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# ELECTRICAL AND COMPUTER ENGINEERING

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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 NPS Institutionally Funded Research (NIFR) 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 that are externally supported by a wide range of government agencies, and by private industry through Cooperative Research and Development Agreements (CRADAs).

In FY 1999, ECE Department reimbursable research totaled \$x.xxM. A total of xx.xx faculty research work years were executed, representing xx% of the Department faculty labor. The department's research work led to 10 journal papers, 46 conference papers, 16 conference presentations, 2 book chapters, and 9 technical reports. These publications are listed following the Research Project Summaries.

Research projects in the department can be grouped into the following specialty areas: Communications; Communication Networks; Computer Engineering; Electromagnetics; Power Electronics, Electrical Machines and Distribution; Infra-Red and Electro-Optics; Radar, Surveillance, and Information Warfare; Signal Processing/Underwater Acoustics; Guidance, Navigation, and Control; Microelectronics; and Signals Intelligence/Space Systems. Following this introduction is a listing of this year's research project titles and principal investigators, by specialty area. Although some projects span more than one area, they are listed in only one.

Complete Project Summaries appear following the specialty area listing. These Summaries appear in alphabetical 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**

### TECHNICAL DESCRIPTION OF THE GLOBALSTAR SATELLITE COMMUNICATION SYSTEM

Vicente Garcia, NSA Chair  
Tri. T. Ha, Professor

### A/N USQ-113 TACTICAL IMPROVEMENT PROGRAM

Rasler W. Smith, Research Assistant Professor

### FREQUENCY COLLISION PLANNING

Donald v. Z. Wadsworth, Senior Lecturer

## **Communication Networks**

### IT-21 VULNERABILITY ASSESSMENT

John McEachen, Assistant Professor

### WIRELESS LOCAL AREA NETWORK (LAN) ANALYSIS

John McEachen, Assistant Professor

### COMPUTER MODELING OF HIGH-SPEED WIRELESS LOCAL AREA NETWORKS (WLAN)

John McEachen, Assistant Professor

### CAMPAIGN BATTLE MANAGEMENT ENGINEERING AND TECHNICAL REPORT

Donald v. Z. Wadsworth, Senior Lecturer

### MOBILE USER OBJECTIVE SYSTEM STUDY

Donald v. Z. Wadsworth, Senior Lecturer

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## WIRELESS DAMAGE CONTROL COMPUTER NETWORKS

Xiaoping Yun, Associate Professor

## ADVANCED AMPHIBIOUS ASSAULT VEHICLE

Raymond F. Bernstein, Jr., Research Assistant Professor

### **Computer Engineering**

## DESIGN ALGORITHMS FOR SUM-OF-PRODUCTS EXPRESSION AND DECOMPOSITION

Jon T. Butler, Professor

## REED-MULLER CANONICAL EXPANSIONS OF LOGIC FUNCTIONS

Jon T. Butler, Professor

### **Electromagnetic Systems**

## SIGNAL-TO-NOISE ENHANCEMENT PROGRAM (SNEP) RESEARCH AND SUPPORT

R.W. Adler, Research Associate Professor

W.R. Vincent, Visiting Research Associate

A.A. Parker, Research Associate

## RSOC RESEARCH AND SUPPORT

R.W. Adler, Research Associate Professor

W.R. Vincent, Visiting Research Associate

A.A. Parker, Research Associate

## LOW PROBABILITY OF INTERCEPT SYSTEM EVALUATION

R.W. Adler, Research Associate Professor

W.R. Vincent, Visiting Research Associate

A.A. Parker, Research Associate

## 3D SITE SPECIFIC PROPAGATION STUDIES FOR WIRELESS COMMUNICATIONS

R. Janaswamy, Associate Professor

## ASSESSMENT OF OCEAN SURFACE ROUGHNESS ON EM PROPAGATION

R. Janaswamy, Associate Professor

## ENGINEERING AND TECHNICAL SUPPORT DETERMINING LIMITATIONS OF ANTENNAS FOR USE IN IW UNDER PHYSICAL CONSTRAINTS

Jovan Lebaric, Visiting Associate Professor

Richard Adler, Research Associate Professor

## PRELIMINARY DESIGN OF LOW FREQUENCY EIGEN ANTENNA FOR EA-6B

Jovan Lebaric, Visiting Associate Professor

Richard Adler, Research Associate Professor

## MEASUREMENTS OF SHIPBOARD FIRE EFFECTS ON RF COMMUNICATIONS IN THE 2.4 GHZ ISM BAND

Jovan Lebaric, Visiting Associate Professor

Richard Adler, Research Associate Professor

## WIDEBAND ANTENNA FEASIBILITY STUDY FOR JOINT TACTICAL RADIO (JTR)

Jovan Lebaric, Visiting Associate Professor

Richard Adler, Research Associate Professor

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EA-6B COTS COMMUNICATIONS EA TRANSMITTER PROJECT

A.A. Parker, Research Associate

POLARIMETRY AND SPECTROPOLARIMETRY FOR REMOTE SENSING

J. Scott Tyo, Assistant Professor

MODELING AND DEVELOPMENT OF UWB ANTENNAS

J. Scott Tyo, Assistant Professor

## **Power Systems**

PEBB ALGORITHM DEVELOPMENT AND LABORATORY ESTABLISHMENT

Robert William Ashton, Associate Professor

ADVANCED POWER CONVERTER MODULES AND ZONAL ELECTRIC DISTRIBUTION

Robert William Ashton, Associate Professor

POWER FET AND SCHOTTKY DIODE DOSE RATE TEST DEVELOPMENT

John G. Ciezki, Assistant Professor

## **Signal Processing/Underwater Acoustics**

EVALUATION OF CLASSIFICATION ALGORITHMS

Charles W. Therrien, Professor

Tri T. Ha, Professor

ESTIMATION OF OCEAN SURFACE CURRENT DATA FROM THE NAVY HF SURFACE WAVE RADAR

Lawrence J. Ziomek, Professor

PROCESSING OF RADAR SIGNATURES USING CORRELATION AND WAVELET CONCEPTS

Ralph D. Hippenstiel, Associate Professor

Monique P. Fargues, Associate Professor

RADAR SIGNAL PROCESSING USING WAVELET-BASED CONCEPTS

Ralph D. Hippenstiel, Associate Professor

Monique P. Fargues, Associate Professor

TIME DIFFERENCE OF ARRIVAL ESTIMATION BASED ON WAVELET SCALES

Ralph D. Hippenstiel, Associate Professor

Tri T. Ha, Professor

IMPROVEMENT OF THE TIME DIFFERENCE OF ARRIVAL ESTIMATION USING WAVELETS

Ralph D. Hippenstiel, Associate Professor

Tri T. Ha, Professor

FEATURE EXTRACTION FOR SIGNAL CHARACTERIZATION IN CLASSIFICATION APPLICATIONS:  
APPLICATIONS TO COMMUNICATION MODULATION

Monique P. Fargues, Associate Professor

BEARTRAP POST-MISSION ANALYSIS SYSTEM

Murali Tummala, Professor

Charles W. Therrien, Professor

DETECTION AND CLASSIFICATION OF UNDERWATER ACOUSTIC SIGNALS

Roberto Cristi, Associate Professor

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## **Microelectronics**

CEPXS/SPICE AUTOMATED SOFTWARE INTERFACE DEVELOPMENT

Douglas J. Fouts, Associate Professor

RADIATION TOLERANT BULK CMOS DIGITAL INTEGRATED CIRCUITS

Douglas J. Fouts, Associate Professor

## **Infra-Red and Electro-Optics**

PHOTONIC SAMPLING ARCHITECTURES FOR MICROWAVE SIGNAL COLLECTION AND ANALYSIS

John P. Powers, Professor

Phillip E. Pace, Associate Professor

## **Radar, Surveillance, and Information Warfare**

SOFTWARE DEVELOPMENT AND RESEARCH SUPPORT FOR ANTI-SHIP MISSILE SIMULATOR TECHNOLOGY

Phillip E. Pace, Associate Professor

TACTICAL REACTIVE EA NETWORK MODELING AND ANALYSIS

Phillip E. Pace, Associate Professor

NULKA BLUE RIBBON PANEL

Phillip E. Pace, Associate Professor

DIGITAL TARGET IMAGING ARCHITECTURES

Phillip E. Pace, Associate Professor

ROBUST SYMMETRICAL NUMBER SYSTEM DIRECTION FINDING ARRAY

Phillip E. Pace, Associate Professor

David C. Jenn, Associate Professor

ELECTRONIC WARFARE ADVANCED TECHNOLOGY STUDIES

R. Clark Robertson, Professor

AIRPLATFORM SURVIVABILITY ENHANCEMENT

R. Clark Robertson, Professor

Frederick Levien, Senior Lecturer

SEI INFORMATION

Lonnie A. Wilson, Research Associate Professor

TARGETING AND THREAT WARNING RECEIVER APPLIQUE FOR LONG RANGE DETECTION AND PROCESSING OF HOSTILE RADAR WEAPONS

Lonnie A. Wilson, Research Associate Professor

LOW-BAND HARM ASSESSMENTS AND EVALUATIONS – PHASE ONE

Lonnie A. Wilson, Research Associate Professor

ECONOMICAL SAR/ISAR SYSTEM DEVELOPMENT FOR UAV APPLICATIONS – PHASE ONE

Lonnie A. Wilson, Research Associate Professor

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## **Guidance, Navigation, and Control**

EVALUATION AND EXTENSIONS OF THE PROBABILISTIC MULTI-HYPOTHESIS TRACKING ALGORITHM TO CLUTTERED ENVIRONMENTS

Robert G. Hutchins, Associate Professor

THEATER BALLISTIC MISSILE DEFENSE – MULTI-SENSOR FUSION, TRACKING, AND TARGETING TECHNIQUES

Robert G. Hutchins, Associate Professor

PHASE ADJUSTMENT CONTROL FOR LORAN-C APPLICATIONS

Murali Tummala, Professor

Roberto Cristi, Associate Professor

ACCURATE CONTROL OF MANIPULATORS USING INERTIAL SENSORS

Xiaoping Yun, Associate Professor

## **Signals Intelligence/Space Systems**

RADIATION HARDENED SPACE BASED SOLAR CELLS AND ELECTRONIC DEVICES

Sherif Michael, Associate Professor

NEUTRON SINGLE EVENT EFFECT STUDIES

Todd Weatherford, Assistant Professor

SILVACO TOOLS DEVELOPMENT FOR RADIATION EFFECTS

Todd Weatherford, Assistant Professor

TIME RESOLVED SINGLE EVENT EFFECT STUDIES IN SOI

Todd Weatherford, Assistant Professor

RADIATION HARDNESS ANALYSIS OF InP AND SiGe TECHNOLOGIES FOR SPACE APPLICATIONS

Todd Weatherford, Assistant Professor

PROJECT GUSTY ORIOLE

H.H. Loomis, Jr., Professor

GEOLOCATION WORKBENCH

H.H. Loomis, Jr., Professor

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## SIGNAL-TO-NOISE ENHANCEMENT PROGRAM (SNEP) RESEARCH AND SUPPORT

**Richard W. Adler, Research Associate Professor**

**Wilbur R. Vincent, Visiting Research Associate**

**Andrew A. Parker, Research Associate**

**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 and at Regional System Operational Centers (RSOCs) worldwide.

**SUMMARY:** Development of techniques and methodology for identifying and locating radio noise sources and sources of interference to data processing and computer systems 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 held in Washington, DC in May.

### CONFERENCE PRESENTATIONS:

Adler, R.W., "The Use of DSP Speech Processing at RSOC Facilities," COMNAVSECGRU N-44 Yearly SNEP Program Review, Fort Meade, MD, May 1999.

Vincent, W.R., "Characteristics of Ground Systems in Data Processing Facilities," COMNAVSECGRU N-44 Yearly SNEP Program Review, Fort Meade, MD, May 1999.

Vincent, W.R., "HF Power-Line-Noise Update," COMNAVSECGRU N-44 Yearly SNEP Program Review, Fort Meade, MD, May 1999.

Vincent, W.R., "The Use of Differential Probes in Determining Data Signal Jitter," COMNAVSECGRU N-44 Yearly SNEP Program Review, Fort Meade, MD, May 1999.

Vincent, W.R., "Equipotential Grounds: Historical Background and Modern Practices," COMNAVSECGRU N-44 Yearly SNEP Program Review, Fort Meade, MD, May 1999.

Vincent, W.R., "Data Cable Coupling Tests," Yearly SNEP Program Review, Fort Meade MD, May 1999.

Vincent, W.R., "Mitigation of RF Noise Currents from UPS Systems," COMNAVSECGRU N-44 Yearly SNEP Program Review, Fort Meade, MD, May 1999.

Vincent, W.R., "The NEC Code and Its Application to Ground Systems in Data Processing Facilities," COMNAVSECGRU N-44 Yearly SNEP Program Review, Fort Meade, MD, May 1999.

### OTHER:

Munsch, G.F., and Adler, R.W., "Signal-to-Noise Enhancement Program Signal Quality Survey, NSGA Rota," Quick-Look Report, prepared for COMNAVSECGRU N-44, June 1999.

Vincent, W.R., Adler, R.W., and Parker, A.A., "Signal-to-Noise Enhancement Team Survey NSGA Northwest," Quick Look Report, prepared for COMNAVSECGRU N-44, May 1999.

Vincent, W.R., Adler, R.W., and Parker, A.A., "Signal-to-Noise Enhancement Program Signal Quality Survey, NSGD Imperial Beach," Quick-Look Report, prepared for COMNAVSECGRU N-44, June 1999.

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Vincent, W.R., Adler, R.W., and Parker, A.A., "Signal-to-Noise Enhancement Team Survey NSGA Sabana Seca," Quick Look Report, prepared for COMNAVSECGRU N-44, July 1999.

Vincent, W.R., Adler, R.W., and Parker, A.A., "Signal Quality Survey at the Field Station Korea and Detachment L," Quick Look Report, prepared for USA INSCOM, October 1999

Vincent, W.R., Adler, R.W., and Parker, A.A., "System Performance Survey at NSGA Naples," Technical Report, prepared for COMNAVSECGRU N-44, Nov. 1999.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Environmental Effects

**KEYWORDS:** Electromagnetic Environmental Effects, Communication Systems, Man-Made Noise, Antennas

## REGIONAL SYSTEM OPERATIONAL CENTER RESEARCH AND SUPPORT

**Richard W. Adler, Research Associate Professor**

**Wilbur R. Vincent, Visiting Research Associate**

**Andrew A. Parker, Research Associate**

**Department of Electrical and Computer Engineering**

**Sponsor: United States Army Information and Security Command**

**OBJECTIVE:** Continued research and development in techniques to improve the signal-to-noise ratio at the Fort Gordon Regional System Operational Center (RSOC).

**SUMMARY:** Development of techniques and methodology for identifying and locating data noise sources and sources of interference to data processing and computer systems at the Fort Gordon RSOC. Support was provided to USA INSCOM via review of pre-survey planning documentation, mitigation plans and authoring a "Quick-Look" and a final site-survey report. Students and RSOC site personnel were trained as part of the INSCOM support.

### CONFERENCE PRESENTATION:

Adler, R.W., "RADHAZ Measurements for Safety Zones at RSOC Facilities," prepared for USA INSCOM at the Yearly SNEP Program Review, Fort Meade, MD, May 1999.

### OTHER:

Vincent, W.R., Adler, R.W., and Parker, A.A., "Signal Quality Survey at the Kunia Regional Systems Operations Center (KRSOC)," Quick-Look Report, prepared for CNSG, February 1999.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Environmental Effects

**KEYWORDS:** Electromagnetic Environmental Effects, Communication Systems, Man-Made Noise, Antennas

## LOW PROBABILITY OF INTERCEPT SYSTEM EVALUATION

**Richard W. Adler, Research Associate Professor**

**Wilbur R. Vincent, Visiting Research Associate**

**Andrew A. Parker, Research Associate**

**Department of Electrical and Computer Engineering**

**Sponsor: Space and Naval Warfare Systems Center-San Diego**

**OBJECTIVE:** Determine the probability of intercept of a candidate LPI system under development at SPAWAR SYSCEN.

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**SUMMARY:** NPS conducted field tests of the system in an urban field environment and showed the effects of different antenna systems on the ability to detect the presence of the LPI signal. The impact of noise on the reception of the PLI signal was demonstrated.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Environmental Effects

**KEYWORDS:** Electromagnetic Environmental Effects, Communication Systems, Man-Made Noise, Antennas

## **POWER ELECTRONIC BUILDING BLOCK ALGORITHM DEVELOPMENT AND LABORATORY ESTABLISHMENT**

**Robert W. Ashton, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Surface Warfare Center-Annapolis Detachment**

**OBJECTIVE:** This research involves the development and testing of Power Electronic Building Block (PEBB) control algorithms and hardware, and for assistance in establishing an Electrical Power Conversion R&D Laboratory at NSWC, Philadelphia. Support includes conducting appropriate tests, analyzing/evaluating technical documentation/data and providing comments. While on-site in Philadelphia, the investigator will assist in evaluating and redesigning specific components of the Power Converter Module 4 (PCM-4) in order to make the 2MW Phase- Controlled Rectifier (PCR) functional. The results/recommendations shall be documented. Travel to NSWC Annapolis and Philadelphia shall be required to implement the above objectives.

**SUMMARY:** This research concentrated on specific issues encountered while on-site in both Annapolis and Philadelphia. While in Annapolis, testing was performed on the phase legs of an in-house 250kW Auxiliary Resonant Commutated Pole (ARCP) inverter using PEBB modules from Harris Corporation. The Annapolis on-site research concentrated on gathering information for future system integration with the Land Based Engineering Site in Philadelphia and converter improvement recommendations. Both the ARCP inverter and the PEBB modules are military specific and utilized to maximize power density and reduce weight. The second part of this research effort took place on-site in Philadelphia. The investigator was challenged with evaluating a 2MW PCR which did not function when the investigator arrived (4160Vac to 1100Vdc). The proprietary design was the first of its kind at the specified power level. A number of design changes were made over a period of five weeks and the unit was tested at the 1MW level by the investigator. Further recommendations were made including a redesign of the driver boards for the SCRs which resulted in a completely functioning unit in late December 1999.

### **THESIS DIRECTED:**

Moore, J.E., "Frequency-Based Load Sharing in Current-Mode-Controlled Buck Converter," Master's Thesis, Naval Postgraduate School, March 1999.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Other (Energy Conversion)

**KEYWORDS:** Power Electronic Building Blocks, Power System, Auxiliary Resonant Commutated Pole Inverter, Phase-controlled Rectifier

## **ADVANCED POWER CONVERTER MODULES AND ZONAL ELECTRIC DISTRIBUTION**

**Robert W. Ashton, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Surface Warfare Center-Philadelphia**

**OBJECTIVE:** This research involves the engineering design of advanced power conversion modules under current Navy development. This task will require the investigation of available power converter design options. Additionally, assistance in the design and development of advanced reconfigurable zonal electric distribution system hardware will be provided in the form of testing, debugging and documentation. Support includes conducting appropriate tests,

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analyzing/evaluating technical documentation/data, and providing comments. The principal investigator shall attend technical meetings, as required, and provide monthly status reports. Travel to CDNSWC-SSES Philadelphia shall be required to implement the above objectives.

**SUMMARY:** This research concentrated on specific issues encountered while on-site in Philadelphia. The investigator was tasked with the evaluation of Power Converter Module 2 (PCM-2), a 250kW three-phase Auxiliary Resonant Commutated Pole (ARCP) inverter designed by General Electric (GE), which is currently utilized at Philadelphia's Land Based Engineering Site (LBES). Initially, all nine phase-legs and both switch gear units for the two PCM-2s were non-operational. After several weeks of evaluation a test setup was established by the investigator in Building 87 Philadelphia for functional testing and repair. These Full Scale Advanced Development (FSAD) units were systematically evaluated, repaired and catalogued. A number of recommended design changes to the phase legs were made. Additionally, a total redesign of the switch gear that holds the phase legs was recommended. The GE units were placed back in LBES and tested successfully. While the investigator was still in Philadelphia, the switch gear catastrophically failed. The evaluation of this catastrophic failure helped the investigator show Philadelphia engineers the mechanism of failure and several possible redesign solutions. In addition to the PCM-2 research, the investigator was responsible for uncovering and evaluating potential new candidate inverters to replace the GE units in LBES. A report was filed which included more than half-a-dozen options that could be implemented within several months.

## **THESES DIRECTED:**

Marinac, M.L., "Control of Paralleled Inverters in the Naval DC Zonal Distribution System," Master's Thesis, Naval Postgraduate School, September 1999.

Turner, C.C., "Design and Implementaion of a Zero-Voltage-Switching, Pulse-Width Modulated, High Frequency, Resonant Buck Chopper," Master's Thesis, Naval Postgraduate School, September 1999.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Other (Energy Conversion)

**KEYWORDS:** Power System, Auxiliary Resonant Commutated Pole Inverter

**ADVANCED AMPHIBIOUS ASSAULT VEHICLE**  
**Raymond F. Bernstein, Jr., Research Assistant Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Advanced Amphibious Assault Vehicle Program Office**

**OBJECTIVE:** The purpose of this effort was to model the High Speed Data Bus (HSDB), CAN Bus, and Utility Bus with sufficient resolution to determine if there were performance issues associated with these buses and the attached nodes. This issue was addressed by simulating the HSDB with an OpNet model.

**SUMMARY:** The HSDB, CAN Bus, and Utility Bus were modeled using OpNet 6.0. The focus of the modeling effort was the HSDB, a FDDI bus with four nodes. Loading of the bus was accomplished based on specifications of the AAV and operational considerations such as input data traffic and scenarios. The FDDI bus bandwidth was found to be acceptable under all scenarios except possibly during high volume database updates.

## **THESIS DIRECTED:**

Peyton, D.G., "Performance Analysis of the Advanced Amphibious Assault Vehicle Personnel Variant (AAAV-P) Vetrionics Communications System High Speed Data Bus," Master's Thesis, Naval Postgraduate School, June 1999.

**DoD KEY TECHNOLOGY AREA:** Computers

**KEYWORDS:** AAV, OpNet, Modeling, Networking

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## DESIGN ALGORITHMS FOR SUM-OF-PRODUCTS EXPRESSION AND DECOMPOSITION

Jon T. Butler, Professor

Department of Electrical and Computer Engineering  
Tsutomu Sasao, Kyushu Institute of Technology, Japan  
Sponsor: Unfunded

**OBJECTIVE:** To understand the extent to which sum-of-products expressions can produce minimal circuits.

**SUMMARY:** For approximately 50 years, the sum-of-products expression has been a widely used implementation of logic circuits. For functions with six or fewer variables, the Karnaugh Map can be used. However, above this limit, only the Quine-McCluskey method produces a minimal expression. The Quine-McCluskey method is tabular and well-suited to computer implementation. However, for functions with 20 or more variables, the Quine-McCluskey method becomes unsuitable because computation time becomes too high. Thus, designers must resort to heuristics for 20 or more variables. Researchers have focused on heuristics that give the fewest product terms, as this produces the most compact circuits. However, two years ago, we showed that certain reasonable heuristics produce the worst, not the best circuit. This startling realization has inspired, for us a careful examination of the functions and the heuristics that cause this phenomenon. Last spring, we refined previously produced results on this, and began an investigation into various decomposition techniques. This is collaborative work with Professor Tsutomu Sasao of the Kyushu Institute of Technology. Plans include extension to multiple-valued functions.

**PUBLICATION:**

Sasao T. and Butler, J.T., "Worst and Best Irredundant Sum-of-Products Expressions," submitted to *IEEE Transactions on Computing*.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Digital Systems, Compact Circuits, Computer-Aided Design Tools, Sum-of-Products Expressions

## REED-MULLER CANONICAL EXPANSIONS OF LOGIC FUNCTIONS

Jon T. Butler, Professor

Department of Electrical and Computer Engineering  
G. W. Dueck, University of New Brunswick, Canada  
V. P. Shmerko, and S. V. Yanushkevich, Technical University of Szczecin, Poland  
Sponsor: Unfunded

**OBJECTIVE:** To improve synthesis techniques for the Reed-Muller canonical representation of logic function.

**SUMMARY:** The Reed-Muller canonical expansion of a logic function uses the Exclusive OR of product terms. It has been shown that this representation requires fewer product terms, on the average, than standard sum-of-products expressions. We have shown an algorithm for finding the minimal Reed-Muller expansion for symmetric functions that runs in  $O(n^3)$  time and uses  $O(n^2)$  storage space [3]. We have applied this to large sets of functions and discovered that two of the  $n$  polarities realize a large percentage of functions (35% for large  $n$ ) [4]. The previous best was  $O(n^6)$  time and uses  $O(n)$  storage space.

**PUBLICATIONS:**

Butler, J.T., Dueck, G.W., Holowinski, G., Shmerko, V.P., and Yanushkevich, S.V., "On Recognition of Symmetries for Switching Functions in Reed-Muller Forms," *Pattern Recognition and Information Processing*, Minsk, Belarus, 18-20 May 1999.

Butler, J.T., Dueck, G.W., Shmerko, V.P., and Yanushkevich, S.V., "Comments on 'Sympathy: Fast Exact Algorithm for Fixed-Polarity Reed-Muller Expansions for Symmetric Functions'," submitted to *IEEE Transactions on Computer-Aided Design of Systems and Circuits*.

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Butler, J.T., Dueck, G.W., Yanushkevich, S.V., and Shmerko, V.P., "On the Use of Transeunt Triangles to Synthesize Fixed-Polarity Reed-Muller Expansions of Symmetric Functions," submitted to *IEE - Proceedings Part E*.

Butler, J.T., Dueck, G.W., Yanushkevich, S.V., and Shmerko, V.P., "On the Number of Generators of Transeunt Triangles," submitted to *Discrete Applied Mathematics*.

Yanushkevich, S.V., Butler, J.T., Dueck, G.W., and Shmerko, V., "Experiments on FPRM Expressions for Partially Symmetric Logic Functions," *Proceedings of the 27th International Symposium on Multiple-Valued Logic*, (accepted) May 2000.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Digital Systems, Compact Circuits, Computer-Aided Design Tools, Exclusive OR Sum-of-Products Expressions, Reed-Muller Canonical Expressions

## POWER FET AND SCHOTTKY DIODE DOSE RATE TEST DEVELOPMENT

**John G. Ciezki, Assistant Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Surface Warfare Center-Crane**

**OBJECTIVE:** The survivability and effectiveness of many weapons systems and space-based applications are contingent on the reliability of the power supplies. In a nuclear environment, such systems are subject to failures due to total dose, dose rate and single-event upsets. Since the power supply has the potential to be the weak link in the system hardening chain, it is critical that designers ensure that the supply recovers quickly enough to guarantee mission completion. The power supply design must address the maintenance of the input and output power rails during large changes in the load photo-current requirements and must ensure that the control loop is fast enough to ride through the event.

This proposed work effort seeks to contribute to the design of rad-hard power supplies by completing the following five tasks over an approximate 18-month work period:

1. Develop and execute a series of radiation tests at NPS on discrete semiconductor components commonly used in power supplies and catalogue the results;
2. Design a dc-dc converter using the evaluated technology and have it built by Raytheon;
3. Perform Flash X-ray and LINAC tests on the fabricated power converter;
4. Modify the converter to employ advanced technology devices for the switching element and a higher-radiation controller chip using emerging technologies; and
5. Perform Flash X-ray and LINAC tests on the modified power converter.

**SUMMARY:** The first task will be completed with consultation with Jeff Titus in Crane, IN. The principal components to be evaluated are Power FETS (IR150, IR250, IR450 and Harris equivalents) and Schottky diodes (IR and EQ100). The devices will be evaluated for photo-current response, breakdown voltage and LVCEO. Devices have been procured from International Rectifier and Harris. Testing circuits have been identified and additional components (i.e., special capacitors and current probes) have been procured. Additional SiC Schottky diodes have been acquired from Dr. Jim Cooper of Purdue University to test. The test circuit boards have been designed and cut using equipment made available by the Space Systems Academic Group. Dosimetry has been established for the NPS Flash X-ray at the golf course and initial test data taken. Problems have been encountered in how to collect the large amount of data that is required. Solutions have been considered and additional funds have been requested to update the laboratory data acquisition capabilities at NPS. If this is not possible, the larger data runs will have to be done at Crane, IN later this year.

The second and third tasks will be completed with consultation with Jim Smith at Raytheon. The designed power supply will be a zero-voltage-switching forward converter operating at a switching frequency exceeding 200kHz and at an output power level ranging from 25-350W. The input voltage will be approximately 30V and there will be multiple outputs with voltages at approximately 2.5V, 3.3V and  $\pm 5V$ . The digital or analog control will be designed to minimize the recovery time of the supply. As of now, these tasks have been prioritized as low by the sponsor and will receive more attention in the coming year. The fourth and fifth tasks focus on integrating new technology, with

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potentially superior rad-hard characteristics, into the existing converter design. The results of the above tasks and  
subtasks will then

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be analyzed, condensed, and submitted in the form of a final report. The proposed work effort may leverage some degree of cost-share with ONR and may utilize advanced technology devices made available through an existing MURI.

A thesis student, CAPT Gerald Bloomfield, is actively involved in this project and will be completing his thesis work in June of 2000. This project has also enabled participation in another research proposal to Honeywell involving the radiation testing of power devices.

**DoD KEY TECHNOLOGY AREA:** Electronics

**KEYWORDS:** Power FET, Schottky Diode, Dose Rate, Operate Through

## DETECTION AND CLASSIFICATION OF UNDERWATER ACOUSTIC SIGNALS

**Roberto Cristi, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Space and Naval Warfare Systems Center-San Diego**

**OBJECTIVE:** To develop computer algorithms for identifying and classifying short signals in colored background noise.

**SUMMARY:** During CY1999 we developed an algorithm, based on current research of the investigator, which enables the detection of short, low energy transients in colored background noise. By this approach we compute a multiscale decomposition of the given signal, into orthogonal components at different sampling rates. The results on test signals seem to be very promising, in the sense that short transients are detected in the channels at high sampling rate, with short integration time, while longer transients with lower amplitude are detected in the channels at lower sampling rates, with longer integration time. The algorithm tested evolves from a novel idea of the investigator, under review for publication.

### CONFERENCE PRESENTATION:

Cristi, R., "Detection of Short Transients in Colored Noise," 4th Annual ADS Technology Day, TRW Systems Services Company, San Diego, CA, September 1999.

**DoD KEY TECHNOLOGY AREA:** Other (Digital Signal Processing)

**KEYWORDS:** Non-Stationary Signals, Multirate, Multiresolution, Kalman Filter

## FEATURE EXTRACTION FOR SIGNAL CHARACTERIZATION IN CLASSIFICATION APPLICATIONS; APPLICATIONS TO COMMUNICATION MODULATION

**Monique P. Fargues, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Center for Reconnaissance Research**

**OBJECTIVE:** The goal of the study is to extend a dimension reduction scheme considered in previous work and to consider its applications to the classification of communication modulation schemes.

**SUMMARY:** In a previous study we proposed a dimension reduction scheme to reduce the dimension of the feature space generated to characterize signal classes and use the resulting information for classification applications. The proposed scheme belongs to the class of projection pursuit algorithms and consists of an iterative scheme which maximizes the projected mean between two classes of data. The proposed scheme was tested both on synthetic and real-world underwater data. Results show similar or better in performance to those obtained using more classical classifiers (such as CART or back-propagation neural networks). In this extension we first propose to consider the spread of the projected data to improve on the previous results, and second, to focus our application to specific types of communication schemes.

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## CONFERENCE PRESENTATION:

Fargues, M.P., "Feature Extraction and Dimension Reduction Issues: Applications to Classification," CRR Briefing, Monterey, CA, April 1999.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Computing and Software

**KEYWORDS:** Classification, Projection Pursuit, Dimension Reduction

## CEPXS/SPICE AUTOMATED SOFTWARE INTERFACE DEVELOPMENT

**Douglas J. Fouts, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Lockheed Martin Space and Missile Systems**

**OBJECTIVE:** The purpose of this research is to create an automated software interface to allow the circuit simulation program known as SPICE to directly read and utilize the output of the radiation effects simulation program known as CEPXS.

**SUMMARY:** The Coupled Electron/Proton Transport Simulator (CEPXS) is used to quantify the amount of energy that is absorbed in each layer of a multi-layer stack of materials when the stack is exposed to nuclear radiation. Typically, the stack of materials represents a transistor that is part of an integrated circuit (IC) in an IC package on a printed circuit board in an enclosure. Thus, the output of CEPXS can be used to determine the amount of energy actually absorbed by a transistor. However, to determine the effects this absorbed energy has on the transistor and on the electronic circuit, the output of CEPXS must be analyzed by hand, many calculations must be made, and then the data can be input into the circuit simulation program SPICE (Simulation Program with Integrated Circuit Emphasis).

The software being developed will eventually provide a complete, fully automated interface between CEPXS and SPICE. This will allow accurate simulations of the effects of nuclear radiation on very large circuits with many transistors, something that cannot be done currently because of the slow, cumbersome, manual interface. At this point in time, two lexical analyzer/parsers have been developed, one to read in the output of CEPXS and the other to read in a SPICE input file that describes an electronic circuit. Both lexical analyzer/parsers are tested and working correctly. Algorithms have been developed that use the output of CEPXS to calculate the magnitude and duration of the photo currents that are induced in the transistors when they are exposed to nuclear radiation. Although not yet coded and tested, these algorithms will allow SPICE simulations to include the effects of these photo currents when the SPICE circuit simulator is run. A code generator that is capable of creating the modified SPICE input file from the original SPICE circuit description has been designed and coded but has not been fully tested yet.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation, Electronics, Materials, Processes, and Structures

**KEYWORDS:** Radiation Effects on Microelectronics, Modeling and Simulation, Space Electronics

## RADIATION TOLERANT BULK CMOS DIGITAL INTEGRATED CIRCUITS

**Douglas J. Fouts, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsors: National Security Agency and Naval Postgraduate School**

**OBJECTIVE:** To develop circuit designs and mask layout techniques that improve the radiation tolerance of digital integrated circuits fabricated with standard, commercial, bulk CMOS processes for use in low-earth orbit spacecraft and high altitude aircraft.

**SUMMARY:** This research project has now been successfully completed. A final presentation on the results has been made to the sponsor. A paper describing the research and the results has been accepted for publication in the research

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journal, *Microelectronics Reliability*, although the specific issue has not yet been determined. A patent application is also in preparation.

The techniques developed, tested, and proven by this research project are very successful and can reduce the radiation-induced, gate, end-around, subthreshold leakage current in CMOS field effect transistors by as much as six orders of magnitude. They are also successful at compensating for radiation-induced threshold voltage shift. The techniques developed are 100% compatible with any standard, commercial, bulk CMOS fabrication process that has two layers of polysilicon.

The success of this research will eventually lead to a significant reduction in the cost and development time of radiation-tolerant digital integrated circuits for low earth orbit applications.

## **PUBLICATION:**

Fouts, D.J., Noe, S.S., Lum, G.K., Lambley, A.S., and McKerrow, G.R., "Second-Layer Polysilicon Structures for Gate End-Around Leakage Current Compensation in Bulk CMOS ICs," *Microelectronics Reliability*, accepted for publication.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Computing and Software, Command, Control, and Communications, Electronic Warfare

**KEYWORDS:** Radiation-hardened Electronics, Space Electronics

## **TECHNICAL DESCRIPTION OF THE GLOBALSTAR SATELLITE COMMUNICATION SYSTEM**

**Vicente C. Garcia, National Security Agency Cryptologic Chair**

**Tri T. Ha, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: National Security Agency**

**OBJECTIVE:** To do a thorough, extensive system review and analysis while at the same time maintaining a coherent and understandable perspective with respect to the key system technologies, specifications, and parameters.

**SUMMARY:** A comprehensive study of all aspects of the GLOBALSTAR system was provided, to include the overall space system architecture and operational capabilities, as well as specific details of the advanced communication techniques used. In addition, the study provided an indepth explanation and technical description of the various communication links, to include all pertinent link parameters and components. This included details of both the communication service links and the telemetry/command links.

## **PUBLICATION:**

Ziegler, W., Itakura, M., Shepard, P., and Vitalich, J., "Technical Description of the GLOBALSTAR Satellite Communications Systems," EC475D Project Report, 13 September 1999.

**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communications

**KEYWORDS:** Satellite, Link

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## PROCESSING OF RADAR SIGNATURES USING CORRELATION AND WAVELET CONCEPTS

**Ralph D. Hippenstiel, Associate Professor**

**Monique P. Fargues, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: National Reconnaissance Office**

**OBJECTIVE:** Investigate wavelet processing to second order statistics obtained from frequency agile Radars with variable pulse repetition frequency (PRF).

**SUMMARY:** Radar characteristics of systems of interest were obtained. Typical attributes of representative electronic signatures were simulated using MATLAB. Results indicated that the correlation wavelet-based approach is not suitable for pulsed signals. This result is in contrast to the results obtained when dealing with constant envelope signals (i.e., frequency hopped signals). Work concentrated on using the wavelet transform directly in the time domain.

### THESIS DIRECTED:

Moraitakis, I., "Feature Extraction of Intra-Pulse Modulated Radar Signals Using Time-Frequency Analysis," Master's Thesis, Naval Postgraduate School, September 1999.

**DoD KEY TECHNOLOGY AREA:** Electronics

**KEYWORDS:** Radar Signals, Signal Detection/classification, Identification

## TIME DIFFERENCE OF ARRIVAL ESTIMATION BASED ON WAVELET SCALES

**Ralph D. Hippenstiel, Associate Professor**

**Tri T. Ha, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Navy Tactical Exploitation of National Capabilities**

**OBJECTIVE:** Support military applications in space by providing a fast way to localize potential emitters. It will demonstrate the feasibility of TDOA estimation using a unique method based on multi-rate and proportional bandwidth processing techniques.

**SUMMARY:** The localization of mobile wireless communication units using time difference of arrival (TDOA) is studied. The wavelet transform is used to increase the accuracy of the TDOA estimation. Several denoising techniques based on the wavelet transform are presented. These techniques are applied to different types of test signals and to a simulated baseband GSM signal. The results of the denoising techniques are compared to the ones employing no denoising in terms of the mean square error. The denoising techniques allow a 28 to 81 percent improvement in TDOA estimation.

### PUBLICATIONS:

Hippenstiel, R. and Aktas, U., "Time Difference of Arrival Estimation Using Wavelet Transforms," *42<sup>nd</sup> Midwest Symposium on Circuits and Systems*, Las Cruces, NM, 9-11 August 1999.

Aktas, U. and Hippenstiel, R., "Localization of GSM Signals Using Wavelet Denoising Based on the Fourth Order Moment," *33<sup>rd</sup> Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, 27-29 October 1999.

Hippenstiel, R., Ha, T.T., and Aktas, U., "Localization of Wireless Emitters Based on the Time Difference of Arrival (TDOA) and Wavelet Denoising," Naval Postgraduate School Technical Report, NPS-EC-99-006, May 1999.

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## **THESIS DIRECTED:**

Aktas, U., "Time Difference of Arrival (TDOA) Estimation Using Wavelet Based Denoising," Master's Thesis, Naval Postgraduate School, March 1999.

**DoD KEY TECHNOLOGY AREA:** Electronics

**KEYWORDS:** Geo-location, Wavelet Processing, Signal Processing, Time Difference of Arrival (TDOA) Estimation

## **EVALUATIONS 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 Division**

**OBJECTIVE:** Dr. Roy Streit and colleagues at the Naval Undersea Warfare Center, Division Newport, 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 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. 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:** Prior work in this project has produced a set of simulation testbeds and algorithm code. This past year, research has focused on running real data through our previously developed algorithms. This portion of this project has been classified SECRET.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Modeling and Simulation

**KEYWORDS:** Sensors, Data Association and Target Tracking

## **THEATER BALLISTIC MISSILE DEFENSE MULTI-SENSOR FUSION, TRACKING, AND TARGETING TECHNIQUES**

**Robert G. Hutchins, Associate Professor**

**Hal Titus, Emeritus Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Navy Tactical Exploitation of National Capabilities**

**OBJECTIVE:** Our ultimate goal is to assess the feasibility of algorithms employing both strategic and theater sensors to detect, track and engage theater ballistic missiles during boost and/or early ballistic missile flight, destroying the missile over the territory of the aggressor.

**SUMMARY:** Our present space sensor devices have the potential to provide the shooter with much earlier ballistic missile launch detection and location information. However, all too often each sensor system will sequentially observe the target until a firm track is established, and then transfer the track information to the shooter. This method incurs significant time lag penalties between detection and launch of an interceptor. Algorithms will be developed that will provide the earliest possible detection and tracking information by fusing information at the earliest possible time, by alerting the shooter with detection data and imprecise location information at the earliest possible time, and by tracking after data fusion for more accurate and faster target location and identification. It is proposed to bring to bear all sensor

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assets available to cover a threatened launch area, including space, shipboard, aircraft and UAV sensors, and to fuse these observations as quickly as they are obtained at a central site. This will allow the shooter to launch at the earliest possible time, including instances of high suspected threat when a launch-before-track strategy may be acceptable.

The thrust of this research to date has been the feasibility of detection queuing of an AEGIS platform from a space-based system. Such a mechanism will initiate an active AEGIS track at the earliest space-based detection of launch prior to a complete track being developed by the spaceborne sensor system. Since the AEGIS system has a much faster revisit schedule to an area of interest than does a space-based sensor, this will permit much faster localization and tracking using the full three-dimensional capabilities (range, azimuth and elevation) of the AEGIS tracking system.

Past work has led to a Kalman-based interactive multiple model design for boost and transition phase tracking of a TBM. Currently focus is on spacecraft-to-AEGIS hand-off issues and on backfitting algorithms to determine TBM launch locations in the shortest possible time. Simulations have been developed to test our sensor fusion and tracking algorithms, and classified missile trajectory data has been acquired for more realistic algorithm tests. Testing and algorithm development is focusing on AEGIS-specific measurement and data acquisition capabilities.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Modeling and Simulation

**KEYWORDS:** Theater Ballistic Missiles, Sensors, Extended Kalman Filters, Data Association and Target Tracking

## ASSESSMENT OF OCEAN SURFACE ROUGHNESS ON EM PROPAGATION

**Ramakrishna Janaswamy, Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Space and Naval Systems Center**

**OBJECTIVE:** To develop theoretical model for assessing the effect of ocean surface roughness on long-range propagation.

**SUMMARY:** When waves travel over a rough surface, its effect on forward propagation at low grazing angles can be studied in terms of an equivalent impedance of a flat plane. The impedance is such that it produces the same reflection coefficient for specularly propagating waves. A multi-section Volterra integral equation procedure was developed to extract this equivalent impedance for the wind-driven ocean surface with a specified sea spectrum. The procedure developed combines the advantages of a Volterra integral equation and the Fourier split-step algorithm of the parabolic wave equation.

### CONFERENCE PRESENTATION:

Janaswamy, R. and Motta, M., "Low Grazing Angle Forward Propagation Over Rough Surface Using Parabolic Equation," URSI General Assembly, University of Toronto, Toronto, Canada, URSI paper # BP2.3.5, 13-21 August 1999.

### THESIS DIRECTED:

Motta, M., "Equivalent Impedance of Rough Surface at Low Grazing Angles," Master's Thesis, Naval Postgraduate School, September 1999.

**DoD KEY TECHNOLOGY AREA:** Battlespace Environments

**KEYWORDS:** Parabolic Equation, Rough Surface, Propagation

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## 3D SITE SPECIFIC PROPAGATION STUDIES FOR WIRELESS COMMUNICATIONS

**Ramakrishna Janaswamy, Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: United States Army Research Office**

**OBJECTIVE:** To develop a 3D propagation prediction model for wireless communications in outdoor environments. This is a 3-year project continuing on until July 2002.

**SUMMARY:** Work was initiated to do the formulation of the problem using a scalar parabolic equation. The final parameters of interest are path loss and the r.m.s. angular spreading of waves. The latter is useful in determining the spacing that is needed in adaptive antenna arrays. Some of the issues considered during formulation were numerical dispersion, numerical anisotropy of errors, boundary conditions on the obstacles, outer boundary conditions, etc.

### CONFERENCE PRESENTATION:

Tan, H.W. and Janaswamy, R., "Effect of Element Mutual Coupling on the Performance of Adaptive Arrays," 1999 Joint IEEE AP-S Symposium/URSI Meeting, Renaissance Hotel, Orlando, FL, URSI paper # URSI-B1-2-014, 11-16 July 1999.

### THESIS DIRECTED:

Wee, T.H., "The Effect of Element Mutual Coupling on the Performance of Adaptive Arrays," Master's Thesis, Naval Postgraduate School, March 1999.

**DoD KEY TECHNOLOGY AREA:** Battlespace Environments

**KEYWORDS:** Parabolic Equation, Wireless Propagation

## ENGINEERING AND TECHNICAL SUPPORT DETERMINING LIMITATIONS OF ANTENNAS FOR USE IN IW UNDER PHYSICAL CONSTRAINTS

**Jovan Lebaric, Visiting Associate Professor**  
**Richard W. Adler, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Electronics Logistics Office (NELO)**

**OBJECTIVE:** The objective of the proposed research is to establish the performance limits, using theoretical and computer models, for various antenna types that could be physically located within the volume of Universal Modular Mast (UMM), assuming that mechanical deployment of the antennas outside of the UMM volume is not desirable.

**SUMMARY:** Computer modeling and simulation of wideband, circularly-polarized directional antennas subject to volume constraints has been performed to identify the antenna design best suited for the sponsor's intended application.

### CONFERENCE PRESENTATIONS:

Lebaric, J., Silva, M., Adler, R., and Cutsumbis, P., "RATTLE-1: A Compact, Broadband Directional UHF Communications Antenna," International Symposium on Antennas and Propagation 2000 (ISAP2000), Fukuoka, Japan, submitted for presentation.

Silva, M., Lebaric, J., Adler, R., and Cutsumbis, P., "The Antenna Comparison Technique (ACT)," International Symposium on Antennas and Propagation 2000 (ISAP2000), Fukuoka, Japan, submitted for presentation.

Silva, M., Lebaric, J., Adler, R., and Cutsumbis, P., "A Method of Obtaining Antenna Overall Efficiency from Antenna Computer Simulations," International Symposium on Antennas and Propagation 2000 (ISAP2000), Fukuoka, Japan, submitted for presentation.

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## **THESES DIRECTED:**

Silva, M., "Optimum Antennas with Dimension Constraints," Engineer's Degree, Naval Postgraduate School, September 1999.

Cutsumbis, P., "Modeling and Prototyping of Cavity Backed Conical Spiral Wideband Antenna for Submarine Applications," Master's Thesis, Naval Postgraduate School, September 1999.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Antennas, Modeling and Simulation

## **PRELIMINARY DESIGN OF LOW FREQUENCY EIGEN-ANTENNA FOR EA-6B**

**Jovan Lebaric, Visiting Associate Professor  
Richard W. Adler, Research Associate Professor  
Department of Electrical and Computer Engineering  
Sponsor: Naval Air Systems Command**

**OBJECTIVE:** To design a wideband antenna (subject to size and shape constraints) capable of extending the range of operation of the aircraft-mounted USQ-113 system to lower frequencies.

**SUMMARY:** Electrical performance (input impedance, radiation patterns, overall efficiency, etc.) of a number of different antennas at several available locations on the EA-6B aircraft has been estimated using computational electromagnetic software in order to determine the location, type, and size/shape of the optimum antenna.

## **CONFERENCE PRESENTATION:**

Lebaric, J. and Miller, C., "Low VHF Antenna Location and Design for the EA-6B," 1999 Antenna Applications Symposium, Robert Allerton Park, Monticello, IL, 15-17 September 1999.

## **THESIS DIRECTED:**

Miller, C., "Low Band VHF Antenna Design for the Grumman EA-6B Aircraft," Master's Thesis, Naval Postgraduate School, June 1999.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Antennas, Computational Electromagnetics

## **MEASUREMENTS OF SHIPBOARD FIRE EFFECTS ON RF COMMUNICATIONS IN THE 2.5 GHZ ISM BAND**

**Jovan Lebaric, Visiting Associate Professor  
Richard W. Adler, Research Associate Professor  
Department of Electrical and Computer Engineering  
Sponsor: Naval Surface Warfare Center-Carderock Division**

**OBJECTIVE:** To determine the effects of fuel fires in ship compartments on propagation of radio signals in the 2.4 GHz ISM band through measurements of signal attenuation using directional and non-directional antennas.

**SUMMARY:** Automated (computer-controlled) measurements of signal propagation losses through diesel (~2 MW) and heptane (~5 MW) fires were performed in the machine compartment aboard ex-USS Shadwell the week of May 5,

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1999. Directional (~ 20 dB gain) and non-directional (~ 3 dB gain) antennas were used to determine the path loss through fire and water mist resulting from the fire extinguishing system.

**THESIS DIRECTED:**

Xifaras, D. and Deyannis, C., "Experimental Determination of the Effects of Shipboard Compartment Fire on RF Communications in the 2.4 GHz ISM Band," Master's Thesis, Naval Postgraduate School, June 1999.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Communications, Fire, Ship

**WIDEBAND ANTENNA FEASIBILITY STUDY FOR  
JOINT TACTICAL RADIO (JTR)**

**Jovan Lebaric, Visiting Associate Professor**

**Richard W. Adler, Research Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Space and Naval Warfare Systems Center-San Diego**

**OBJECTIVE:** To determine the antenna system for the man-portable implementation of the Joint Tactical Radio (JTR).

**SUMMARY:** The JTR is intended to operate over an extremely wide bandwidth (2 to 2000 MHz). In order to cover this frequency range with a man-portable antenna, the concept of COMbat Wear INtegration (COMWIN) concept was developed the PIs. The essence of the COMWIN concept is integration of several antennas (each covering a section of the JTR frequency range) with the items of combat wear of a dismounted soldier, such as the (kevlar) helmet and the flak vest.

**CONFERENCE PRESENTATIONS:**

Lebaric, J., and Adler, R., "COMbat Wear INtegration (COMWIN) Antenna Concept for Man-Portable Implementation of the Joint Tactical Radio System (JTRS)," MILCOM 2000, Los Angeles, CA, submitted for presentation.

Gainor, T., Lebaric, J., and Adler, R., "Ultra-Wideband VHF/UHF Radio Frequency Vest Antenna for Man-Portable Implementation of the Joint Tactical Radio System (JTRS)," MILCOM 2000, Los Angeles, CA, submitted for presentation.

Lebaric, J., Tan, A., and Adler, R., "An Ultra-Wideband UHF Helmet Antenna for Man-Portable Implementation of the Joint Tactical Radio System (JTRS)," MILCOM 2000, Los Angeles, CA, submitted for presentation.

**THESIS DIRECTED:**

Tan, A-T., "Design of an Ultra-Wideband Low Profile Vertically Polarized UHF Antenna for the U.S. Ground Troop Helmet," Master's Thesis, Naval Postgraduate School, March 1999.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Wideband Antennas, JTR, COMWIN

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## PROJECT GUSTY ORIOLE

Herschel H. Loomis, Jr., Professor

Department of Electrical and Computer Engineering and Space Systems Academic Group  
RADM Thomas C. Betterton, USN (Ret), Naval Space Technology Chair Professor of Space Systems

Alan Ross, Professor, Navy TENCAP Chair Professor

Sponsor: National Reconnaissance Office

**OBJECTIVE:** To conduct research into architectures and algorithms for the acquisition, processing, and communication of tactical information. To provide support for the course Space Systems 3001, Military Applications of Space and for SS4041 and SS4051, Military Space Systems and Technologies.

**SUMMARY:** Investigated Algorithms and architectures of systems for the production, distribution and analysis of tactical information. Investigated architectures of spaceborne computer systems. Planned a multi-source maritime situational awareness experiment for Spring 1999. Planned the inclusion of a major space system architecture study in SS4051 in Winter 1999. Worked in support of a Communications Directorate project which has been transitioned to direct support through a CRADA. Developed Computer algorithms for application to SBIFE, the correction of Doppler errors and geolocation based on cyclostationarity. Presented research results on a classified communications systems design at a Technical Interchange Meeting at an LA area contractor facility, to officers of the Communications Directorate, National Reconnaissance Office, December 1999.

### PUBLICATION:

Loomis, H.H., Jr., "Geolocation of Electromagnetic Emitters," Naval Postgraduate School Technical Report, NPS-EC-099-008, October 1999.

### THESES DIRECTED:

Conner, M., "Detection and Geolocation of Wideband Transmissions (U)," Master's Thesis, Naval Postgraduate School, March 1999.

Linton, S.G., "Multi-Sensor Data for Maritime Situational Awareness (U)," Master's Thesis, Naval Postgraduate School, September 1999.

Olsen, M., "Simulation of a Multi-target, Multi-sensor, Track-Splitting Tracker for Maritime Surveillance," Master's Thesis, Naval Postgraduate School, September 1999.

Streight, D., "Maximum-Likelihood Estimators for the Time and Frequency Differences of Arrival of Cyclostationary Digital Communications Signals," Ph.D. Dissertation, Naval Postgraduate School, June 1999.

**DoD KEY TECHNOLOGY AREA:** Space Vehicles

**KEYWORDS:** Space Based Computing, Situational Awareness

## GEOLOCATION WORKBENCH

Herschel H. Loomis, Jr., Professor

Department of Electrical and Computer Engineering

Timothy Shimeall, Professor

Department of Computer Science

Sponsor: Reconnaissance Research Center

**OBJECTIVE:** To develop a software workbench in the MATLAB environment to facilitate the development and testing of algorithms related to the geopositioning of electromagnetic emitters from various types of observation platforms.

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**SUMMARY:** Concluded the project after the departure of Prof. Shimeall in April 1999. The workbench now supports: 1) The conversion of pre-detected IF sampled signal files from a variety of standard formats to an internal standard compatible with the CPEG program files; 2) Routines for writing and reading internal standard PDW data files; 3) The inclusion of several demonstration signal processing routines; 4) The inclusion of several demonstration signal display routines; and 5) The inclusion of a 2 dimensional TDOA based Newton-Raphson geolocation algorithm for pedagogical purposes.

An abstract was submitted and accepted for the presentation of a demonstration of the program at the NRO/NSA Geolocation Workshop to be held on 22-24 March 2000.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Emitter Location, Geolocation

## IT-21 VULNERABILITY ASSESSMENT

John McEachen, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Engineering Logistics Office

**OBJECTIVE:** Develop models and simulations of IT-21 specific standards-based digital communications networks using MIL3's OPNET network modeling software environment. Determine infrastructure constraints and vulnerabilities based on simulated results. This work is part of a continuing project with NELO.

**SUMMARY:** Two subprojects are addressed within this project: 1) IT-21 standards-based software modeling for susceptibility analysis; and 2) hardware simulation and testing. With respect to the first topic, a baseline simulation model has been developed of a projected IT-21 standards-based network. Additionally, two initial attack simulations have been developed. These simulations have shown that significant vulnerabilities exist in the way traffic is routed through IT-21 networks. Under the second subproject, a simulated IT-21 compliant wide area network (WAN) has been constructed in the Advanced Networking Laboratory using the SX-14 data channel simulator. Actual vulnerability analysis began with the delivery of an Adtech AX/4000 analyzer/generator test system in March. The project has yielded several significant findings related to vulnerabilities of WAN routing protocols and has proposed several solutions to protecting IT-21 networks, specifically the technique of connection utilization masking. Several aspects of this project are classified. This project is in its second year of funding.

## PUBLICATIONS:

Carlson, F.R. and McEachen, J.C., "OPNET Performance Model of Kerberos Authentication Service," *Proceedings of OPNETWORK '99*, Vol. 1, Washington, D.C., pp. 232-235, 24-29 August 1999.

Fuller, O.K., McEachen, J.C., and Therrien, C.W., Content Analysis of Random Cell Injection in ATM Networks, *Proceeding of the 33<sup>rd</sup> IEEE Asilomar Conference on Signals, Systems and Computers*, Vol. 2, pp. 1013-1016, Pacific Grove, CA, 24-27 October 1999.

McEachen, J.C., Fuller, O.K., and Therrien, C.W., "Analyzing ATM Traffic Content using Hidden Markov Models," *Proceeding of the 1999 IEEE 2<sup>nd</sup> International Conference on Information, Communication, and Signal Processing*, Vol. II, Singapore, pp. 186-190, 7-10 December 1999.

McEachen, J.C., Fuller, O.K., Powers, D.A., and Kirwin, J.P., "Network-Centric Vulnerability Assessment of IT-21 Compliant Architectures," *Proceedings of 1999 IEEE Military Communications International Symposium (MILCOM '99)*, Vol. C1, Atlantic City, NJ, pp. 24-27, 31 October – 3 November 1999.

McEachen, J.C. and Batson, M. S., "Performance Analysis of an ATM High-speed Network Interface," *Proceedings of the 6<sup>th</sup> IEEE International Conference on Electronics, Circuits and Systems*, Vol. 1, Pafos, Cyprus, pp. 101-104, 3-5 September 1999.

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McEachen, J.C. and Batson, M. S., "Modeling Bus Contention in an ATM High-speed Network Interface Architecture," *Proceedings of the 42nd Midwest Symposium on Circuits and Systems*, Los Gatos, NM, 8-11 August 1999.

Powers, D.A. and McEachen, J.C., "Modeling the Performance of Border Gateway Protocol (Bgp-4) Route Flap Damping Algorithms in the Internet," *Proceedings of OPNETWORK '99*, Vol. 1, Washington, DC, pp. 360-363, 24-29 August 1999.

## CONFERENCE PRESENTATIONS:

McEachen, J.C., "Vulnerability Assessment of NT Networking over ATM," ACM sponsored lecturer, United States Naval Academy, Annapolis, MD, 23 January 1999.

McEachen, J.C., "Modeling Bus Contention in an ATM High-Speed Network Interface Architecture," 42nd Midwest Symposium on Circuits and Systems, Los Gatos, NM, 10 August 1999.

McEachen, J.C., "Performance Analysis of an ATM High-Speed Network Interface," 6<sup>th</sup> IEEE International Conference on Electronics, Circuits and Systems, Pafos, Cyprus, 3 September 1999.

McEachen, J.C., "Content Analysis of Random Cell Injection in ATM Networks," 33<sup>rd</sup> IEEE Asilomar Conference on Signals, Systems and Computers, Pacific Grove, CA, 26 October 1999.

McEachen, J.C., "Network-Centric Vulnerability Assessment of IT-21 Compliant Architectures," 1999 IEEE Military Communications International Symposium (MILCOM '99), Atlantic City, NJ, 1 November 1999.

McEachen, J.C., "Analyzing ATM Traffic Content using Hidden Markov Models," 1999 IEEE 2<sup>nd</sup> International Conference on Information, Communication and Signal Processing, Singapore, 10 December 1999.

## THESES DIRECTED:

Carlson, F.R., "OPNET Performance Simulation of Network Security Services," Master's Thesis, Naval Postgraduate School, June 1999.

Cay, A., "Connection Utilization Masking in ATM Networks," Master's Thesis, Naval Postgraduate School, December 1999.

DeMille, D.W., "Design of Advance Analysis Software for IT-21 Compliant Networks," Master's Thesis, Naval Postgraduate School, December 1999.

Fuller, O.K., "Mitigating Network Intrusion in Encrypted ATM Layer Networks," Master's Thesis, Naval Postgraduate School, September 1999.

Kirwin, J.P., "Asynchronous Transfer Mode and Local Area Network Emulation Standards, Protocols, and Security Implications," Master's Thesis, Naval Postgraduate School, December 1999.

Powers, D.A., "Influencing Route Selection Performance in Border Gateway Protocol (BGP)," Master's Thesis, Naval Postgraduate School, September 1999.

Prisella, J.R., "Analysis of an Emulated IT-21 LAN Over a Simulated Ship-to-Shore Satellite Link," Master's Thesis, Naval Postgraduate School, September 1999.

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Modeling and Simulation, Computing and Software

**KEYWORDS:** Information Operations, Asynchronous Transfer Mode (ATM), ATM Traffic Modeling, SONET

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## WIRELESS LOCAL AREA NETWORK (WLAN) ANALYSIS

John McEachen, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: National Security Agency

**OBJECTIVE:** Perform analysis on the susceptibility of WLANs to passive intercept. Provide guidance and consultation on future initiatives in wireless LAN research.

**SUMMARY:** Interest in portable, high-bandwidth digital communications methods spans the world and presents a formidable challenge to the Defense Department of the United States. While anxious to use new communications equipment, the armed services are wary of the vulnerabilities they expose. This project examines the vulnerability of wireless local area networks (WLANs) when used by tactical units in an urban setting.

The U. S. Marine Corps experimented with WLANs during Exercises Urban Warrior '99 and Kernel Blitz '99. Samples of exercise transmissions were collected and recorded in support of this project. Two direct sequence spread spectrum (DSSS) WLAN detectors were designed and implemented to analyze the data. One is an optimal detector and the other is non-optimal. This project details the design of the detectors and presents an analysis of the performance of the non-optimal detector. This project also examines potential configurations of future WLANs and Ad-Hoc networks in a tactical setting.

### PUBLICATION:

Tope, M.A., and McEachen, J.C., "Low-Power Multipoint Relay of Tactical Communications in a Fading Environment with Interference," *Proceedings of the 1999 IEEE Military Communications International Symposium (MILCOM 1999)*, Vol. C2, Atlantic City, NJ, pp. 459-462, October 1999.

### THESIS DIRECTED:

Weber, T.A., "Detection of Wireless Local Area Networks in an Urban Tactical Environment," Master's Thesis, Naval Postgraduate School, December 1999.

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Modeling and Simulation, Computing and Software

**KEYWORDS:** ATM, Wireless, LAN, High Speed Networking, Ad-Hoc Networking

## COMPUTER MODELING OF HIGH-SPEED WIRELESS LOCAL AREA NETWORKS

John McEachen, Assistant Professor

Department of Electrical and Computer Engineering

Sponsor: National Security Agency

**OBJECTIVE:** Develop models for the assessment of wireless LAN performance over non-standard distances. Provide guidance and consultation on future initiatives in wireless LAN research.

**SUMMARY:** An extension of the WLAN analysis project, this project uses the OPNET Modeler network simulation tool to perform computer simulation of radio frequency (RF) environments where wireless LANs may be implemented. Issues relating to receiver sensitivity and performance in noisy environments will be examined. Modeling includes analysis of ad-hoc networks as well. Work on this project began in November 1999.

### PUBLICATIONS:

Tope, M.A. and McEachen, J.C., "Performance Evaluation of Synthetic Waveguide Communication in a Nakagami M-Fading Environment," to appear in the *Proceedings of the 2000 IEEE Military Communications International Symposium (MILCOM 2000)*, Los Angeles, CA, October 2000.

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Tope, M.A. and McEachen, J.C., "An Ad-Hoc Network with Spatial Diversity Routing," to appear in the *Proceedings of the 2000 IEEE Military Communications International Symposium (MILCOM 2000)*, Los Angeles, October 2000.

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Modeling and Simulation, Computing and Software

**KEYWORDS:** ATM, Wireless, LAN, High Speed Networking, Ad-Hoc Networking

## RADIATION HARDENED SPACE BASED SOLAR CELLS AND ELECTRONIC DEVICES

**Sherif Michael, Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Research Laboratory**

**OBJECTIVE:** To study the Space radiation effects on state-of-the-art solar cells including GaAs and InP cells. To investigate annealing methods developed in previous NPS research on the recovery of radiation degraded performance of advanced space cells. And develop radiation hardened Analog VLSI circuits for space applications.

**SUMMARY:** Continuation of the ongoing research on Photovoltaic Power Technology. Research tasks include optimizing current annealing methods previously developed for GaAs cells. The tasks also include investigating of the new Laser annealing technique on GaAs and InP solar cells. Irradiating solar cells using NPS Linear Accelerator, and measuring their characteristics using the newly developed Solar Simulator Facilities. Other tasks are to investigate radiation effects on different electronic devices. Radiation testing of Analog VLSI chips previously designed and fabricated, using the NPS Linear Accelerator. Major research thrusts are annealing of radiation-damaged solar cells, investigating of laser annealing techniques for radiation-damaged solar cells, and radiation tolerant ASIC and analog IC design, implementation, and testing.

### PUBLICATIONS:

Pieper, R. and Michael, S., "Circuit Modeling to Predict the Performance of Forced Cooled Plate Structure," *Proceedings of the 1999 IEEE International Symposium on Circuits and Systems*, Orlando, FL, June 1999.

Pieper, R. and Michael, S., "A Robust Algorithm for Predicting Freezeout and Exhaustion Under Equilibrium Conditions," *Proceedings of the Second International Conference on Modeling and Simulation of Microsystems*, San Juan, PR, April 1999.

### THESES DIRECTED:

Kubicki, A.R., "The Design and Implementation of a Digitally Programmable GIC Filter," Master's Thesis, Naval Postgraduate School, September 1999.

Lewis, B.P., "Dark Current Analysis and Computer Simulation of Triple-Junction Solar Cells," Master's Thesis, Naval Postgraduate School, December 1999.

McCloy, D.J., "High Efficiency Solar Cells: A Model in SILVACO," Master's Thesis, Naval Postgraduate School, September 1999.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Environmental Quality

**KEYWORDS:** Space Radiation Effects, Satellites, Annealing, Radiation Hardened, Computer Modeling

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## PHOTONIC SAMPLING ARCHITECTURES FOR MICROWAVE SIGNAL COLLECTION AND ANALYSIS

Phillip E. Pace, Associate Professor

John P. Powers, Professor

Department of Electrical and Computer Engineering

Sponsors: Center for Reconnaissance Research and Naval Postgraduate School

**OBJECTIVE:** This project continues the investigation of photonic sampling of wideband radio frequency and microwave signals and examines the subsequent analog-to-digital conversion process. In particular, it continues an experimental evaluation of the NPS sigma fiber laser and the development of optical signal processing architectures for oversampling sigma-delta modulation in order to relax the sampling laser's jitter and optical pulsewidth requirements.

**SUMMARY:** A novel fiber lattice accumulator for integrated optical  $\Sigma\Delta$  digital antenna technology has been designed. The fiber lattice design uses phase modulation to produce the proper interference between the input optical pulse and a recirculating optical pulse in order that they may be coherently combined. In this manner, the accumulation takes into account the sign of the sampled bipolar antenna signal. The fiber lattice performance was numerically evaluated within a first-order optical  $\Sigma\Delta$  digital antenna phase-coherent simulation. The error in antenna performance for several input signals has also been quantified. An experiment was designed to confirm operation of the fiber lattice accumulator and components were ordered to implement the experiment. In addition, modifications to the NPS sigma laser were designed to achieve narrower pulses and decreased jitter and components were ordered for implementation of the improved design.

### PUBLICATIONS:

Butler, J.M., Pace, P.E., and Powers, J.P., "Experimental Results of a Low-Power Sigma Mode-Locked Laser for Applications in Mobile Sampling of Wideband Antenna Signals," *Proceedings of the 9th Annual DARPA Symposium on Photonic Systems for Antenna Applications*, Monterey, CA, February 1999.

Pace, P.E., Bewley, S.A., and Powers, J.P., "Fiber Lattice Accumulator Design Considerations for Optical Analog-to-Digital Converters," accepted for publication in *Optical Engineering*.

Pace, P.E., Bewley, S.A., and Powers, J.P., "Fiber Lattice Accumulator Design Considerations for Optical Digital Antennas," *Proceedings of the 9th Annual DARPA Symposium on Photonic Systems for Antenna Applications*, Monterey, CA, February 1999.

Pace, P.E., Powers, J.P., Butler, J.M., and Bewley, S., "NPS Research in Digital Antennas," *Proceedings of the DARPA/ETO Photonic A/D Converter Technology Meeting*, MIT-Lincoln Laboratory, 20 April 1999.

### CONFERENCE PRESENTATIONS:

Butler, J.M., Pace, P.E., and Powers, J.P., "Experimental Results of a Low-Power Sigma Mode-Locked Laser for Applications in Mobile Sampling of Wideband Antenna Signals," 9th Annual DARPA Symposium on Photonic Systems for Antenna Applications, Monterey, CA, February 1999.

Pace, P.E., Bewley, S.A., and Powers, J.P., "Fiber Lattice Accumulator Design Considerations for Optical Digital Antennas," 9th Annual DARPA Symposium on Photonic Systems for Antenna Applications, Monterey, CA, February 1999.

Pace, P.E., Powers, J.P., Butler, J.M., and Bewley, S., "NPS Research in Digital Antennas," DARPA/ETO Photonic A/D Converter Technology Meeting, MIT-Lincoln Laboratory, Lexington, MA, 20 April 1999.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Electronic Warfare, Other (Optics)

**KEYWORDS:** Mode-locked Fiber Lasers, Sigma-delta, Analog-to-Digital Converter, Wideband Signal Sampling

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## ROBUST SYMMETRICAL NUMBER SYSTEM DIRECTION FINDING ARRAY

Phillip E. Pace, Associate Professor

David C. Jenn, Associate Professor

Department of Electrical and Computer Engineering

Sponsors: Center for Reconnaissance Research and Naval Postgraduate School

**OBJECTIVE:** This research investigated a new direction finding (DF) antenna architecture based the robust symmetrical number system (RSNS). The RSNS has an inherent performance advantage over the earlier optimum symmetrical number system (OSNS) design. The antenna is capable of wideband, instantaneous direction finding. The baseline (physical length) is much smaller than conventional designs, yet high resolution DF is possible.

**SUMMARY:** The RSNS theory was developed and a prototype array antenna designed. A computer simulation of the array was developed, and the array performance computed as a function of several design parameters. The prototype design is presently being built and measurements in the NPS anechoic chamber are planned. Specialized printed circuit antenna elements were designed to allow for the close spacing of the elements. Microwave components were purchased and tuned over the frequency band of operation (7 to 8 GHz). The electronic circuits that digitize and compute the signal's angle of arrival are currently being designed and built. A program design review was held at NPS in July 1999.

### PUBLICATIONS:

Jenn, D.C., Pace, P.E., and Powers, J., "High-Resolution Acoustic Arrays Using Optimum Symmetrical Number System Processing," *Acoustical Imaging*, Vol. 24, (to be published).

Pace, P.E., Styer, D., Akin, I.A., "A Folding ADC Preprocessing Architecture Employing a Robust Symmetrical Number System with Gray-Code Properties," *IEEE Transactions on Circuits and Systems-II: Analog and Digital Signal Processing*, (to be published).

Wickersham, D.J., Pace, P.E., Styer, D., Jenn, D.C., Vitale, R., and York, N.S., "High Resolution DF Architectures Using a Robust Symmetric Number System Encoding," *IEEE International Phased Array Systems and Technology Conference*, PAST-071, Dana Point, CA, 21-26 May 2000 (to be published).

### CONFERENCE PRESENTATIONS:

Wickersham, D.J., Jenn, D.C., Pace, P.E., and Vitale, R., "Robust Symmetrical Number System Phase Sampled Antenna Architectures," presentation to NPS Center for Reconnaissance Research Sponsor, Monterey, CA, 8 July 1999.

Wickersham, D.J., Pace, P.E., Styer, D., Jenn, D.C., Vitale, R., and York, N.S., "High Resolution DF Architectures Using a Robust Symmetric Number System Encoding," to be presented at the *IEEE International Phased Array Systems and Technology Conference*, Dana Point, CA, 21-26 May 2000.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics

**KEYWORDS:** Direction Finding, Symmetrical Number System, Antenna Design

## DIGITAL TARGET IMAGING ARCHITECTURES

Phillip E. Pace, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Research Laboratory

**OBJECTIVE:** This project continues investigating the feasibility of developing a digital signal processor to intercept wideband (chirp) signals from a high-resolution inverse synthetic aperture radar and synthesize a false target using all-digital complex modulation techniques.

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**SUMMARY:** A method and system for signal processing, especially useful as a signal repeater, i.e., for simulating the characteristic echo signature of a pre-selected target was invented. The system has a digital radio frequency memory (DRFM) and associated circuitry, including digital tapped delay lines, and a modulator in each delay line to impose both amplitude and frequency modulation in each line. Use of digital semiconductor technology increases the bandwidth and sensitivity of such a repeater over prior analog based systems. It also reduces the noise of the repeated signal, reduces the size and cost of such a system, and permits real time alteration of operating parameters, permitting rapid and adaptive shifting among different kinds of targets to be simulated. Preferably the associated circuitry is unitary with, and part of, the DRFM. A unique property of the DIS is its ability to synthesize false targets using chirp signals of any duration. The number of tap stages is equal to the target range-extent desired for synthesis.

## **PUBLICATION:**

Pace, P.E., "Digital Target Imaging," *Proceedings of the ONR EW S&T Gatherings*, Naval Research Laboratory, Washington, DC, 19-23 April 1999.

## **CONFERENCE PRESENTATION:**

Pace, P.E. and Surratt, R.E., "Digital Image Synthesizers for ISAR Counter-Targeting," presentation to Code 5740 Ships Self-Defense, Naval Research Laboratory, Washington, DC, 3 March 1999.

## **PATENT APPLICATION:**

Pace, P.E., Surratt, R.E., and Yeo, S-Y., "Signal Synthesizer and Method Therefor," Patent Application NC 79,429, Naval Research Laboratory Code 3008, filed 1 September 1999.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics

**KEYWORDS:** Target Imaging, Inverse Synthetic Aperture Radar, Counter-Targeting, Application Specific Integrated Circuit

## **SOFTWARE DEVELOPMENT AND RESEARCH SUPPORT FOR ANTI-SHIP MISSILE SIMULATOR TECHNOLOGY**

**Phillip E. Pace, Associate Professor  
Department of Electrical and Computer Engineering  
Sponsor: Naval Research Laboratory**

**OBJECTIVE:** This project continues the investigation into a relative targeting algorithm for visualizing test range results using only the captive carry onboard sensors (GPS, INS, simulator seeker targeting information) is investigated. This project also continues to provide support for the Chair of the N9 surface Navy's Threat Missile Simulator Validation Working Group.

**SUMMARY:** A relative targeting architecture that displays the test range results in geodetic coordinates using only the sensors available on board the captive carry platform is reported. To derive the target position in geodetic coordinates, a lever-arm correction process is described that determines each seeker's position and the corresponding pitch and yaw of the simulator. Combining the seeker's positional parameters with its targeting variables, the seeker track point is calculated and displayed in geodetic coordinates. A track tagging algorithm is presented to identify the true target (e.g., the ship) using the drift angle from the INS. A spatial filtering algorithm is also described to reduce the visual noise in the track image. Experimental results using the India II, Kilo, Quebec, Lima, Alpha I and Golf I (Sim 1, Sim 13) anti-ship cruise missile simulators are reported. The simulators were captive-carried onboard the NRL P-3 research aircraft flying towards the USS Peterson (DD 969) on the VACAPES test range, July 9 1998. Simulator experimental results are used to demonstrate the feasibility of the relative targeting algorithm for determining the EW effectiveness of the ship's Nulka off board decoy system in near real-time.

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## **PUBLICATION:**

Pace, P.E., Nash, M.D., Zulaica, D.P., Di Mattesa, A.A., and Hosmer, A., "A Relative Targeting Architecture for Captive-Carry Missile Simulator Experiments," *IEEE Transactions on Aerospace and Electronic Systems*, (in review).

## **CONFERENCE PRESENTATIONS:**

Pace, P.E., "Introduction to the NPS Center For Joint Services EW and SVWG Program Overview," presented to the N9 Threat ASCM Simulator Validation Working Group, Naval Postgraduate School, 13 April 1999.

Pace, P.E., "SVWG Validation Plan Review and Comments," presented to the N9 Threat ASCM Simulator Validation Working Group, Naval Postgraduate School, 13 April 1999.

Pace, P.E., "Overview of the Surface Navy's Unique Threat Simulator Validation Working Group (U)," presentation to the DoD Threat Systems Validation Working Group (SECRET), Naval Weapons Center, China Lake, CA, 7-9 December 1999.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics

**KEYWORDS:** Relative Targeting, Anti-Ship Cruise Missiles, Effectiveness Calculations

**NULKA BLUE RIBBON PANEL**  
**Phillip E. Pace, Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Research Laboratory**

**OBJECTIVE:** The four-member Nulka Blue Ribbon Panel was established by the Chief of Naval Operations in order to review the Nulka/MK53 decoy launch system test requirements and test procedures. The analysis performed by COMOPTEVFOR, Pt. Mugu/China Lake, and NRL were to be reviewed. The reviews were done in order to assess the validity of the test procedures and the analysis methodology.

**SUMMARY:** The Nulka Blue Ribbon Panel (with representatives from NPS, Chief of Naval Operations, Center for Naval Analysis and the Applied Physics Laboratory) provided conclusions and recommendations on the adequacy of EW test procedures and assets utilized. The Blue Ribbon Panel also provided an independent assessment and performance analysis of the Nulka/MK53 decoy launch system during the operational test in question. Future testing concerns and recommendations concerning fleet introduction of the Nulka were given.

## **PUBLICATION:**

Blake, D., Borrelli, R., Feldman, L., and Pace, P.E., "Nulka OPEVAL Assessment Blue Ribbon Panel (U)," *Center for Naval Analysis Informal Paper 06-990053.00* (SECRET), 20 January 1999.

## **CONFERENCE PRESENTATION:**

Blake, D., Borrelli, R., Feldman, L. and Pace, P.E., "Nulka OPEVAL Assessment Blue Ribbon Panel (U)," presentation to CNO and Commander, Operational Test and Evaluation Force (SECRET), Naval Research Laboratory, Washington, DC, 15 January 1999.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics

**KEYWORDS:** Nulka, Ship-self Defense, Blue Ribbon Panel

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## TACTICAL REACTIVE EA NETWORK MODELING AND ANALYSIS

Phillip E. Pace, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Research Laboratory

**OBJECTIVE:** The simulation analysis of several tactical reactive EA network grids and sub-grid configurations using Ares and OPNET is proposed. The augmentation of the EA-6B with off-board sensors (UAVs, micro-UAVs, ground sensors etc.) is studied to determine the impact of network performance on the C2W mission. Validation of the Ares simulation code is accomplished by comparing the results with a number of first order formulations. After the Ares results are obtained, the node patterns will be ported to OPNET in order to determine the detailed link performance.

**SUMMARY:** A single ES (electronic support) system with 15% look-through at a fixed range of 0.5 nm from a scanning radar surface-to-air missile (SAM) site was evaluated (both isotropic antenna and sinc<sup>2</sup> approximation). The ES system was then moved away from the scanning radar SAM site in 10 nm steps out to 100nm (main beam only detections). The lookthrough time was then increased to 100% and the simulation was run again. Also investigated were the use of two ES systems that are spatially separated by 0.5nm with a full update datalink. The use of two ES systems (1 an inbound strike aircraft), a UAV and a mix of 100 early warning radars and SAM radar sites (some with agile PRF, agile frequency) were also investigated. An additional 4 micro-UAVs at 1000ft each with 40MHz bandwidth and -70 dB sensitivity (micro-UAV subgrid) were then added along with 2 groups of ground sensors dispensed about the area of engagement. Only one of the sensors in each group had the power to communicate with the micro-UAV subgrid (uplink sensor). The remaining sensors within each group relayed to each other within the line-of-site until their information reached the uplink. The addition of 2-3 jamming micro-UAVs that listen to the micro-UAV subgrid were also included in the study.

### OTHER:

Goksin, C. and Guven, E., "EC4690 Network Centric Radar Electronic Warfare Experiments Notebook," EC4690 Network Centric Radar EW Laboratory, 17 September 1999.

Guimaraes, E., and Ceylan, O., "EC4690 Network Centric Radar Electronic Warfare Experiments Notebook," EC4690 Network Centric Radar EW Laboratory, 17 September 1999.

Shaw, A., "EC4690 Network Centric Radar Electronic Warfare Experiments Notebook," EC4690 Network Centric Radar EW Laboratory, 17 September 1999.

Swee, J., Garrido, E., and Widow, R., "Network Centric Results and Report Notebook," EC4690 Network Centric Radar EW Laboratory, 17 September 1999.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Sensors, Electronics

**KEYWORDS:** Suppression of Enemy Air Defense, Electronic Attack, UAVs, Micro Air Vehicles

## EA-6B COTS COMMUNICATIONS EA TRANSMITTER PROJECT

Andrew A. Parker, Research Associate

Department of Electrical and Computer Engineering

Sponsor: Office of Naval Research

**OBJECTIVE:** Investigate, modify, and test the feasibility of using commercial off-the-shelf (COTS) radio transceivers to augment the electronic attack (EA) capabilities of existing EA-6B aircraft.

**SUMMARY:** NPS modified existing COTS transceivers for use in EA augmentation. Existing EA-6B antennas were tested with the modified COTS transceivers to determine transmitter efficiency and applicability. Physical integration of COTS transceivers was considered and projected costs for implementation of the system.

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**DoD KEY TECHNOLOGY AREAS:** Sensors, Environmental Quality

**KEYWORDS:** Electromagnetic Environmental Effects, Communication Systems, Man-made Noise, Antennas

## AIRPLATFORM SURVIVABILITY ENHANCEMENT

**R. Clark Robertson, Professor**

**Frederick Levien, Senior Lecturer**

**Department of Electrical and Computer Engineering**

**Sponsors: Naval Air Warfare Center-Aircraft Division and Naval Postgraduate School**

**OBJECTIVE:** The objectives for this project are to evaluate the effectiveness of combining countermeasures with low-observable technology, both in the RF and IR domain, to evaluate the effectiveness of an IR-TALD in enhancing airplatform survivability, and to investigate the GITSIMS and MOSAIC programs individual ability to model IR tactical engagement scenarios.

**SUMMARY:** It is well known through both simulation and field tests that IR flare countermeasures can be effective in reducing the vulnerability of aircraft to incoming IR missile seekers. Smart missiles employing sophisticated CCM (counter-countermeasure) tracking algorithms can reduce or even eliminate the flare's effectiveness. Nonetheless, another gambit for the aircraft designer is the employment of designs that would either reduce IR signature or redistribute the power in the IR signature to make the aircraft less vulnerable. This parametric study demonstrates the level of synergism between the employment of both decoy flares and the employment of stealthy IR reduction methods. The effects of IR signature reduction for a large number of one-on-one simulation engagements using MOSAIC have been completed. Our results indicate that IR signature reduction does not significantly increase the effectiveness of IR flares.

### CONFERENCE PRESENTATION:

Copeland, B., Pieper, R., Robertson, C., and Levien, F., "IR-Signature Dependent Effectiveness of Flare Countermeasures," Advanced Technology Electronic Defense Systems (ATEDS) 1999 Symposium, Monterey, CA, 16-18 March 1999.

### THESES DIRECTED:

Copeland, B.W., "Comparing the MOSAIC and GTSIMS Programs in the Infrared Signature Reduction and Countermeasure Environment," Master's Thesis, Naval Postgraduate School, September 1999.

Demestihias, M., "Simulations to Predict the Countermeasure Effectiveness of Pyrophoric Type Packets Deployed from TALD Aircraft," Master's Thesis, Naval Postgraduate School, September 1999.

Rodriguez, A., "A Simulation Based Study Yielding a Full Characterization of the Miss Distance Topological Manifold for the F/A-18CD, Varying Range, Angle, Wet versus Dry Conditions and IR Signature," Master's Thesis, Naval Postgraduate School, September 1999.

**DoD KEY TECHNOLOGY AREA:** Electronic Warfare

**KEYWORDS:** Electronic Countermeasures, IR Countermeasures, Low-Observable Technology, IR Signature Reduction

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## ELECTRONIC WARFARE ADVANCED TECHNOLOGY STUDIES

**R. Clark Robertson, Professor**

**Ron Pieper, Visiting Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsors: Naval Air Warfare Center-Aircraft Division and Naval Postgraduate School**

**OBJECTIVE:** The objective of this project is to determine the conditions for which the aim point of an infrared (IR) missile on a "hot" aircraft will be on a location other than the hot metal parts of the engine and the effect this variation in aim point has on IR countermeasures (IRCM) effectiveness.

**SUMMARY:** Aircraft survivability under conditions of a missile attack depends to a large extent on the tracking performance of the missile. Because the missile will tend to track on and aim for the "hottest" part of the target within the unobscured FOV, tracking performance is expected to depend on the angle of the attack. Missiles characterized by having a spatially discriminating detection system, typically based on reticule detection technology, automatically introduce aim point sensitivity into the tracking process. The aim point of a missile threat on a targeted aircraft can be expected to change as functions of both the aspect of attack and the field of view (FOV) of the missile detection system. This raises a practical point of query. Under what conditions, if any, will the aim point move from the rear hot metal parts and plume to, for example, the nose of the plane, and what is the effect of this change in aim point on the optimum employment of IRCM? This information is relevant to the design of effective flare countermeasures. It is expected that the effectiveness of flare countermeasures will depend on a number of factors, including the aim point of the missile on the target and the relationship of the aim point to the deployment location of IRCM.

This project is new for FY00 and is ongoing.

**DoD KEY TECHNOLOGY AREA:** Electronic Warfare

**KEYWORDS:** Electronic Countermeasures, IR Countermeasures, IR Signature Reduction, IR Sensors

## A/N USQ-113 TACTICAL IMPROVEMENT PROGRAM

**Rasler W. Smith, Research Assistant Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: U.S. Pacific Fleet**

**OBJECTIVE:** Develop tactical employment of USQ-113 communications jammer and EA-6B against various radio receiving systems.

**SUMMARY:** The USQ-113 tactical communications jammer is currently carried aboard the EA-6B for use against communications receivers. However, optimum employment against radio systems have not yet been developed. Parameters being analyzed in this research effort are: aircraft positioning to account for antenna patterns and proximity to ground and jamming waveforms for use against different analog and digital modulations.

**PUBLICATIONS:** Unclassified report completion expected July 2000, Secret report September 2000, and Top Secret report October 2000.

**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communications

**KEYWORDS:** Signals Intelligence, Information Operations, Information Warfare, Communications Engineering, Communications Systems

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## EVALUATION OF CLASSIFICATION ALGORITHMS

**Charles W. Therrien, Professor**

**Tri T. Ha, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: National Security Agency**

**OBJECTIVE:** Develop methodology and software for testing of signal classification algorithms.

**SUMMARY:** This is a new program begun on 1 October 1999. The main activity for this period was to prepare a comprehensive plan for testing the HBC (Higher Order Cyclostationarity (HOCS)-based classifier) on some specific modulation types and to begin testing on some of these waveforms. Signals are being generated on a Hewlett Packard workstation using the ADS software. Initially some time was spent testing the ADS software and data transfer so that reliable testing of the HBC could be carried out according to the plan. By the end of the current reporting period we have completed initial testing of the HBC on BPSK and QPSK waveforms.

**DoD KEY TECHNOLOGY AREA:** Other (Signal Processing)

**KEYWORDS:** Signal Classification, Higher Order Cyclostationarity

## BEARTRAP POST-MISSION ANALYSIS SYSTEM

**Murali Tummala, Professor**

**Charles W. Therrien, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Advanced Maritime Projects Office**

**OBJECTIVE:** To design and develop a signal processing system capable of implementing narrowband frequency tracking, multi-target tracking, wideband and related processing, time-domain analysis, and data fusion for Beartrap post-mission analysis. The system is known as S2K (for System 2000).

**SUMMARY:** The S2K system is being developed based on commercial off the shelf technology: PentiumPro-based PC with Windows NT operating system. The user interface is being developed using Microsoft Visual C++; all processing algorithms are being coded in the C++ language as well.

During 1999, several new modules were developed for S2K. These include a DIFAR and Bearing Demultiplexer module, Broadband and Swath SPL module, Broadband Cross-Correlation Tracker module, and EER module with code for both buoy repositioning and event detection. In addition the EMST tracker and several smaller modules were fully integrated and tested in the system. The research is producing software for delivery to the sponsor. A beta version of the software is due for delivery to multiple Beartrap sites in the Spring 2000 and Version 1.0 of the software is scheduled for release at the end of summer 2000. As of October 1999 funding for the project was moved from AMPO to the program office PMA-264 in Patuxent River, MD.

### THESES DIRECTED:

Bitting, J.H. "Development of Software Modules for Calculation of Sound Pressure Levels in Broadband and Swath Acoustic Signals," Master's Thesis, Naval Postgraduate School, June 1999.

Danks, J.C., "Design and Development of the EER Module for Beartrap Post-Mission Processing System 2000," Master's Thesis, Naval Postgraduate School, December 1999.

Race, H.R. "Development of a Digital DIFAR Demultiplexer and Bearing Tracker Module," Master's Thesis, Naval Postgraduate School, June 1999.

Widow, R., "Development of Visual C++ Version of the Broadband Cross-Correlation Time Delay Tracker Module for S2K," Master's Thesis, Naval Postgraduate School, September 1999.

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**DoD KEY TECHNOLOGY AREAS:** Sensors, Computing and Software, Human Systems Interface, Other (signal processing)

**KEYWORDS:** Signal Processor Design, Acoustic Signal Processing, Graphical User Interface Design

## PHASE ADJUSTMENT CONTROL FOR LORAN-C APPLICATIONS

**Murali Tummala, Professor**

**Roberto Cristi, Associate Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: United States Coast Guard-Loran Support Unit**

**OBJECTIVE:** To develop algorithms for estimation and control of time difference error in LORAN-C receivers to replace the existing CALOC system.

**SUMMARY:** A multi-rate, multi-resolution, recursive Kalman filter algorithm is developed to model short term (on the order of seconds) as well as long term (on the order of hours) influences of disturbances. An approach to the decomposition of time difference measurements into orthogonal components at different resolution levels is studied. This enables multiple multi-resolution, multi-rate observations to be combined in an optimal manner.

### **PUBLICATION:**

Cristi, R. and Tummala, M., "Multi-Rate, Multi-Resolution Recursive Kalman Filter," *Journal of Signal Processing*, submitted in revised form.

**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communications

**KEYWORDS:** Time Difference Error, Stochastic Model, Kalman Filter

## POLARIMETRY AND SPECTROPOLARIMETRY FOR REMOTE SENSING

**Capt J. Scott Tyo, USAF, Assistant Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** Develop sensors and image processing techniques for exploiting polarimetric and spectropolarimetric information in remotely sensed images.

**SUMMARY:** A variable retardance, Fourier transform spectropolarimeter was tested in conjunction with the Space Vehicles Directorate of the Air Force Research Lab. The device was shown to be capable of reconstructing the full polarization information at each pixel, as well as measuring the spectrum in the visible. By using a pushbroom scanning methodology, the VRFTSP built up fully 7-dimensional spectropolarimetric images.

Initial results obtained with the VRFTSP indicated that there were signal-to-noise ratio problems that were inherent to the collection strategy. By analyzing the measurement system, the SNR was shown to be reduced by as much as 8 dB without improving any of the optical components. This result was generalized to apply to other polarimetric imaging configurations, and has important ramifications for the design of future polarimeters.

In addition to the above output tested, several works in progress continue as a result of this effort. In the area of spectral imaging, work continues with Professor Chris Olsen of the Physics Department on image information, and a thesis is currently under direction by LT Joel Robertson of the Information Warfare curriculum on target spectra variability in spectral images. The journal article, "Improvement of the Point Spread Function in Scattering Media by Polarization Difference Imaging," by J.S. Tyo was published in January 2000, and a second journal article, "Noise Equalization in Variable Retardance Polarimeters," by J.S. Tyo was submitted to *Optics Letters* in January 2000. The manuscript, "Variable Retardance, Fourier Transform Imaging Spectropolarimeters for Visible Spectrum Remote Sensing," by J.S. Tyo and T.S. Turner is being prepared for submission to *Applied Optics*. Additionally, four conference abstracts were submitted as a result of the work performed under this task, "Maximization of Information

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Content in Polarimetric Measurements,” by J.S. Tyo for the *IEEE Antennas and Propagation International Symposium*, “Considerations in Polarimeter Design,” by J.S. Tyo for *Polarization Measurement, Analysis, and Instrumentation III* sponsored by the Society of Photo-Optical Instrumentation Engineers (SPIE), and the two papers, “Development of an Invariant Display Strategy for Spectral Imagers,” by J.S. Tyo and R.C. Olsen and “Statistics of Target Spectra in HSI Scenes,” by J.S. Tyo, J. Robertson, J. Wollenbecker, and R.C. Olsen were submitted to *Imaging Spectrometry VI*, also sponsored by SPIE.

## **PUBLICATION:**

Tyo, J.S. and Turner, T.S., Jr., “Imaging Spectropolarimeters for Use in Visible and Infrared Remote Sensing,” *SPIE, Imaging Spectrometry V*, Vol. 3753, M. Descour and S. Shen, eds., Bellingham, WA, pp. 214-225, 1999.

## **CONFERENCE PRESENTATION:**

Tyo, J.S. and Turner, T.S., “Use of a Variable Retardance, Spatial Fourier Transform Imaging Device to Obtain Spectropolarimetric Images for Remote Sensing,” 1999 Optical Society of America Annual Meeting, San Jose, CA, 29 September - 3 October 1999.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** Polarization, Spectral Imagery, Spectropolarimetry

## **MODELING AND DEVELOPMENT OF UWB ANTENNAS**

**Capt J. Scott Tyo, USAF, Assistant Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** Investigate the performance of ultra-wideband antennas and electromagnetic systems in order to improve the performance of impulse radiating systems.

**SUMMARY:** Using computational electromagnetic techniques, synthetic media and reflector impulse radiating antennas were investigated. A new class of artificial dielectrics composed of longitudinally symmetric inclusions was developed for time-domain applications. Such media might be used to improve the prompt efficiency of IRAs as well as fabricate time-domain anti-reflection coatings for antenna optics. This class of material is the first to be proposed that can propagate a transverse electromagnetic wave along the material boundary, and the results can be generalized to assist in the development of UWB arrays.

A project that continues into CY00 is the optimization of the feed structure and aperture shape of impulse radiating antennas. By simply modifying the extent of the focusing optic, significant increases in radiated power are possible. The new designs developed under this project in 1999 should result in a 35% increase in peak power radiated from an IRA based on available results. Current work in this area involves shaping of the aperture to further increase the radiated fields.

In addition to the output below, this research project resulted in several additional works that are in progress. The journal article “Prompt Aperture Efficiency of Impulse Radiating Antennas with Application to Ultra-Wideband Arrays” by C.J. Buchenauer, J.S. Tyo, and J.S.H. Schoenberg, was provisionally accepted for publication in *IEEE Transactions on Antennas and Propagation* in December 1999, and the article “Optimization of the TEM Feed Structure for 4-Arm Impulse Radiating Antennas,” by J.S. Tyo was submitted to *IEEE Transactions on Antennas and Propagation*, in November 1999. Additionally, two abstracts were submitted for presentation at the *EUROEM 2000* meeting to be held in Edinburgh, Scotland in May 2000, “Optimal Feeds for 4-Arm IRAs” by J.S. Tyo and “Compact Sensors for Time-Domain Measurements,” by J.S. Tyo and C.J. Buchenauer.

## **PUBLICATION:**

Tyo, J.S., “Optimization of the Feed Impedance 4-Arm IRAs with Arbitrary Orientation of the Feed Arm Pairs,” *Sensor and Simulation Notes #438*, USAF Research Lab, Kirtland AFB, NM, C. E. Baum, ed., November 1999.

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## CONFERENCE PRESENTATIONS:

Tyo, J.S., Buchenauer, C.J., and Schoenberg, J.S.H., "Beamforming in Time Domain Arrays," 1999 IEEE AP-S International Symposium, Orlando, FL, 7-11- July 1999.

Tyo, J.S., Buchenauer, C.J., Gueits, J.C., and Schoenberg, J.S.H., "Artificial Materials for Time-Domain Applications," 1999 URSI General Assembly, Toronto, Canada, 13-21 August 1999.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Directed Energy Weapons

**KEYWORDS:** Ultra Wideband Electromagnetics, Impulse Radar, Ultra Wideband Arrays

## CAMPAIGN BATTLE MANAGEMENT ENGINEERING AND TECHNICAL SUPPORT

**Donald v. Z. Wadsworth, Senior Lecturer**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Space and Naval Warfare Systems Command**

**OBJECTIVE:** Research enabling communications technologies, particularly wireless ATM, to support mobile forces in connection with Campaign Battle Management. Specifically, assist the SPAWAR PD 13P-5 in connection with the satellite/ATM interface for the operational experimentation program.

**SUMMARY:** Funding covered only the last 3 weeks of September 1999. This initial effort was directed at obtaining background information, including the recent TIA IS-787 spec written by the Common ATM Satellite Interface Interoperability (CASI) working group, determining the scope of a follow-on experimental/modeling effort including an NPS C4I Master's Degree thesis effort (student identified with June 2000 graduation date), preparing a proposal for this follow-on effort, and networking to determine synergies with other related efforts. A proposal was prepared in detail but was not submitted due to the student's change of thesis topic and no replacement available. This project was not suitable for future IJWA funding.

Should the effort be re-initiated, the following classified contacts, obtained while the PI attended the IEEE/AFCEA MILCOM1999 conference in November 1999, would be of value: "Tactical ATM Over Military Satellite Communications Performance Studies," MILCOM1999 paper, USACECOM and S&TCD; "TCP/IP over ATM with SATCOM," MILCOM1999, Booz Allen & Hamilton and S&TCD; "Network Centric Vulnerability Assessment of IT-21 Compliant Architectures," MILCOM1999 paper, NPS, Professor John McEachen. Professor McEachen has an ATM simulation for interconnections with Ethernet. A further Navy contact is John Curran.

**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communications

**KEYWORDS:** SATCOM, ATM, Battle Management

## FREQUENCY COLLISION PLANNING

**Donald v. Z. Wadsworth, Senior Lecturer**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Space Command**

**OBJECTIVE:** Predict and evaluate the potential for disastrous radio frequency interference (RFI) from new and emerging commercial satellite systems into the systems upon which U.S. Naval and other U.S. Forces rely for worldwide military operations. The results may enable NPS to propose solutions for mitigating RFI due to both co-channel and spurious/out-of-band emissions.

**SUMMARY:** The initial step in this effort was to compile information on the current status of RFI with satellite systems. This work included interactions with contractors, USSPACECOM, Joint Spectrum Center, NTIA, SPAWAR, NSC, Aerospace Corp., and many others. Available software databases were examined. The results were included in the NPS Master's Thesis by Cook, which the sponsor said would be of great benefit to military involved in spectrum

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acquisition and management. The effort to assess the future impact of RFI on satellite systems is continuing under an extension of this research funding into CY2000.

## **THESIS DIRECTED:**

Cook, J.P., "Joint Spectrum Acquisition and Management for the 21st Century," Master's Thesis, Naval Postgraduate School, June 1999.

**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communications

**KEYWORDS:** Satellite, Communications, Spectrum, RFI

**MOBILE USER OBJECTIVE SYSTEM STUDY**  
**Donald v. Z. Wadsworth, Senior Lecturer**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Space and Naval Warfare Systems Command**

**OBJECTIVE:** Develop a MUOS concept which meets CERD requirements.

**SUMMARY:** An IPT consisting of 3 NPS students and the PI completed a conceptual design for the successor to the Navy's UFO satellite constellation, including the GEO constellation architecture, communications satellite design, and feasibility of cellphone terminals. At the request of the sponsor, this design was presented in the MILCOM 1999 conference and published in the Proceedings. The proposed spacecraft uses non-processing repeaters and multiple spotbeams for worldwide earth-coverage of legacy UHF terminals and cellphones. UHF frequency reuse enables at least a 5-fold increase, compared to the current UFO system, in the number of narrowband voice/data channels available to mobile units. A key feature is the reuse of both the satellite slots and frequency channels allocated to the UFO constellation. A new design element for SATCOM systems is the large antenna reflector with an area of 1250 square meters. A relocatable spare UHF satellite improves both the capacity and higher elevation angles required in urban warfare. Electric propulsion for orbit raising from LEO to GEO was investigated as a significant cost and risk reduction factor for launching the successor to the UFO and will be reported in Y2000.

## **PUBLICATIONS:**

Cook, J.P., "Joint Spectrum Acquisition and Management for the 21st Century," Master's Thesis, Naval Postgraduate School, June 1999.

Paxton, S.G.B., "A Scenario-Based Analysis of the Mobile Satellite Services," Master's Thesis, Naval Postgraduate School, June 1999.

Riley, J.R., "A Future C4 Architecture for Military Operations on Urbanized Terrain," Master's Thesis, Naval Postgraduate School, June 1999.

Wadsworth, D.v.Z., "Military Communications Satellite System Multiplies UHF Channel Capacity for Mobile Users," *Proceedings of the IEEE/AFCEA MILCOM 1999*, Atlantic City, NJ, 31 October – 3 November 1999.

**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communications

**KEYWORDS:** Satellite, Communications, Mobile, Urban

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## RADIATION HARDNESS ANALYSIS OF InP AND SiGe TECHNOLOGIES FOR SPACE APPLICATIONS

Todd Weatherford, Assistant Professor  
Department of Electrical and Computer Engineering  
Sponsor: Center for Reconnaissance Research

**OBJECTIVE:** To investigate the radiation hardness of InP and GaAs state-of-the-art electronic technologies for use in military space environments.

**SUMMARY:** Experiments utilized femto-second lasers with photo-conductive sampling probes to measure the first recorded radiation induced in-situ voltage transients internal to an integrated circuit operating at 10 GHz. Facilities at the University of Michigan's Center of Ultrafast Science were utilized for the laser experiments and computer modeling of the underlying charge transport mechanisms were performed at NPS. Results in 1998/9 showed single event sensitivity. Efforts in 1999 utilized device modeling to understand sensitivity and presented techniques to eliminate soft error sensitivity.

### PUBLICATIONS:

Weatherford, T.R., "Low Temperature Grown GaAs Buffers for Rad-Hard Applications," *2<sup>nd</sup> Symposium On Non-Stoichiometric III-V Compounds*, Erlangen, Germany, 4-6 October 1999. (invited paper)

Weatherford, T.R., "Low Temperature (LT) Grown GaAs Buffer Layers for III-V Semiconductor Processes," *IEEE GaAs IC Symposium Technical Digest*, 18 October 1999. (invited paper)

### CONFERENCE PRESENTATIONS:

Weatherford, T.R., "Low Temperature Grown GaAs Buffers for Rad-Hard Applications," *2<sup>nd</sup> Symposium On Non-Stoichiometric III-V Compounds*, Erlangen, Germany, 4-6 October 1999. (invited paper)

Weatherford, T.R., "Low Temperature (LT) Grown GaAs Buffer Layers for III-V Semiconductor Processes," *IEEE GaAs IC Symposium Technical Digest*, 18 October 1999. (invited paper)

### THESES DIRECTED:

Dailey, J., "Characterization of Semiconductor Devices for Radiation Effects Studies," Master's Thesis, Naval Postgraduate School, June 1999.

Schiefelbein, P., "Transient Response to Single Event Upset in AlInAs/GaInAs Heterojunction Bipolar Transistors," Master's Thesis, Naval Postgraduate School, September 1999.

Stansell, M., "DC Characterization of EFETs Grown on Bulk GaAs and Over Buffer Layers of Low Temperature Grown GaAs (Be)," Master's Thesis, Naval Postgraduate School, December 1999.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Materials, Processes and Structures, Modeling and Simulation

**KEYWORDS:** Radiation Effects, Indium Phosphide, Gallium Arsenide

## SILVACO TOOLS DEVELOPMENT FOR RADIATION EFFECTS

Todd Weatherford, Assistant Professor  
Department of Electrical and Computer Engineering  
Sponsors: Naval Surface Warfare Center-Crane

**OBJECTIVE:** To develop semiconductor simulation tools to improve modeling of radiation effects in semiconductor devices.

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**SUMMARY:** Work in 1999 has focused on modeling hole trapping effects in Silicon-on-Insulator technologies. Two-dimensional device simulations have been used to model threshold shifts in n-channel SOI MOSFETs due to charge traps in buried oxides. An edgeless transistor is modeled to eliminate side channel leakage and to concentrate on back channel leakage. Results have shown to date identical leakage patterns but error in absolute values in voltage shift. Work is being continued to model the MOSFET in Three-dimensions to eliminate effects related to modeling body ties in two-dimensions.

**THESES DIRECTED:**

Beltz, N., "Evaluation of Radiation Induced Hole Trapping Model for Simulating Back-Channel Leakage in an Edgeless SOI nMOSFET," Master's Thesis, Naval Postgraduate School, December 1999.

Stansell, M., "DC Characterization of EFETs Grown on Bulk GaAs and Over Buffer Layers of Low Temperature Grown GaAs (Be)," Master's Thesis, Naval Postgraduate School, December 1999.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Materials, Processes and Structures, Modeling and Simulation

**KEYWORDS:** Silicon-on-Insulator, TCAD

## **TIME RESOLVED SINGLE EVENT EFFECT STUDIES IN SOI**

**Todd Weatherford, Assistant Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: Air Force Research Laboratory**

**OBJECTIVE:** To measure single event transients in very high speed digital circuits fabricated with silicon on insulator (SOI) technologies with ion and laser facilities. The picosecond transients will be compared to circuit and device simulations.

**SUMMARY:** SOI circuits fabricated in MIT Lincoln Laboratory's 0.25 $\mu$ m and 0.11 $\mu$ m semiconductor process in early 1999 were measured at University of Michigan's Center for Ultrafast Science utilizing their *in-situ* photoconductive probe and lasers. These results are the first sub nanosecond charge collection measurements on silicon MOSFET devices utilizing photoconductive sampling measurements. Measurements have been limited to discrete devices due to difficulty obtaining specific circuit designs to measurement signals within integrated circuits. Work has been initiated in 1999 to develop specific test structures to use the measurement technique on integrated circuits.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Modeling and Simulation, Space Vehicles

**KEYWORDS:** Silicon-on-Insulator, Single Event Upsets, Picosecond Transients

## **NEUTRON SINGLE EVENT EFFECT STUDIES**

**Todd Weatherford, Assistant Professor**

**Department of Electrical and Computer Engineering**

**Sponsors: Navy Strategic Systems Programs Office**

**OBJECTIVE:** To examine semiconductor device degradation effects related to neutron irradiation.

**SUMMARY:** Initial work investigated Single Event Effects, but has recently been modified to examine neutron degradation in photodetectors. Efforts are in place to perform neutron and Flash X-ray experiments on InGaAs photodetectors. Devices will be studied for changes in responsivity and photocurrent response. Device modeling may be required to understand damage effects.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Materials, Processes and Structures, Modeling and Simulation

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**KEYWORDS:** Indium Gallium Arsenide, Neutron Radiation

## ECONOMICAL SAR/ISAR SYSTEM DEVELOPMENT FOR UAV APPLICATIONS - PHASE ONE

**Lonnie A. Wilson, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Office of Naval Research**

**OBJECTIVE:** To develop new innovative and economical SAR/ISAR techniques for potential UAV applications. Emphasis is on using new SAR/ISAR waveforms and new-concept SAR/ISAR processing techniques.

**SUMMARY:** The EVASAR (Economical Virtual Aperture SAR) System project develops a new-concept *Virtual-Aperture* type of SAR that provides high resolution SAR/ISAR/gMTI technical performance capabilities and provides opportunities for significant reduction in unit installation cost, for at-sea and littoral surveillance from unmanned air vehicles (UAVs) and manned aircraft.

The Navy and Marine Corps have limited operational capability for high-resolution SAR detection of fixed and moving targets. The EVASAR architecture/design is a major departure from conventional SAR architecture/design.

EVASAR System's high technical performance capabilities and important, considerable affordability aspects result from (the new architecture choice):

- New Virtual-Aperture architecture choice based on narrow BW hopped-frequency pulse waveforms, narrow BW processing, lower digitization rates and associated processing,
- Single channel gMTI implementation,
- Reduction in wide-bandwidth RF hardware content,
- Simplified two-dimensional data sampling, motion correction and processing,
- Throughput management to minimize sampling and processing load,
- Off-board processing option,
- Auto calibration for reduced costs of RF hardware,
- Use of high volume COTS products,
- Reduced complexity and prime power requirements.

The proposed Virtual-Aperture MTI/SAR/ISAR concept provides SAR surface target mapping, ISAR ship-target imaging and high area coverage GMTI with overlay display of detected moving targets on SAR maps. This new SAR concept uses economical COTS products for generating moderate instantaneous bandwidth waveforms, digital sampling with low-speed A/D converters and signal processing with relatively low-speed DSPs.

### **OTHER:**

Wilson, L.A., Dinger, R.J., and Wehner, D.R., "Economical Virtual-Aperture SAR/ISAR/MTI/ (EVASAR) System For UAV and Other Airborne Applications– Technical Proposal," submitted to Office of Naval Research Code 313, March 1999.

Wilson, L.A., presentation to Surface/Aerospace Surveillance Technology Meeting, Naval Research Laboratory, Washington DC, March 1999.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Other (Radar, Surveillance, Targeting)

**KEYWORDS:** SAR, ISAR, DSP, Hopped-frequency, Chirped, Virtual Aperture Processing, MTI

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## LOW-BAND HARM ASSESSMENTS AND EVALUATIONS - PHASE ONE

**Lonnie A. Wilson, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Air Systems Command**

**OBJECTIVE:** To provide initial analysis and assessments of low band HARM Guidance System architectures and designs and enabling technologies and products.

**SUMMARY:** The HARM missile guidance section provides basic guidance and control functions for the missile. The low band HARM System concept is a next step in the evolution of HARM missile development. At lower frequencies, unique and application specific signals and potential unintentional signals exist, which have not been exploited for HARM applications. The HARM missile can be improved by exploiting these new signal opportunities.

**OTHER:** Summary project presentation was made to NAVAIR sponsor and support contractor in February 1999.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Other (Missiles, Guidance, Targeting)

**KEYWORDS:** Guidance System, RF Receiver, Video Processor, Signal Extraction, Parameter Extraction, Low Band, Antenna

## TARGETING AND THREAT WARNING RECEIVER APPLIQUE FOR LONG RANGE DETECTION AND PROCESSING OF HOSTILE RADAR WEAPONS

**Lonnie A. Wilson, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**CAPT James R. Powell, USN, Information Warfare Academic Group**  
**Sponsor: Naval Air Systems Command**

**OBJECTIVE:** The goal of the Targeting and Radar Warning Receiver (TRWR) Appliqué is to improve ALR-67 V2 performance (detection and emitter ID) against high valued threat radar weapons systems, and accurately ID friendly radar systems at extended ranges. The Appliqué's range envelope should extend beyond ranges of potential threat weapons systems, and should be greater than the standoff ranges of our weapons to aid targeting. Extended range envelope performance also improves platform survivability. Also, high quality ID performance with fewer ambiguities reduces fratricide problems. Basic objectives are: 1) Improve sensitivity against high valued radar weapon systems (relative to the ALR-67 V2); 2) Provide long range emitter detection and signal processing performance for advanced electronic situational awareness; and 3) Provide high quality emitter ID performance capability with reduced ambiguities using digital parameter measurements.

**SUMMARY:** The TRWR project was divided into three development tasks. Development was successfully completed in September 1999. These tasks are:

- 1) TRWR Appliqué Requirements Analysis and Specifications: The Targeting and Radar Warning Receiver Appliqué requirements were identified for the technical feasibility development. System performance goals, key technical specifications and important technical feasibility demonstrations were identified. Key ALR-67 V2 and ALR-67 V3 receiver and processor deficiencies were identified and major operational performance limitations were summarized.
  - 2) TRWR Appliqué Architecture and Interface Architecture: The architecture was developed for the Targeting and Radar Warning Receiver Appliqué and all associated interfaces with the ALR-67 system and associated modules. The system architecture exceeded all goals and requirements identified in task 1. The interface architecture was compatible with existing ALR-67 V2 and ALR-67 V3 architectures.
  - 3) IF Analog Section and Digital Hardware Section Designs: TRWR analog design was successfully completed for the ALR-67 V2 system. The IF Analog Section was designed using high quality commercial RF components. Front end IF amplifiers and IF down converters channels will be configured to demonstrate technical performance against multiple hostile radar weapons systems and friendly radar weapons systems. The TRWR Appliqué is technically feasible for the ALR-67 V2 (existing deficiencies
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are resolved). Several A/D converters are currently available for this application. A/D converter performance specifications, ease of use, and support availability will be key selection factors.

In addition, initial concept design was completed for the ALR-67 V3 and this TRWR implement appears to be technically feasible. The ALR-67 V3 was beyond the scope of the funded effort.

Summary project presentation was made to NAVAIR sponsor in September 1999.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Other (Missiles, Guidance, and Targeting)

**KEYWORDS:** Targeting, Radar, RWR, DSP, Emitter ID, Emitter Signal Sorting

## **SPECIFIC EMITTER IDENTIFICATION INFORMATION**

**Lonnie A. Wilson, Research Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: National Reconnaissance Office**

**OBJECTIVE:** To provide SEI (Specific Emitter Identification) background information to potential NPS thesis students and PANSAT engineering personnel.

**SUMMARY:** Key SEI developments were completed several years ago: 1) Fundamental MOP theory has been developed, and keys tradeoffs understood; 2) Radar Emitter experimental characterizations have been performed; 3) Completed preliminary algorithm development of High Performance SEI Processor; 4) New phase MOP signal added, which has better SNR characteristics for high signal fidelity conditions; 5) Optimal SNR processing utilized from receiver front end to final DSP SEI decision algorithms; 6) High accuracy and high resolution analog/digital hardware design utilized to handle modern complex radars; 7) New SEI Algorithm developed with adaptive threshold and selectable probability of errors; 8) SEI Software development completed on PC; 9) Significant SEI performance improvements have been demonstrated, at low SNR<sub>IF</sub> and single pulse; 10) Tonal interference problems have been theoretically quantified, and current SEI Processor limitations are serious; 11) Database transportability issues have been considered, and current SEI Processor limitations understood; and 12) All experimental SEI assessments have confirmed the new MOP theory.

This SEI background information was presented to CDR Mitch Free, USN, NPS thesis student and PANSAT engineering personnel (David Rigmaiden and Jim Horning).

**DoD KEY TECHNOLOGY AREAS:** Sensors, Other (Targeting)

**KEYWORDS:** SEI, ID, RF Receiver, MOP Signal Extraction, Parameter Extraction

## **WIRELESS DAMAGE CONTROL COMPUTER NETWORKS**

**Xiaoping Yun, Associate Professor**  
**Department of Electrical and Computer Engineering**  
**Sponsor: Naval Sea Systems Command**

**OBJECTIVE:** To determine the minimum number of access points (APs) that are required to provide full coverage of the Los Angeles class submarines by a COTS wireless LAN, and to develop client side damage control (DC) Java software module.

**SUMMARY:** A comprehensive test of wireless local area networks onboard the USS Memphis (SSN 691) was conducted on August 4-7, 1999. The testing results positively validated the feasibility of deploying wireless local area networks onboard Los Angeles class fast attack submarines. Furthermore, the testing results provided valuable information regarding the minimum number of access points required to cover the forward compartment and the engine room, proposed feasible install locations for access points, and documented achievable data rates.

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## THESES DIRECTED:

Collins, W.E., "A Routing-Based Solution to Simulating an Access Point," Master's Thesis, Naval Postgraduate School, September 1999.

Matthews, M.M., "Analysis of Radio Frequency Components for Shipboard Wireless Networks," Master's Thesis, Naval Postgraduate School, December 1999.

Roemhildt, M.W., "Analysis and Vulnerability of Spread Spectrum Wireless Local Area Networks on Surface and Sub-Surface Combatants," Master's Thesis, Naval Postgraduate School, September 1999.

Rothenhaus, K.J., "Distributed Software Applications in Java for Portable Processors Operating on a Wireless LAN," Master's Thesis, Naval Postgraduate School, September 1999.

Sayat, H., "Damage Control and Log Taking Java Applications for Shipboard Wireless LANs," Master's Thesis, Naval Postgraduate School, December 1999.

## OTHER:

Yun, X., Lewis, T., Matthews, M., Roemhildt, M., and Rothenhaus, K., "USS Truman Hangar Bay Wireless LAN and Wearable and Pen Based PC Testing Report," project report submitted to NAVSEA, August 1999.

Yun, X., "Wireless LAN Testing Results Onboard USS Memphis (SSN 691)," project report submitted to NAVSEA PMS450T2, August 1999.

Yun, X., "Wireless," [Alumni@NPS](#) (The Official Newsletter for Alumni of the Naval Postgraduate School), Spring 2000.

Yun, X., Lewis, T., Matthews, M., Roemhildt, M., Rothenhaus, K., and Sayat, H., "Feasibility Analysis of Deploying Wireless Local Area Networks (WLANs) Onboard Submarines and Surface Ships," NPS Research, October 1999.

**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communications

**KEYWORDS:** Damage Control, Wireless Computer Networks

## ACCURATE CONTROL OF MANIPULATORS USING INERTIAL SENSORS

Xiaoping Yun, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: National Science Foundation

**OBJECTIVE:** To develop an inertial sensor system for autonomous underwater vehicle (AUV).

**SUMMARY:** A new version of the SANS navigation system is developed and tested. Most hardware components including the onboard processing computer, IMU, and water speed sensor have been replaced with the latest COTS products. The previous constant gain filter was replaced by a Kalman filter. As a result, the system sampling rate was increased by ten times while maintaining the overall size of the system. Extensive bench testing and ground vehicle testing were conducted to validate the performance of the new system. The ground vehicle testing results indicated that the system is able to navigate between intermittent GPS fixes with an accuracy of 10 meters or better.

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Yun, X., Bachmann, E.R., McGhee, R.B., Whalen, R.H., Roberts, R.L., Knapp, R.G., Healey, A.J., and Zyda, M.J., "Testing and Evaluation of an Integrated GPS/INS System for Small AUV Navigation," *IEEE Journal of Oceanic Engineering*, Vol. 24, No. 3, pp. 396-404, July 1999.

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Backmann, E.R., Duman, I., Usta, U.Y., McGhee, R.B., Yun, X., and Zyda, M.J., "Orientation Tracking for Humans and Robots Using Inertial Sensors," *Proceedings of the 1999 International Symposium on Computational Intelligence in Robotics and Automation*, Monterey, CA, pp. 187-194, 8-9 November 1999.

**THESIS DIRECTED:**

Akyol, K., "Hardware Integration of the Small Autonomous Underwater Vehicle Navigation System (SANS) Using a PC/104 Computer," Master's Thesis, Naval Postgraduate School, March 1999.

**DoD KEY TECHNOLOGY AREA:** Sensors

**KEYWORDS:** INS, GPS, AUV, Navigation, Kalman Filter

## EVALUATION OF DEINTERLEAVER ALGORITHMS

**Lawrence J. Ziomek, Professor**

**Department of Electrical and Computer Engineering**

**Sponsor: National Security Agency**

**OBJECTIVE:** The proposed work supports the Naval Postgraduate School (NPS) Cryptologic Research Laboratory (CRL). In order for the NPS CRL to create its own "generic testing environment" so that it can independently evaluate the effectiveness of various deinterleaver algorithms, work will begin on developing mathematical models and computer simulations of waveforms that are due to the superposition (interleaving) of several different, individual pulse trains. The capability to model and generate computer simulated data is very important because it will provide the NPS CRL with the "correct answers" necessary to evaluate various deinterleaver algorithms, and to gain insight as to which currently existing measures of effectiveness (MOE) are best, or if new MOE need to be formulated.

**SUMMARY:** A general time-domain and frequency-domain mathematical model for individual transmitted pulse trains has been derived. Each pulse train is allowed to have its own number of amplitude-weighted pulses, carrier frequency, and total duration. In addition, each pulse within a given pulse train is allowed to have different amplitude-modulating and angle-modulating functions if desired, and pulse lengths. Furthermore, the pulse-repetition interval (PRI) for a given pulse train may be equal to a constant, or it may vary according to some equation. A general time-domain and frequency-domain mathematical model for the random received signal has also been derived. The received signal is modeled as being equal to the superposition (interleaving) of  $N$  pulse trains. Each individual pulse within a given received pulse train is allowed to have its own time delay, Doppler shift, random amplitude, and random phase. Two computer programs were also written. One program generates the actual time series data corresponding to the received signal, that is, the superposition (interleaving) of many individual pulse trains. The second program generates "pulse-parameter vectors." At present, each pulse-parameter vector contains the following information: carrier frequency, type of amplitude and angle modulation used, pulse amplitude, start time, pulse length, phase shift (if PSK is used), frequency shift (if FSK is used), swept bandwidth (if LFM is used), and up-chirp and down-chirp information (if LFM is used).

Two FORTRAN computer programs were written and one technical report is in progress.

**DoD KEY TECHNOLOGY AREAS:** Electronic Warfare, Modeling and Simulation

**KEYWORDS:** Interleaved Pulse Trains, Deinterleaver Algorithms, Measures of Effectiveness

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## EVALUATION OF OCEAN SURFACE CURRENT DATA FROM THE NAVY HF SURFACE WAVE RADAR

Lawrence J. Ziomek, Professor

Department of Electrical and Computer Engineering

Sponsor: Office of Naval Research

**OBJECTIVE:** This project will analyze data collected during initial shore-based testing of the new Navy High Frequency Surface Wave Radar (HFSWR) for its capability to measure surface ocean currents. Doppler backscatter spectra will be formed from HFSWR measurements for the purpose of estimating surface currents in the manner employed by existing shore-based HF ocean current radar systems. The purpose of this project is to determine how well the HFSWR can be extended to also map surface ocean currents.

**SUMMARY:** A FORTRAN computer program was written that performed beamforming (in both the near-field and far-field) for a radar planar array. In addition, the program computed the frequency spectrum of the resulting composite signal from the array. In this project, the frequency spectrum of the resulting composite signal corresponded to the Doppler spectrum of ocean-surface backscatter. Preliminary testing and validation of the program was performed.

One FORTRAN computer program was written.

**DoD KEY TECHNOLOGY AREA:** Environmental Quality

**KEYWORDS:** Ocean Currents, Ocean Waves, Air-Sea Interaction

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McEachen, J.C., "Online.ECE WWW Course Portal," Established a consolidated course portal for EC web-based learning initiatives sponsored by COMSPAWARSYSCOM. This course provided a focal point for electronic course materials developed within the EC department. The development of the site was briefed to CINCPACFLT (ADM Clemens), COMSPAWARSYSCOM (ADM Gauss) and CNET (VADM Craine).

McEachen, J.C., "NSA Distance Learning Remote Computer Facility," Installed and configured a system for Distance Learning students at the NSA to run EC computer assignments (MATLAB and OPNET) from their remote workcenter desktop by leveraging off research facilities locally. Facility included a WWW site for dissemination of class assignments, instructions, lecture notes, and software. To date, the facility had been successfully used by students in EC4960 and EC3850. This was done at no cost to the government.

McEachen, J.C., "EC4960 Course Materials WWW Server (<http://web.nps.navy.mil/~mceachen/ec4800/>).” A resource containing complete collection of lecture notes, computer assignments, homework solutions, test keys, and software help manuals used to facilitate the instruction of EC4800. This was done at no cost to the government.

McEachen, J.C., "EC3850 Course Materials WWW Server (<http://web.nps.navy.mil/~mceachen/ec3850/>).” A resource containing complete collection of lecture notes, computer assignments, homework solutions, test keys, and software help manuals used to facilitate the instruction of EC3850. This was done at no cost to the government.

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McEachen, J.C., "EO3513 Course Materials WWW Server (<http://web.nps.navy.mil/~mceachen/eo3513/>)." A resource containing complete collection of lecture notes, computer assignments, MATLAB code, frequently asked questions, homework solutions, test keys, and software help manuals used to facilitate the instruction of EO3513. This was done at no cost to the government.

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