN)

CONFERENCE PRESENTATIONS:

Pace, P.E., Nishimura, B.H., Cooper, C.R., and Surratt, R.E., "Correlation of Anti-Ship Cruise Missile Simulator Experiments for High-Confidence ECM Effectiveness Calculations," 1995 Joint Western Mountain Region EW Technical Symposium, San Antonio, TX, pp. 23-40, 24 April 1995.

Pace, P.E., Moreno, M.S., Nishimura, B.H., Morris, W.M., and Surratt, R.E., "Measuring the Effectiveness of ASCM Jamming By P-3 Captive-Carry Correlation," 63rd Military Operations Research Society Symposium, Working Group 13, U. S. Naval Academy, MD, 7 June 1995.

THESES DIRECTED:

Nishimura, B.H., "Correlation of HIL Captive Carry Experiments for Tactical Evaluation of ECM Effectiveness (U)," Master's Thesis, June 1995. (SECRET/NOFORN)

Moreno, M.S., "Measuring the Effectiveness of ASCM Countermeasures with the P-3 Captive Carry Correlation (P3C3) Environment (U)," Master's Thesis, September 1995. (SECRET/NOFORN)

OTHER:

Pace, P.E., Moreno, M.S., Nishimura, B.H., and McGinnis, R.D., "P3C3: Program for P-3 Captive Carry Correlation," developed under the U. S. Navy's ENEWS program Task 2.3310. (MATLAB Software Program).

DOD KEY TECHNOLOGY AREAS: Electronic Warfare, Modeling and Simulation, Conventional Weapons

KEYWORDS: Anti-Ship cruise missile simulators, countermeasure effectiveness, hardware-in-the-loop threat missile simulators

AUTOMATIC EXTRACTION OF THREAT CRITICAL PARAMETERS FROM ANTI-SHIP CRUISE MISSILES (ASCM) SIMULATOR CHARACTERIZATION EXPERIMENTS
Phillip E. Pace, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Tactical Electronic Warfare Division, Naval Research Laboratory

OBJECTIVE: The objective of this project was to develop a set of algorithms which enable the automatic extraction of electronic warfare integrated reprogrammable (EWIR) parameters from any ASCM missile simulator in order to support the validation of the simulator against the actual threat.

SUMMARY: A modular architecture to perform the automatic extraction of threat simulator critical parameters was constructed. The software (AETSCP Ver 1.0) provides high-speed simulator validation with an improved accuracy over manual parameter extraction. A total of 40 critical EWIR parameters can be extracted against CTS characterization formats V1a, V1b and V2. After extraction, a comparison of the extracted parameter with the ONI generated EWIR database is performed automatically generating a delta parameter. The operational impact of any significant differences between the threat simulator and the actual threat is also addressed. The AETSCP software has been utilized to aid in validating two ASCM threat simulators (SIM7 and INDIA).

ELECTRICAL AND COMPUTER ENGINEERING

CONFERENCE PRESENTATIONS:

Pace, P.E., Dix, S., Zwick, D., and Tigani, J., "Automatic Extraction of Threat Simulator Critical Parameters for ASCM Simulator Validation: Initial Progress," Navy's Simulator Validation Working Group, Naval Research Laboratory, Washington, DC, 1 February 1995.

Pace, P.E., Cardenas, L., and Tigani, J., "Automatic Extraction of Threat Simulator Critical Parameters (AETSCP)," Navy Simulator Validation Working Group, Naval Research Laboratory, Washington DC, 25 July 1995.

THESES DIRECTED:

Dix, S.M., "Automatic Extraction of Threat Simulator Critical Parameters (U)," Master's Thesis, March 1995. (SECRET/NOFORN)

Zwick, D.L., "Automatic Extraction of Threat Critical Parameters of Anti-Ship Cruise Missile Simulators," Master's Thesis, March 1995. (SECRET/NOFORN)

Cardenas, L.T., "Automatic Extraction of Threat Simulator Critical Parameters (U)," Master's Thesis, September 1995. (SECRET/NOFORN)

Tigani, J.A., "Automatic Extraction of Threat Simulator Critical Parameters, Software Architecture and Extraction Algorithms (U)," Master's Thesis, September 1995. (SECRET/NOFORN)

Pugh, L.A., "Parametric (EWIR) Differences in HIL Missile Simulators: Impact on Electronic Attack Systems," Master's Thesis, December 1995.

OTHER:

Pace, P. E., Tigani, J., Dix, S., Zwick, D., and Cardenas, L., "AETSCP: Program for the Automatic Extraction of Threat Simulator Critical Parameters Ver. 1.0," developed under the Navy's Threat Simulator Validation Working Group. (MATLAB Software Program)

DOD KEY TECHNOLOGY AREAS: Electronic Warfare, Conventional Weapons

KEYWORDS: Electronic warfare integrated reprogrammable parameters, hardware-in-the-loop threat missile simulators

HIGH RESOLUTION DIRECT DIGITIZATION AND OPTICAL TELEMETRY OF ANTENNA SIGNALS
P. E. Pace, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this research was to investigate the feasibility of directly digitizing, wideband direction finding antenna signals using high-resolution symmetrical number system (SNS) encoding techniques. This is a continuing project.

SUMMARY: The prototype of a 5-bit electro-optical SNS ADC was constructed in hardware in the NPS Optical Electronics Laboratory. The transfer function of the 5-bit device was obtained at 5 MHz to determine the feasibility of the concept and demonstrate the advantages of the SNS encoding approach. Next, the design of a 14-bit ADC was

initiated. The interferometers for the 14-bit device were delivered and characterized. After characterization of the interferometers, the 14-bit ADC design was completed. The 14-bit device uses three interferometers, has a sampling frequency of 5 MHz and uses 253 comparators with a maximum of 64 loaded in parallel.

PUBLICATIONS:

Pace, P.E., Walley, R.J., Pieper, R.J., Powers, J.P., "5-Bit Guided-Wave SNS Transfer Characteristics," IEE Electronics Letters, Vol. 31, No. 21, pp. 1799-1800, October 1995.

Pace, P.E., Schafer, J.L., and Styer, D. "Optimum Analog Preprocessing For Folding ADCs," IEEE Transactions on Circuits and Systems - II: Analog and Digital Signal Processing, Vol. 42, No. 12, pp. 825-829, December 1995.

Pace, P.E., Powers, J.P., Pieper, R.J., Walley, R., Yamakoshi, H., Crowe, C., and Nimuri, B., "Design of a High-Speed Optical Analog-To-Digital Converter," Proceedings of the 27th IEEE Southeastern Symposium on System Theory, Mississippi State University, 12-14 March 1995.

Pace, P.E. and Schafer, J.L., "Decimation of Encoding Errors in an Optimum SNS Folding ADC," IEEE International Symposium on Circuits and Systems, Seattle, WA. pp. 1324-1337, 30 April - 1 May 1995.

CONFERENCE PRESENTATIONS:

Pace, P.E., "Wideband ADC Project Review and Status," presentation to PMW-178 SPAWAR, Optical Electronics Laboratory, Naval Postgraduate School, Monterey, CA, 13 January 1995.

Pace, P.E., Powers, J.P., Pieper, R.J., Walley, R., Yamakoshi, H., Crowe, C., and Nimuri, B., "Design of a High-Speed Optical Analog-To-Digital Converter," 27th IEEE Southeastern Symposium on System Theory, Mississippi State University, MS, 12 March 1995.

Pace, P.E. and Schafer, J.L., "Decimation of Encoding Errors in an Optimum SNS Folding ADC," IEEE International Symposium on Circuits and Systems, Seattle, WA, 2 May 1995.

Pace, P.E., "Wideband ADC Project Review and Status," PMW-178 SPAWAR, Optical Electronics Laboratory, Naval Postgraduate School, Monterey, CA, 8 June 1995.

Pace, P.E., "Wideband SNS Processing of DF Antenna Signals, PMW-178 SPAWAR Baseline Review, SPAWAR, Washington DC, 6 September 1995.

Pace, P.E., "Guided-Wave SNS Transfer Characteristics and Applications," Tri-Service Digital RF Memory Workshop '95, Georgia Tech Research Institute, Atlanta, GA, 28 September 1995.

THESES DIRECTED:

Crowe, C.A., "Optical SNS Folding Circuit Design," Master's Thesis, March 1995.

Schafer, J.L., "Decimation of Encoding Errors in an Optimum SNS 2 um Low-Noise CMOS ADC," Master's Thesis, March 1995.

Yamakoshi, H., "The Performance Characteristics of an Electrooptic SNS Analog to Digital Converter," Master's Thesis, June 1995.

Walley, R.D., "A Prototype Encoding Scheme for Electrooptic Analog to Digital Converters," Master's Thesis, June 1995.

ELECTRICAL AND COMPUTER ENGINEERING

PATENT APPLICATION:

Pace, P.E., "High Resolution Encoding Circuit and Process for Analog to Digital Conversion," Patent NC76164: Filed 28 February 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Electronics

KEYWORDS: Direction finding antennas, symmetrical number system, analog-to-digital conversion, preprocessing

EXTENDING THE VISIBILITY MINIMUM RESOLVABLE TEMPERATURE DIFFERENCE (MRTD) MODEL TO SECOND GENERATION THERMAL IMAGING SYSTEMS
Ron J. Pieper, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: To develop both analytic guidelines and the corresponding computer code which would extend the basic concepts for the first generation visibility model so that MRTDs for second generation thermal imaging systems could be predicted.

SUMMARY: A new model is presented for predicting the MRTD performance of second generation thermal imaging systems based on minimum input contrast, and a contrast reduction factor due to aliasing and blurring effects. The model makes no assumptions regarding the recognition process, which allows for a separate threshold value to be defined for either a human or machine observer. The model incorporates aliasing concepts and extends performance prediction beyond the nominal Nyquist rate of the system. The model's predictions are compared to the prediction of the current standard FLIR92 model and measured results from laboratory focal plane array imaging systems. A scheme for performing laboratory objective MRTD performance tests is proposed and tested.

THESES DIRECTED:

Groen, M., "Development and Validation of a Second Generation Visibility Model for Predicting Minimum Resolvable Temperature Difference for Thermal Imaging Systems," Master's Thesis, December 1995.

Koc, C., "Modeling and Experimental Testing for the Future Development of the U.S. Army's Night Vision Electro-Optic FLIR 92 model," Master's Thesis, December 1995.

OTHER:

Pieper, R.J., "A Second Generation Visibility Based Model for Objective/Subjective FLIR MRTD," to be published in the ERIM Proceedings for the 1996 IRIS Specialty Group on Passive Sensors.

Pieper, R.J., "A Second Generation Visibility Based Model for Objective/Subjective FLIR MRTD," to be presented at the 1996 IRIS Specialty Group on Passive Sensors, March 13, Monterey CA.

DOD KEY TECHNOLOGY AREAS: Electronics, Modeling and Simulation, Sensors

KEYWORDS: Thermal imaging, MRTD, focal plane arrays

ELECTRICAL AND COMPUTER ENGINEERING

DUAL BASELINE TRIANGULATION
Ron J. Pieper, Associate Professor
Department of Electrical and Computer Engineering
Alf Cooper, Professor
Department of Physics
Sponsors: John Hopkins University, Applied Physics Lab and Naval Sea System Command

OBJECTIVE: Despite the disadvantages of active radar, modern combat stems (AEGIS and FAAD) are typically built around active radar target detection and tracking. It has been recognized that ESM IR and TV sensors are capable of providing useful inputs to such systems, particularly for application for low flying targets to be tracked in from the horizon. In this environment passive IR sensor with their greater range of detection show significant advantages. For combat systems the target designation and response must be based on the cooperative use of data from dissimilar sensor. This requires that simultaneous data from these sensors must be compatible for system use. While a passive IR system can provide detection and pointing precision advantages over that available with active radar, the complimentary use of both systems will generally be useful for target identification.In addition, the more extensive time requirement for radar scanning to detect a remote target also supports the need for a complementary system. The passive IR system can not only provide advance data on detecting targets as they appear on the horizon but also range information in order to assess the urgency of the fire control problem. This project addresses one approach to the provision of target range information by cooperative use of two or more passive sensor.

SUMMARY: A new method for IR passive ranging based on the principle of triangulation has been considered. The proposed orthogonal dual baseline scheme eliminates the well known geometric dilution effect, inherent in single baseline methods. The performance of each of the two orthogonal baselines depends on target orientation and limitations in the precision in the bearing measurements. A general expression, involving both baselines, for the maximum triangulation range is derived as a function of polar angle measured relative to the center of the dual baseline system. Limitations in the dual baseline model due to the geometrically assessed optical horizon are also considered.

PUBLICATION:

Pieper, R., Cooper, A., and Pelegris, G., "Dual Baseline Triangulation," Proceedings of the 27th Southeastern Symposium on System Theory, pp 424-428, March 1995.

CONFERENCE PRESENTATION:

Pieper, R., Cooper, A., and Pelegris, G., "Dual Baseline Triangulation," 27th Southeastern Symposium on System Theory, March 1995.

THESIS DIRECTED:

Pelegris, G., "A Triangulation Method for Passive Ranging," Master's Thesis, June 1994. (Co-Advisor Alfred Cooper)

OTHER:

Pieper, R., Cooper, A., and Pelegris, G., "Passive Range Estimation Using Dual Baseline Triangulation, accepted for publication by editor, Optical Engineering.

DOD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Surface/Under Surface Vehicles

KEYWORDS: IR, passive ranging, triangulation

ELECTRICAL AND COMPUTER ENGINEERING

ULTRA-WIDEBAND IMPULSE SIGNAL PROPAGATION
R. Clark Robertson, Associate Professor
Michael A. Morgan, Professor
Ramakrishna Janaswamy, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: US Army Communications-Electronics Command, Signals Warfare Directorate

OBJECTIVE: The goal of this project was development of a software package for use in estimating transient electromagnetic signals at a location near the signal source based on measurements of the signal at a different (generally more distant) location.

SUMMARY: A procedure was developed for predicting the waveshape of an ultra-wideband, impulsive electromagnetic signal at a specified location over a rough ground using measurements of the same signal at another location. Impulsive signals are transient signals of very short duration containing very high spectral content. The estimation procedure was developed by modeling the ground as homogeneous, conducting, non-permeable, half-space with a random surface. Using this model for the ground, we developed frequency domain transfer functions relating fields at differing locations for both horizontally and vertically polarized signals. The signal at a specified point can then be obtained via the inverse discrete Fourier transform of the product of the transfer function and the discrete Fourier transform of the measured impulsive signal. The locations of both the measured and the estimated signals must be in the far-field of the impulsive signal source. The transmitting antenna is assumed to be a circular reflector with an azimuthally symmetric aperture distribution. The estimation procedure was validated using a synthetic impulse signal and field tested using measured vertically polarized, impulsive signals.

OTHER:

Robertson, R.C., Morgan, M.A., and Janaswamy, R., "Ultra-Wideband Impulse Propagation," Naval Postgraduate School Technical Report NPS-EC-96-002, to appear March 1996.

Robertson, R.C., Janaswamy, R., and Morgan, M.A., "Ultra-Wideband Impulse Propagation," Abstracts of Ultra-Wideband, Short Pulse EM 3 Conference, 1996.

Robertson, R.C., Morgan, M.A., and Janaswamy, R., "Ultra-Wideband Impulse Propagation," in Ultra-Wideband, Short-Pulse Electromagnetics 3, L. Carin and L.B. Felsen, eds., Plenum Press, New York, to be published 1996.

Robertson, R.C., Janaswamy, R., and Morgan, M.A., "Ultra-Wideband Impulse Propagation," 3rd International Conference on Ultra-Wideband, Short-Pulse Electromagnetics, Albuquerque, NM, forthcoming 27-31 May 1996.

DOD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Ultra-Wideband signals, impulse signals, transient response

ELECTRICAL AND COMPUTER ENGINEERING

SONAR SIGNAL MODELING
Charles W. Therrien, Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Undersea Warfare Center - New London Detachment

OBJECTIVE: This research involves the development of models for underwater signals received by a passive sonar, to support work in classification. The research is part of a continuing project begun in 1992.

SUMMARY: During FY1995 a combined deterministic/stochastic signal model for transients was investigated; a new lattice form of time-varying autoregressive model was developed; and transient synthesis methods were automated. Results are reported in the technical report and the theses below.

PUBLICATIONS:

Therrien, C.W., et al., "Summary Report on Sonar Signal Modeling for FY95, Naval Postgraduate School Technical Report, NPS-EC-95-015, December 1995. (SECRET)

Therrien, C.W. and Velasco, C.H., "An Iterative Prony Method for ARMA Signal Modeling," IEEE Transactions on Signal Processing, Vol. 43, No. 1, January 1995.

THESES DIRECTED:

Allison, D.E., "A Deterministic-Stochastic Decomposition Method for Synthesis of Acoustic Signals," Master's Thesis, March 1995.

Lam, B.M., "An Adaptive Lattice Approach to Transient Analysis and Synthesis," Master's Thesis, September 1995.

Jones, M.P., "Automatic Synthetic Sonar Transient Generation," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Passive sonar, signal modeling, acoustic transients

RESEARCH IN DATA COMPRESSION TECHNIQUES
Murali Tummala, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: Data compression techniques for still image signals with emphasis on hierarchical reconstruction have been investigated. Real-time transmission constraints of compressed data have been addressed. Application to DoD and commercial satellite imagery have been investigated. The work has been carried out during AY94 and AY95.

SUMMARY: The work consists of a comprehensive survey of military data compression standards and an investigation of the image compression techniques based on wavelet transforms and the quad tree method. Several military standards examined appear to be lacking in both performance and technology when compared to commercial standards available. Commercial standards could support the objectives as well as the functionality of military systems such as the Global Command and Control System. Commercial standards could also provide better long term inter-operability and information exchange capabilities than the currently available military standards.

A multiresolution image compression scheme based on hierarchical reconstruction has been developed. The algorithm uses discrete wavelet transform with a nonstandard tiling method. These wavelet sequences are encoded using a uniform quantizers and a new multiresolution coding scheme. The bit rates achieved are on the order of 0.5 bits per pixel, which corresponds to a compression ratio of 16:1. The scheme allows a user to choose from five different resolution levels, providing different image qualities at different bit rates. Because the scheme is scalable, it enables the user to upgrade the quality of a lower resolution transmission until sufficient detail is obtained. The scheme was applied to transmission of image data over a common data link channel under jamming conditions. Using the scheme along with some forward error correction techniques, the image was recovered satisfactorily.

A layered image compression scheme based on quad tree decomposition technique (QTD) is developed. The image is decomposed into three layers, where layers are added to a base image to incrementally improve the quality of the reconstructed image. The performance of the QTD is enhanced by adding a DCT algorithm with adaptive bit allocation and a region of interest methodology. The quad tree is then extended to a nona tree whereby pixel blocks of size 3 ′ 3 are processed instead of 2 ′ 2. Depending on the number of layers transmitted, preliminary results indicate that compression gains achieved range from 60:1 to 16:1. Both the above schemes exhibit graceful degradation of the reconstructed image and some error tolerant capabilities.

THESES DIRECTED:

Seng, L., "Image Compression Scheme for Network Transmission," Master's Thesis, March 1995.

Walker, T.O., "Real-Time Compressed Video Transmission Across the Common Data Link," Electrical Engineer's Degree, June 1995.

Carvalho, R.M., "Multiresolution Image Compression Using Subband Coding and Wavelet Decomposition," Electrical Engineer's Degree, December 1994.

Pratt, E.S., "Data Compression Standards and Applications to Global Command and Control System," Master's Thesis, December 1994.

DOD KEY TECHNOLOGY AREAS: Sensors, Other (Communications Networking)

KEYWORDS: Data compression, image coding, text compression, wavelet transform, data compression standards, JPEG, MPEG

MULTI-SENSOR DATA FUSION FOR THE VTS SYSTEM
Murali Tummala, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: U.S. Coast Guard, Electronics Engineering Center

OBJECTIVE: An algorithm has been developed to fuse redundant data due to multiple observations due to multiple sensor coverage of a vessel. The work supports the US Coast Guard's VTS system upgrade project; it is part of a multi-year effort.

SUMMARY: The USCG Electronics Engineering Center (EECEN) is in the process of modernizing their existing vessel traffic services (VTS) system. In a typical VTS, the data is originated by radars, automatic dependent surveillance system, standard routs software daemon, and VTS operators' prospective lists. Effective use of these multi-sensor data leads to improved harbor traffic monitoring and port safety. Fuzzy associative techniques and neural network methods are explored to develop multisensor data fusion algorithms that will be integrated into the VTS software.

Fuzzy membership functions are used as a measure of correlation, and a fuzzy associative system determines which observations represent the same vessel. An algorithm based on this approach has been applied to a simulated harbor scenario. The algorithm consists of alignment of the received data, association of these data based on their degree of similarity, and estimation of the features of the fused template. The features of the vessel that make up the template are position, course, speed, sensor and track identification. Using the neural network approach, an algorithm for data fusion based on competitive learning and adaptive resonance theory has been investigated. Based on the results, a decision was made to focus the effort on the investigation of the fuzzy association approach. A refinement of the harbor simulation, data format conversion, and testing of the algorithm have been carried out. Further study and testing of the algorithm are in progress.

THESES DIRECTED:

Ruthenberg, T., "Multi-Sensor Data Fusion: the Fuzzy Membership Approach," Master's Thesis, March 1995.

Koh, L., "Multi-Sensor Data Fusion: the Neural Networks Approach," Master's Thesis, March 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Other (Communications Networking)

KEYWORDS: Data fusion, vessel traffic control, fuzzy logic, neural networks, data compression

MODELING AND ANALYSIS OF AIRCRAFT ELECTROMAGNETIC TRANSIENT WAVEFORMS
Murali Tummala, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Air Warfare Center - Aircraft Division

OBJECTIVE: Develop signal processing algorithms for the analysis of electromagnetic pulse (EMP) waveforms measured in aircraft testing and synthesis of the measured waveforms to produce composite test signals for determining aircraft margin of survivability. This is a multi-year effort; the work reported here consists of the results obtained during the fourth year of this effort.

SUMMARY: The Naval Air Warfare Center (Code 5.1.7.2) conducts EMP testing of aircraft. In order to improve the effectiveness of their EMP testing techniques, a method for "bounding" the stress waveforms measured inside the aircraft from a series of tests is sought. At each test-point in an aircraft under test, four to eight stress waveforms (signals received at a test-point in response to a simulated EMP pulse) are measured. The waveforms are typically obtained by performing two types of tests: EMP pulse test and low level continuous waveform test; and two different aircraft orientations: horizontal and vertical; more orientations, however, are possible. The EMP waveforms are currently sampled at about 2 GHz; the bandwidth of interest is from about 400 kHz to 100 MHz. The LLCW waveforms are measured in the frequency domain in six separate bands each with a different frequency resolution.

A scheme for wideband signal analysis using multirate digital filter bank techniques has been investigated. A composite wideband signal has been synthesized from two constituent signals with an overlapping frequency spectrum using tree structured filter banks and sinusoidal modeling. Since the LLCW waveforms were not available, simulated waveforms with overlapping spectrum have been used to study the effectiveness of the method. Currently further design and testing using measured LLCW data are in progress.

ELECTRICAL AND COMPUTER ENGINEERING

OTHER:

Frazier, S., Parimuha, E., Tummala, M., Winnenberg, T.F., and Martin, C.E., "Waveform Bounding and Combination Techniques for Inductively Coupled Direct Drive Testing," HART Conference, Orlando, FL, forthcoming May 1996.

Software developed in Matlab for EMP signal analysis was delivered to Code 5.1.7.2, NAWC.

THESIS DIRECTED:

Martin, C.E., "Wideband Signal Analysis Using Multirate Filter Banks," Master's Thesis, December 1994.

DOD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Data compression, EMP waveform, discrete wavelet transform, waveform synthesis

RESEARCH IN SIGNAL PROCESSING FOR DIGITAL COMMUNICATIONS
Murali Tummala, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Command, Control and Ocean Surveillance Center,
Research and Development Division

OBJECTIVE: Develop signal processing algorithms for digital communication systems. The investigation includes the design of signal processing algorithms for digital programmable receivers (more popular name is software radio) and M-ary digital modulation schemes.

SUMMARY: Programmable digital signal processing hardware (and the algorithms) can be applied to digital communication systems to achieve modular, reconfigurable, and multipurpose systems. We have investigated software implementation of a modem digital communication system combining various DSP functions, channel forward error correction techniques (FEC) algorithms, and digital modulation methods. This system will serve as a tool useful for simulating the transmission and reception of any digital data (audio, video, and text).

A combination of signal processing and neural network algorithms have been investigated to address the problem of predistortion of nonlinear, high-power amplifiers in digital modulators. A neural network algorithm has been used to implement a predistortion technique which takes advantage of realistic assumptions about the amplifier response. The technique results in fewer parameters, reduced computational cost, and improved performance over other types of predistortion. Further work is in progress, and funding for FY96 is in the approval process.

PUBLICATION:

Watkins, B.E., North, R., and Tummala, M., "Neural Network Based Adaptive Predistortion for the Linearization of Nonlinear RF Amplifiers," MILCOM-95, pp. 145-149, 1995.

THESIS DIRECTED:

Ghate, D.B., "Implementation of a Digital Communication System Using QPSK Modulation," Master's Thesis, December 1995.

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OTHER:

Watkins, B.E., North, R., and Tummala, M., "Model Based Neural Network Predistortion of Nonlinear Amplifiers," submitted to WCNN 1996.

DOD KEY TECHNOLOGY AREAS: Other (Communications Networking), Sensors

KEYWORDS: Digital modulation, bandwidth efficiency, system modeling, high power amplifiers

COMMUNICATIONS VULNERABILITY TO JAMMING
Donald v. Z. Wadsworth, Senior Lecturer
Department of Electrical and Computer Engineering
Sponsor: Chief of Naval Operations

OBJECTIVE: This is a continuing project by the same sponsor covering CY 1994 and 1995. The primary goal is to model the vulnerability of selected (blue) RF tactical communications links to both conventional and "smart" jamming, for purposes of mission planning and analysis.

SUMMARY: The initial effort was directed toward collecting existing vulnerability analyses and engineering specifications for six high priority communications systems: NTDS Links (4A, 11, 16), TADIXS B, TACINTEL, and SINCGARS. Organizations which supported this task included N6, NAVSECGRU, PD-50, Johns Hopkins APL, ARL/SLAD/EW, and Army RDEC/IEWD. An original model for the performance of the Navy TADIL C (aka Link 4A) in its antijam mode was developed and described in a Naval Postgraduate School technical report. This project supported development of a vulnerability model for another of the above communications systems, resulting in a student thesis, which was incorporated into a "black" program. The intent is to exercise these vulnerability models in a mission planning software system, either the Navy RFMP (RF Mission Planning System -- installed in JMCIS) or the AFIWC COMJAM program. Due to the delay in obtaining these projects, this goal could not be achieved within the program schedule (end of 1995), but will be pursued in a student thesis in 1996. A tested version of COMJAM was obtained in mid-1995 and a version of RFMP is now planned for early 1996 deliver, to the Naval Postgraduate School.

PUBLICATION:

Wadsworth, D.v.Z., "Antijam Communications Performance Model for Navy TADIL-C," Naval Postgraduate School Technical Report, NPS-EC-012, December 1995.

DOD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: Electronic warfare, command and control warfare, communications, EW, C2W, C3I

ELECTRICAL AND COMPUTER ENGINEERING

COORDINATION OF MOBILE MANIPULATORS
Xiaoping Yun, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: National Science Foundation

OBJECTIVE: The goal of this project is to investigate the coordination of a mobile manipulator consisting of a mobile platform and a multi-link manipulator.

SUMMARY: This work is part of a continuing project. The focus of the past year's effort was on cooperative task execution of a human and a mobile manipulator. In this study, a human and a mobile manipulator jointly perform a task, e.g., jointly carry a large object. The human and mobile manipulator share the same workspace, and physically interact with each other. A coordination algorithm was developed for the mobile manipulator that is able to follow the trajectory initiated by the human participant, and share the load with the human. The main feature of the algorithm is its ability to tolerate uncertainties. The human acts as a leader to decide task trajectories. The mobile manipulator is able to follow and support the human without any *a priori* knowledge of the trajectories to be taken by the human.

PUBLICATIONS:

Yamamoto, Y. and Yun, X., "Coordinated Obstacle Avoidance of a Mobile Manipulator," Proceedings of the 1995 IEEE International Conference on Robotics and Automation, Nagoya, Japan, pp. 2255-2260, 21-27 May 1995.

Yun, X., "State Space Representation of Holonomic and Nonholonomic Constraints Resulting from Rolling Contacts," Proceedings of the 1995 IEEE International Conference on Robotics and Automation, Nagoya, Japan, pp. 2690-2694, 21-27 May 1995.

CONFERENCE PRESENTATION:

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DOD KEY TECHNOLOGY AREAS: Ground Vehicles, Sensors, Computing and Software

KEYWORDS: Robotics, autonomous vehicles, dynamic systems, human-robot cooperation

COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE) RESEARCH INSTRUMENTATION EXPERIMENTAL STUDY OF MULTIPLE COOPERATIVE MOBILE MANIPULATORS
Xiaoping Yun, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: National Science Foundation

OBJECTIVE: The goal of this project is to study coordination of multiple mobile robots to perform a common task.

SUMMARY: This work is part of a continuing project. The effort of the past year was concentrated on developing agent-level modules and integrating multiple agents to build a distributed multi-agent system for cooperative material handling. Because a human agent is included in the system for task planning, task monitoring, and error recovery, the system is neither fully autonomous nor fully teleoperated. It is designed to make effective use of human abilities within the present state of the art of autonomous systems.

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DOD KEY TECHNOLOGY AREAS: Ground Vehicles, Computing and Software

KEYWORDS: Robotics, autonomous agent, human-robot cooperation

ELECTRICAL AND COMPUTER ENGINEERING

DEVELOPMENT OF COOPERATIVE CONTROL ALGORITHMS
FOR A MULTI-ROBOT SYSTEM
Xiaoping Yun, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: The goal of this project is to investigate modeling, control, and coordination of mobile robots/vehicles.

SUMMARY: It is known that four-wheel steering and four-wheel driving vehicles offer greater traction over rough terrains, and are highly maneuverable in confined space. However, the control of such vehicles is less intuitive and difficult. A *dynamic* feedback control algorithm is developed, which automatically controls such a vehicle to move from any given initial configuration (position and orientation) to any final configuration. This result is expected to have significant impact on mine countermeasures using autonomous mobile robots/vehicles. Most existing mobile robots are designed for indoor environments or for outdoor paved surfaces. The new result will lead to a design of mobile robots for rough terrain environments, which are in great need for land mine hunting.

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DOD KEY TECHNOLOGY AREAS: Ground Vehicles, Computing and Software

KEYWORDS: Robotics, autonomous vehicles, dynamic systems

RECURSIVE RAY ACOUSTICS FOR THREE-DIMENSIONAL
SPEEDS OF SOUND
Lawrence J. Ziomek, Professor
Department of Electrical and Computer Engineering
Sponsor: Program Executive Office for Undersea Warfare,
Advanced Systems and Technology

OBJECTIVE: Continue to generalize, test, and evaluate the Recursive Ray Acoustics (RRA) Algorithm. The RRA Algorithm is a simple, fast, and accurate algorithm that can be used to find eigen rays and to compute the position, angles of propagation, travel time, phase, and path length along a ray path and to draw ray trace plots for speeds of sound that are functions of all three spatial variables. The phase calculations take into account phase shifts due to ocean surface and bottom reflections. In addition, the RRA Algorithm can calculate the sound-pressure level (SPL) along individual ray paths for arbitrary, one-dimensional, depth-dependent speeds of sound.

SUMMARY: Since SPL and phase calculations can now be performed along individual eigenrays, the RRA algorithm was incorporated into the full-wave, pulse-propagation computer program LSVOCN (Linear Space-Variant Ocean) in order to model acoustic pulse (transient) propagation in an inhomogeneous ocean. This new capability has potential for simulating active sonar systems in realistic ocean environments. Preliminary results concerning the use of two-dimensional orthogonal function expansions to fit surfaces to two-dimensional ocean bottom depth data, that is, bathymetry as a function of cross-range and down-range, were very promising. Such ocean bottom surface fits allow for the prediction of out-of-plane ray propagation due to bottom bounces. In addition, preliminary results concerning the use of two-dimensional orthogonal function expansions to fit surfaces to two-dimensional speed-of-sound data, that

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is, sound speed as a function of depth and down-range, were also very promising. However, additional study of the two-dimensional orthogonal function expansion technique is required in order to improve the surface fits.

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DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Three-Dimensional ray acoustics, pulse (transient) propagation modeling, underwater acoustics, undersea warfare

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