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

R.W. Adler, Research Associate Professor
W.R. Vincent, Research Associate Professor
A.A. Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsor: Naval Security Group Command

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 two-day HF Technical Review of Factors that Affect Performance of Naval Receiving Sites was organized and held in Monterey in October.

DoD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEY WORDS: Electromagnetic Environmental Effects, Communication Systems, Man-Made Noise, Antennas

FIELD SITE AND RSOC RESEARCH AND SUPPORT

R.W. Adler, Research Associate Professor
W.R. Vincent, Research Associate Professor
A.A. Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsor: U. S. Army Information and Security Command

OBJECTIVE: Continued research and development in techniques to improve the signal-to-noise ratio at Regional System Operational Centers and at field sites.

SUMMARY: Development of techniques and methodology for identifying and locating data noise sources and sources of interference to data processing and computer systems and location of radio noise and interference sources at remote and local field sites. 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 a part of the INSCOM support.

DoD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

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

LOW PROBABILITY OF INTERCEPT SYSTEM EVALUATION

R.W. Adler, Research Associate Professor
W.R. Vincent, Research Associate Professor
A.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 SPAWWAR SYSCEN.

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 Quality

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

INTEGRATED FIGHT-THROUGH POWER AND ADVANCED POWER CONVERTER MODULES

Robert 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, 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 surrounding the Land Based Engineering Site (LBES) in Philadelphia. The investigator was tasked with the evaluation of data from test runs for a number of Power Converter Modules (PCM) ranging from 250kW to 19MW. Test results were analyzed and used by the investigator to aid in making recommendations for future PCMs. In addition, three specific failure events took place on the 19MW PWM electric drive unit. Each event was analyzed using the available data including forensics on the components. Reports and presentations were made in Philadelphia and Rugby, England. The results of the investigator have been utilized in redesign efforts by the vendor.

DoD KEY TECHNOLOGY AREA: Electronics

KEYWORDS: Power System, Auxiliary Resonant Commutated Pole Inverter, Electronic Devices, Energy Conversion

DEVELOPMENT OF ALGORITHMS SUPPORTING HARDWARE-IN-THE-LOOP CONTROL OF SYNCHRONOUS MACHINES

Robert Ashton, Associate Professor
John G. Ciezki, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center-Philadelphia

OBJECTIVE: The Navy's revitalized interest in electric drive and employing variable-speed drives in place of current fixed-frequency drives has motivated the need to study competing motor control strategies and motor drive topologies. The focus of this research was to develop a DSP platform for testing motor control algorithms. The platform is intended to have hardware-in-the-loop capability so that actual amplifiers and motors can be studied. Though interest has been expressed in studying propulsion motor applications, the platform should be generic enough to handle proof-of-concept studies for any number of types of motors or drives. Initially, the unit should be demonstrated on a 30-HP permanent-magnet synchronous machine driven by three H-bridge current amplifiers. Deliverables include an operational platform, the investigation of several open-loop and closed-loop synchronous machine speed-control

algorithms, the implementation of said algorithms using dSPACE, and studies documenting the performance of the drive.

SUMMARY: The platform consisted of three H-bridge current amplifiers provided by NPS. The amplifiers, since they were internally grounded, had to be coupled to a three-phase load through transformers. The commanded machine current was generated by a dSPACE hardware-in-the-loop processor/software package. A convenient input/output panel for the dSPACE card and a host personal computer were also mounted in the 19-inch standard cabinet. Algorithms were developed by Dr. Ciezki and tested by LCDR Govier using ACSL and dSPACE at NPS. The algorithms were then transferred to Philadelphia and load into the unit there. Tests were originally executed open loop while nuances involving the position encoder were resolved. The 30-HP PM motor was then controlled in closed-loop mode using field-oriented vector control Upon resolving some filtering issues, the unit was demonstrated to run properly at no-load and while loaded. Furthermore, more complex algorithms using speed and position information were tested and confirmed in the laboratory. The Philadelphia sponsor received a thesis as a deliverable and three conference papers.

PRESENTATIONS:

Ciezki, J.G., Ashton, R.W., and Fikse, T., "A Survey of AC Drive Propulsion Options," presented at the 3rd Naval Symposium on Electric Machines, Philadelphia, PA, 4-7 December 2000.

Ciezki, J.G., Ashton, R.W., and Govier, C., "Algorithms for a Reduced-Scale Permanent-Magnet Synchronous Machine Propulsion Drive," presented at the 3rd Naval Symposium on Electric Machines, Philadelphia, PA, 4-7 December 2000.

Ashton, R.W., Ciezki, J.G., and Lewis, T., "The Development of a Motor Controller Evaluation Platform," presented at the 3rd Naval Symposium on Electric Machines, Philadelphia, PA, 4-7 December 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Power System Enhancement)

KEYWORDS: PWM Inverter, Synchronous Machine, Vector Control, DSP

DESIGN ALGORITHMS FOR SUM-OF-PRODUCTS EXPRESSIONS OF FUNCTIONS WITH BI-COMPOSITIONS

Jon T. Butler, Professor
Department of Electrical and Computer Engineering
Tsutomu Sasao, Kyushu Institute of Technology, Japan
Sponsor: Unfunded

OBJECTIVE: To produce efficient design techniques for functions with bi-decompositions.

SUMMARY: A function $f(X, Y)$ has an AND bi-decomposition if it can be expressed as $f(X,Y) = g(X)\,h(Y)$, and X and Y are disjoint sets of variables. Many benchmark functions have AND (and other types, e.g., OR and exclusive OR) bi-decompositions. Since benchmark functions are representative of functions found in practical logic applications, there is significant interest in bi-decompositions. The goal of this research is to find efficient algorithms for producing minimal circuits for functions with bi-decompositions. One approach for functions with AND bi-decompositions is to minimize the two sub functions, $g(X)$ and $h(Y)$ separately, then AND their minimal forms together. Since the best-known algorithm for finding minimal forms is exponential in the number of variables, this "divide-and-conquer" technique produces significant reduction in computation time. However, it has been known (for about 10 years) that this will not always produce the minimal form for $f(X,Y)$. The goal of our research is to understand the extent to which this degrades minimization. For example, while this divide-and-conquer technique may not always produce a minimal form, it may be close to minimal. It is an open question as to what extent such a technique produces minimal or near-minimal realizations. We have shown a whole class of functions where the divide-and-conquer algorithm fails to find a minimal circuit and where the circuit found is significantly

larger than the minimal form (the size difference is exponential in the number of variables). Another goal is to quantify the set of functions for which the divide-and-conquer technique always produces a minimal form. We have shown that a class of functions, called orthodox functions, has this property.

PRESENTATION:

Sasao, T. and Butler, J.T., "On the Minimization of SOPs for Bi-Decomposable Functions," Asian South Pacific Design Automation Conference (ASP-DAC), Yokohama, Japan, February 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software

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

REED-MULLER CANONICAL EXPANSIONS OF LOGIC FUNCTIONS

Jon T. Butler, Professor
Department of Electrical and Computer Engineering
G.W. Bueck, University of New Brunswick, Canada
V.P. Shmerko, Technical University, Szczecin, Poland
S.V. Yanushkevich, Technical University, 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 developed a technique for designing Reed-Muller expansions for symmetric functions using the transeunt triangle. It is faster and requires less storage than the next best technique. We are now applying this to partially symmetric functions, which are more general than symmetric functions. We are also extending our results to include "mixed" polarity implementations, which enlarge the forms in which functions can be expressed. The advantage to this is that more compact circuits are possible.

PUBLICATIONS:

Butler, J.T., Dueck, G.W., Shmerko, V.P., and Yanushkevich, S.N., "Comments on 'Fast Exact Minimization of Fixed Polarity Reed-Muller Expansion for Symmetric Functions," *IEEE Transactions on Computer-Aided Design*, Vol. 19, No. 11, November 2000, pp. 1386-1388.

Yanushkevich, S.V., Butler, J.T., Dueck, G.W., and Shmerko, V., "Experiments on FPRM Expressions for Partially Symmetric Logic Functions," *Proceedings 30th International Symposium on Multiple-Valued Logic*, May 2000, pp. 141-146.

Butler, J.T., Dueck, G.W., Yanushkevich, S.N., and Shmerko, V.P., "On the Number of Generators for Transeunt Triangles," *Discrete Applied Mathematics* (accepted).

DoD KEY TECHNOLOGY AREAS: 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, Associate 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 photocurrent requirements and must ensure that the control loop is fast enough to ride through the event.

The work effort was modified by the sponsor to focus primarily on the testing and characterization of the dose-rate responses of commercially available rad-hard power devices. In particular, power FETs were investigated in both the on state and the off-state and Schottky diodes were investigated in the off state. All testing was performed at the NSWC Crane, Indiana facilities and was coordinated by Jeff Titus. CAPT Gerald Bloomfield's thesis was predicated on collection of the data, comparing the data against theoretical predictions, and analyzing failure modes.

SUMMARY: Upon obtaining device samples from Intersil and International Rectifier, a test rig was fabricated and a test plan established. The off-state 20-nsec transient responses of rad-hard power MOSFETs manufactured by IR, using devices of three different voltage ratings and three different die sizes, were measured over a wide range of dose rates and drain bias conditions. Similarly, components from Intersil, including p-channel and n-channel power MOSFETs of differing rated voltages and die sizes, were subjected to similar testing. The prompt photocurrent response of several reverse-biased Schottky diodes during exposure to 20-nsec 40-MeV electron pulses were recorded over a wide range of beam intensities. Devices were observed to catastrophically fail. The test data was assimilated and summarized in a thesis report and three conference papers. Mechanisms for device failures were discussed, motivating the need for further modeling and simulation to confirm hypotheses.

PUBLICATIONS:

Ciezki, J., Titus, J.L., Skinner, S., Bloomfield, G., and Smith, J.E., “Off-State Dose-Rate Responses of Power MOSFETs,” to appear as a poster paper at the Hardened Electronics and Radiation Technology (HEART) Conference, San Antonio, TX, 7 March 2001.

Titus, J.L., Skinner, S., Bloomfield, G., Ciezki, J., and Smith, J.E., “Dose-Rate Responses of Reverse-Biased Power Schottky Diodes,” to appear as a poster paper at the Hardened Electronics and Radiation Technology (HEART) Conference, San Antonio, TX, 7 March 2001.

Titus, J.L., Skinner, S., Bloomfield, G., Gillberg, J., Burton, D., Wheatley, C.F., and Ciezki, J., “Dose-Rate Responses of Commercial Rad-Hard Power MOSFETs Biased in an Off-State Condition,” to appear as a poster paper at the Hardened Electronics and Radiation Technology (HEART) Conference, San Antonio, TX, 7 March 2001.

DoD KEY TECHNOLOGY AREAS: Electronics

KEYWORDS: Power FET, Schottky Diode, Dose Rate, Operate Through, Electronic Devices

COMPONENT MODELING AND SIMULATION EFFORTS FOR A PROPOSED LHD-8 AC ZONAL DISTRIBUTION SYSTEM

John G. Ciezki, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center-Philadelphia

OBJECTIVE: The LHD-8 craft is planned to employ an AC zonal electric distribution system. The operation of the system requires study using computer models. Studies of interest include balanced faults, transient stability, and load sharing. Models required include 3-phase delta-delta transformers, three-phase wye-connected synchronous machines driven by diesel engines, and any additional connection software required to merge the models with current transmission line, circuit breaker, and load models. All models will be developed in ACSL and the appropriate field excitation and governor controls derived for baseline components. Deliverables include ACSL models, interconnection software, control algorithms, and assistance in running system studies.

SUMMARY: The work is ongoing. Models for the transformer and synchronous machine have been developed. A literature search on diesel engine modeling has been performed and various dynamic models uncovered. The controls for the diesel governor and the synchronous machine exciter were developed with the help of MATLAB and ACSL simulation. Some ACSL development has been slowed by virtue of difficulty getting the ACSL software renewed and difficulty getting the update for the FORTRAN compilers. No thesis is currently supporting this effort.

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

KEYWORDS: AC Zonal Distribution, Diesel Generators, Transformers, ACSL Simulation

FEATURE EXTRACTION FOR SIGNAL CHARACTERIZATION IN CLASSIFICATION APPLICATIONS; APPLICATIONS TO COMMUNICATION MODULATIONS

Monique P. Fargues, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Center for Reconnaissance Research

OBJECTIVES: The goal of this on-going study is to extend a dimension reduction scheme considered in previous work. First, we investigated the scheme application to the classification of communication modulation schemes, and next we considered the application of higher-order statistics as class features for specific digital types of modulations specified by the sponsor.

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 maximized 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). During the first part of the CY2000 study we considered the spread of the projected data to improve on previous work. Results showed no significant improvements for variants of the original scheme. During the second part of the study we considered high-order statistic parameters as class features and specific types of communication schemes, as requested by the sponsor. Modulation types considered are: 2-8PSK, 2-8FSK, and 16-64-256QAM. Robustness due to additive white Gaussian noise and multipath environments are considered. The proposed classification scheme combines neural networks and equalization schemes to differentiate all specified modulation types.

PRESENTATION:

Fargues, M., “Feature Extraction and Dimension Reduction Issues: Applications to Classification,” CRR

Research Briefings, Monterey, CA, February and September 2000.

THESIS DIRECTED:

San Pedro, M., "Signal Classification Using the Mean Separator Neural Network," Masters Thesis, Naval Postgraduate School, March 2000.

DoD KEY TECHNOLOGY AREAS: Electronics, Computing and Software

KEYWORDS: Classification, Projection Pursuit, Dimension Reduction, Higher-Order Statistics

CEPXS/SPICE AUTOMATED SOFTWARE INTERFACE DEVELOPMENT

Douglas J. Fouts, Associate Professor
Department of Electrical and Computer Engineering and
Space Systems Academic Group
Sponsor: Lockheed Martin Space and Missile Systems and Naval Postgraduate School

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 operation of 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).

This project was successfully completed during the calendar year 2000. The software that was developed by this research provides a complete, fully automated interface between CEPXS and SPICE. This allows accurate simulations of the effects of nuclear radiation on very large circuits with many transistors, something that could not be done previously because of the slow, cumbersome, manual interface. At this point in time, the software has been delivered to the research sponsor, Lockheed Martin Missiles and Space. Both the source code and a compiled and ready to run version were provided. The first draft of an MSEE thesis that documents the program in detail is currently being reviewed by the sponsor. The final version of the thesis will soon be finished.

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

NSA/K51 CRYPTOLOGIC RESEARCH LABORATORY AND THESIS RESEARCH SUPPORT

Tri T. Ha, Professor
Department of Electrical and Computer Engineering
Sponsor: National Security Agency

OBJECTIVE: Support for the Cryptologic Research Lab at the Naval Postgraduate School wherein graduate students perform research in support of K51.

SUMMARY: The Cryptologic Research Laboratory, sponsored by the National Security Agency's K51, is a valuable resource which provides a cost effective, viable and robust research platform for NPS graduate

students and faculty in Electrical Engineering, Information Warfare, and Computer Science and related curricula. It offers an unclassified environment wherein graduate students can develop an in-depth understanding of Cryptology and related disciplines by researching capabilities, limitations, design, and operations of digital signal processing and exploitation techniques, satellite communications technologies, cellular technologies, wireless communications and other analogous cryptologic areas.

THESIS DIRECTED:

Cadenazzi, M., "Performance Analysis of the Higher Order Cyclostationary Based Classifier," Masters Thesis, Naval Postgraduate School, March 2000.

DoD KEY TECHNOLOGY AREAS: Other (Electrical Engineering, Information Operations)

KEYWORDS: Cryptology, Exploitation, Wireless

PROCESSING OF RADAR SIGNATURES USING CORRELATION AND WAVELET BASED CONCEPTS

Ralph D. Hippenstiel, Associate Professor
Monique P. Fargues, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Center for Reconnaissance Center

OBJECTIVE: The objective of this research is to simulate a typical modern radar signature exhibiting frequency agility and a variable PRF and to perform the correlation-wavelet-based estimation to obtain some system parameters. As a by-product radar status information might be obtained.

SUMMARY: The work investigates the detection of pulses and the extraction of modulation parameters of different types of time-limited chirp signals, as may be found in pulse-compression radars. The first part discusses detection and pulse start and stop time estimation. Three-time correlation function (TCF) based schemes and an envelope detection algorithm are compared. Results show that none of the pulse detection schemes considered are clearly superior for the SNR range considered. The specific selection will be a function of desirable characteristics to be optimized, such as P_{FA} or P_D. The second part focuses on the extraction of modulation parameters from linear and hyperbolic chirp modulation. Results show that time-frequency transformations lead to better focused images when dealing with noisy signals than wavelet-based decompositions. Better images allow more robust modulation estimation schemes.

PUBLICATION:

Hippenstiel, R., Fargues, M., Moraitakis, I., and Williams, C., "Detection and Parameter Estimation of Chirped Radar Signals," Naval Postgraduate School Technical Report, NPS-EC-00-001, January 2000.

THESIS DIRECTED:

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

DoD KEY TECHNOLOGY AREAS: Electronic Devices

KEYWORDS: Radar Signals, Signal Detection/Classification, Wavelet-Based Decomposition

IMPROVEMENT OF THE TIME DIFFERENCE ARRIVAL ESTIMATION OF GSM SIGNALS USING WAVELETS

Ralph D. Hippenstiel, Associate Professor
Tri T. Ha, Professor
Department of Electrical and Computer Engineering
Sponsor: Navy Tactical Exploitation of National Capabilities (TENCAP) Office

OBJECTIVE: To simulate typical GSM signals at an intermediate frequency (IF), as may be obtained from two spatially separated surveillance receivers. Use wavelet based de-noising to enhance the time difference of arrival (TDOA) estimation.

SUMMARY: Using the Hewlett-Packard Advanced Design System (HP-ADS), GSM data cuts (signatures) at an IF frequency are obtained. Typical electronic signatures are simulated at various signal-to-noise (SNR) levels using MATLAB. A method based on the approximation of the modified maximum likelihood technique and on a fourth order moment are demonstrated. Improvement in the mean square error (MSE) is obtained as a function of data parameters. The improvement is shown to be a function of SNR, data length, and spectral position relative to the sampling rate.

PUBLICATION:

Hippenstiel, R., Haney, T., and Ha, T.T., "Improvement of the Time Difference of Arrival (TDOA) Estimation of GSM Signals Using Wavelets," Naval Postgraduate School Technical Report, NPS-EC-00-008, June 2000.

THESIS DIRECTED:

Haney, T., "Generation of GSM Signals and Their Time Difference of Arrival (TDOA) Estimation," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Electronics

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

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 (TENCAP) Office

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. We focused on algorithms that would 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. Such an approach can bring to bear all sensor 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 allows 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 was to assess 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. Research during last year focused on spacecraft-to-AEGIS hand-off issues and on backfitting algorithms to determine TBM launch locations in the shortest possible time. We developed simulations to test our sensor fusion and tracking algorithms, and we used classified missile trajectory data for more realistic algorithm tests. Testing and algorithm development focused 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, Target Tracking

ASSESSMENT OF OCEAN SURFACE ROUGHNESS ON EM PROPAGATION

R. Janaswamy, Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Center-San Diego

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

SUMMARY: A theoretical formulation to include roughness-induced immittance within the framework of the split-step algorithm of the parabolic equation was developed. The present form of the split-step algorithm is capable of incorporating angle-dependent surface losses arising from roughness and is also applicable to underwater sound propagation over irregular ocean bed. The formulation was validated by considering several examples of radio propagation over wind-driven ocean surface under various ducting conditions. Frequencies from HF through microwave for both wave polarizations were considered in the validations.

PUBLICATION:

Janaswamy, R., “Radiowave Propagation Over a Non-Constant Immittance Plane,” to appear in *Radio Science*, 2001.

PRESENTATION:

Janaswamy, R., “Rigorous Propagation Modeling Over Rough Sea Surface by the Parabolic Equation,” paper # F2-9, 2001 URSI Meeting, University of Colorado, Boulder, CO, January 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Surface Roughness, Parabolic Equation

3D SITE SPECIFIC PROPAGATION STUDIES FOR WIRELESS COMMUNICATIONS

R. Janaswamy, Professor
Department of Electrical and Computer Engineering
Sponsor: U. S. Army Research Office

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

SUMMARY: A parabolic equation based Fourier algorithm of solving 3D wave propagation in an urban environment comprised of vertical buildings of polygonal cross sections lying on flat ground was developed. The algorithm neglects depolarization and backscattering of waves, but includes several important propagation mechanisms such as reflections and diffractions by building rooftops, building sides, and ground. The algorithm was demonstrated for perfectly reflecting 2D and 3D buildings and was shown to be effective for implementation on a PC for obstacles scattered in a layout size as large as 0.6 km $\times$ 0.6 km at 1 GHz. Work is ongoing on extending the algorithm to non-perfectly reflecting obstacles.

PRESENTATION:

Janaswamy, R., "A 2.5D Hybrid Parabolic Equation/Ray Tracing Approach for Modeling Path Loss in Urban Environments," Paper No. C3-2, 2001 URSI Meeting, University of Colorado, Boulder, CO, January 2001.

DoD KEY TECHNOLOGY AREAS: Other (Tactical Battlespace Communications)

KEYWORDS: Wireless Propagation, Parabolic Equation

RADAR REMOTE SENSING

Jeffrey B. Knorr, Professor
Department of Electrical and Computer Engineering
Bob Bluth, Research Associate
Center for Interdisciplinary Remotely Piloted Aircraft Studies
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project is to acquire and modify two military radars for meteorological research.

SUMMARY: An Army AN/MPQ-64 Sentinal radar was acquired in the spring of 1999 and was brought to operational status during the fall of 1999 and the winter of 2000. An SBIR project N01-035, Weather Processor for Rapid Scanning Tactical Radars, was initiated with ProSensing, Amherst, MA to add a Doppler processor to the radar for severe storm research. During 2000 steps were also taken to obtain an Army AN/TPQ-37 Fire finder radar and delivery is expected in April 2001. This radar is similar to the An/SPY-1 radar installed on the Navy's Aegis cruisers and destroyers. A project is planned to add a weather processor to this radar so it can be used as a test bed for investigation of AN/SPY-1 algorithms to extract meteorological data. The long-term objective of this project is to develop radar remote sensing capabilities that will provide meteorological data that can be used to describe weather phenomena, particularly in support of air operations in the fleet battle space.

PUBLICATION:

Knorr, J.B., "Analysis of the AN/SPY-1 and AN/TPQ-37 Radars (U)," SECRET working paper prepared for the Office of Naval Research, December 2000, 9 pp.

PRESENTATION:

Knorr, J.B., "AN/MPQ-64 Radar Application to Severe Storm Research," presented at Ground Based Mobile Instrumentation Workshop, National Center for Atmospheric Research, Boulder, CO, 22-24 February 2000.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Remote Sensing, Radar Meteorology

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

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

OBJECTIVE: The objective is to design a wideband eigen-antenna to extend the range of transmitter/receiver operation to lower frequencies for which conventional antennas would be too large to implement on an EA-6B.

SUMMARY: The objective would be accomplished by one or more electrically small eigen antennas using near-field coupling to the platform (EA-6B aircraft), electromagnetic eigen-modes (resonant modes) to increase their radiation/reception effectiveness. This phase of research involves the eigen-mode mapping for the EA-6B aircraft, identification of suitable eigen-modes for the desired polarization (vertical) and far-field pattern (omnidirectional in azimuth), selection of optimal location(s) for the eigen-antenna(s), and preliminary computer verification of the eigen –antenna design. This is considered phase 1 of a larger research effort to result in a verified EA-6B eigen-antenna design for the user-specified frequency range.

Previously, electrical performance (input impedance, radiation patterns, overall efficiency, etc.) of a number of different antennas at several available locations on the EA6-B aircraft have been estimated using computational electromagnetic software in order to determine the location, type and size/shape of the optimum antenna.

THESIS DIRECTED:

Ertel, T.M., "Ultra-Wideband, Low Profile, Vertically Polarized Antenna Designs for Military Applications," MastersThesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Antennas, Computational Electromagnetics

SSN UNIVERSAL MODULAR MAST (UMM) ANTENNA DESIGN AND PROTOTYPING

Jovan Lebaric, Visiting Associate Professor
Richard Adler, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: Optimization of the computer model and building a prototype to verify the model of the UMM antenna designed by the NPS in FY99.

SUMMARY: The new attack submarine universal modular mast wideband antennas were designed by the NPS in FY99. The NPS will optimize the computer model and then build a prototype to verify the model created using computer electromagnetic simulation software (GNEC). The NPS will provide the data and a

prototype to the program manager as an aid in determining and evaluating the design for the antenna system.

PRESENTATION:

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

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

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

THESES DIRECTED:

Cutsumbis, P.M., "Design, Prototyping and Measurement of a Cavity-Backed Conical Spiral Wideband Antenna for Submarine Applications," Masters Thesis, Naval Postgraduate School, June 2000.

Silva, M.M., "Design of an Ultra-Wideband Directional Antenna for a Given Set of Dimension Constraints," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Antennas, Computational Electromagnetics

DESIGN AND PROTOTYPING OF WIDEBAND USQ-113 ANTENNA FOR EA-6B

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

OBJECTIVE: Design and prototype two wideband antennas for the USQ-113 system onboard EA-6B aircraft.

SUMMARY: One of the proposed antennas is an evolution (reduced size) of the "bell" antenna design tested at NPS earlier in FY99, while the other is a new low-profile design conformal to the aircraft "skin." The research included computer modeling and simulation, prototyping, and electrical performance verification via measurements.

THESIS DIRECTED:

Al-Habsi, R.M., "An Ultra Wideband Antenna with Size Constraints," Masters Thesis, Naval Postgraduate School, March 2000.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Antennas, Computational Electromagnetics

JOINT TACTICAL RADIO (JTR) COMBAT WEAR INTEGRATED (COMWIN) VHF AND UHF ANTENNA DEVELOPMENT

Jovan Lebaric, Visiting Associate Professor
Richard Adler, Research Associate Professor
Andrew Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: The preliminary design of two (VHF and UHF) Combat Wear Integrated (COMWIN) Antennas for the Man-Protable Joint Tactical Radio (JTR).

SUMMARY: Investigated designs of lightweight antennas devoid of any visual signature with frequency coverage from 30MHz to 2,000 MHz. The concept is based on the 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.

PRESENTATIONS:

Gainor, T., Lebaric, J., 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.

Gainor, T., Lebaric, J., Adler, R., "Ultra-Wideband RF Helmet Antenna," MILCOM 2000, Los Angeles, CA.

Lebaric, J., Tan, A., Adler, R., "An Ultra-Wideband UHF Helmet Antenna for Man-Portable Implementation of the Joint Tactical Radio System (JTRS)," JWWG Meeting, SPAWAR System Center, San Diego, CA.

THESES DIRECTED:

Tan, A.T., "Design of an Ultra-Wideband Low Profile Vertically Polarized UHF Antenna for the U.S. Ground Troop Helmet," Masters Thesis, Naval Postgraduate School, March 2000.

Gainor, T., "Ultra-wideband Radio Frequency Vest Antenna Design," Masters Thesis, Naval Postgraduate School, September 2000

Limbert, M.E., "Ultra-wideband Combat Wearable Integrated (COMWIN) Antenna Design for the Joint Technical Radio System (JTRS)," Masters Thesis, Naval Postgraduate School, September 2000.

Emo, T., "Low-Profile Man-Portable HF Antenna Design," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Antennas, Computational Electromagnetics

ADVANCED PROCESSOR AND MEMORY RESEARCH

H. H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering
Sponsor: NPS Foundation, Inc.

OBJECTIVE: The objective in this task is to design two key very large-scale integrated circuits (VLSI) for a vector pipelined processor architecture. The first chip performs the function of interfacing baked memories using permutation-based decoding to a bus. The second chip is a pipelined vector processor that performs Radix-R Butterfly operations, complex vector addition and multiplication.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Vector Processor, Pipelining, Fast Fourier Transform, Digital Signal Processing

CRYPTOLOGIC COMMUNICATIONS SYSTEMS LABORATORY DEVELOPMENT
H. H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering
Sponsor: Center for Reconnaissance Research

OBJECTIVE: Perform design, implementation and documentation of new cryptologic communications laboratory for wireless simulation, generation and reception for use by students studying in various aspects of Information Operation/Information Warfare.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications

KEYWORDS: Signal Intelligence, Information Warfare, Engineering, Communications Systems, Technical Education

JOINT IO/IW RESEARCH INITIATIVE BETWEEN
NPS/NSA CRYPTOLOGIC
CHAIR AND AFIWC
H. H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering
Sponsor: U. S. Air Force Information Warfare Center

OBJECTIVE: Promote innovative Information Operations Research by NPS academia to support AFIWC mission.

DoD KEY TECHNOLOGY AREAS: Electronics

KEYWORDS: Communications, Signal Processing, Computers, Network Security

NRL SUPPORT FOR NPS STUDENT THESIS RESEARCH ON VSAT EXPLORATION
H. H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Research Laboratory

OBJECTIVE: Promote innovative VSAT research by NPS students in support of the NRL mission

DoD KEY TECHNOLOGY AREAS: Other (Cryptology)

KEYWORDS: Communications, Signal Processing, VSAT, Collection, Radio Frequency

PROJECT GUSTY ORIOLE
H. 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, Navy Tactical Exploitation of National Capabilities (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 SS4051, Military Space Systems and Technologies.

SUMMARY: Completed work on the following tasks: a) developed plans for a Satellite Communications System, which has been transitioned to a CRADA with Hughes Space and Communications Company (since acquired by Boeing Space Systems); b) completed triple-modular redundancy computer test bed for development of single-event-upset tolerant space-based computers from COTS computers. Entering test phase of this project now; c) analyzed data from Fleet Battle Experiment Echo supporting development of data fusion algorithms for Maritime Situational Awareness; and d) supported courses SS3001, SS4041, and SS4051 by the development of geolocation material and the arrangement of field trips to visit contractor sites.

THESES DIRECTED:

Summers, D., "Design and Construction of a Fault-Tolerant Computer," Masters Degree, Naval Postgraduate School, July 2000.

Hofheintz, D., "Development of a Fault-Tolerant Computer for Space Applications," Masters Thesis, Naval Postgraduate School, July 2000.

Martin, S.G., "Space-Based Computer Network Operations (CNO)," Masters Thesis, Naval Postgraduate School, September 2000.

Racinez, R., "Transitioning to the Unified Cryptologic Architecture," Masters Thesis, Naval Postgraduate School, September 2000

Wagonner, W.R., "Integration of Maritime Shipping Technical Data into a Common Database for Use in a Graphical Display," Masters Thesis, Naval Postgraduate School, September 2000.

Ziegler, W., "The Roles and Required Capabilities of Future National SIGINT Systems (U)," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Spaceborne Computers, Space Communications

GEOLOCATION WORKBENCH
H. H. Loomis, Jr., Professor
Department of Electrical and Computer Engineering and Space Systems Academic Group
Sponsor: Center for Reconnaissance Research

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.

SUMMARY: Concluded the project after the departure of Professor Shimeall in April 1999. The workbench now supports:

- 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;
- Routines for writing and reading internal standard PDW data files;
- The inclusion of several demonstration signal processing routines;
- The inclusion of several demonstration signal display routines;
- The inclusion of a 2-dimensional TDOA based Newton-Raphson geolocation algorithm for pedagogical purposes.

The software runs under MATLAB Version 5.x. It has been distributed to a contractor of the NRO for coordination with operational geolocation software.

PRESENTATION:

Loomis, H.H., Jr., "The Geolocation Workbench," presentation and demonstration to the Geolocation Workshop, National Reconnaissance Office, Chantilly, VA, March 2000.

OTHER:

Loomis, H.H., Jr., "Geolocation Workbench," Version 1.0, Department of Electrical and Computer Engineering, Naval Postgraduate School, January 2001. (MATLAB 5.x software)

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Geolocation

IT-21 WAN 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. Initiate a new focus on SS7 networks and their interface with IP networks such as IT-21. This work is part of a continuing project with NELO.

SUMMARY: 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 project identified and reported a significant vulnerability in the Open Shortest Path First (OSPF) link state routing protocol and the Multiprotocol Label Switching (MPLS) label distribution protocol. The project also continues to investigate vulnerabilities in ATM's PNNI routing protocol. High-fidelity simulations of the SS7 network for testing and analysis of SS7/IP integration were developed. Several aspects of this project are classified. This project is in its third year of funding.

PUBLICATIONS:

McEachen, J.C. and Cay, A., "Masking Compressed Video Connection Utilization in ATM Networks," to appear in the *Proceedings of the 2001 IEEE International Symposium on Circuits and Systems (ISCAS 2001)*, Sydney, May 2001.

McEachen, J.C., Ow, K.C., and Lim C. T., "A System Level Description and Model of Signaling System No. 7," to appear in the *Proceedings of the 2001 IEEE International Symposium on Circuits and Systems (ISCAS 2001)*, Sydney, May 2001.

McEachen, J.C. and Chesser, R.C., "Vulnerabilities in the Open Shortest Path First Routing Protocol," *Proceedings of the 2000 IEEE Military Communications International Symposium (MILCOM 2000)*, Los Angeles, CA, October 2000.

McEachen, J.C., Ow, K.C. and Lim C. T., "A Modeling Architecture For Standards-based Simulation of Signaling System No. 7," *Proceedings of OPNETWORK2000*, Washington, D.C., August 2000.

Cay, A. and McEachen, J.C., "Spectral Analysis of Connection Utilization Masking in ATM Networks," *Proceedings 25th IEEE International Conference on Acoustic, Speech and Signal Processing (ICASSP 2000)*, Istanbul, 3-5 June 2000.

PRESENTATIONS:

McEachen, J.C., "Vulnerabilities in the Open Shortest Path First Routing Protocol," 2000 IEEE Military Communications International Symposium (MILCOM 2000), 24 October 2000.

McEachen, J.C., "A Modeling Architecture For Standards-based Simulation of Signaling System No. 7," OPNETWORK2000, Washington, D.C., 1 September 2000.

McEachen, J. C., "Modeling Satellite Communications," OPNETWORK 2000, Washington, D.C., 31 August 2000.

THESES DIRECTED:

Chesser, R.L., "Vulnerabilities in the Open Shortest Path First Routing Protocol," Masters Thesis, Naval Postgraduate School, March 2000.

Ow, K.C., "OPNET Simulation of Signaling System No. 7 (SS7) Network Interfaces," Masters Thesis, Naval Postgraduate School, March 2000.

Lim, C.T., "Simulation of Signaling System No. 7 (SS7) Message Transfer Part 2 (MTP-2)," Masters Thesis, Naval Postgraduate School, March 2000.

Dixon, G.L., "Dynamics of Private Network-to-Network Interface (PNNI) Routing In ATM Vulnerability Assessments," Masters Thesis, Naval Postgraduate School, September 2000.

Stone, G.N., "Path-based Network Policy Language," Doctor of Philosophy, Naval Postgraduate School, September 2000.

MacRitchie, J.R., "An Examination of Possible Attacks on Cisco's IPSec-based VPN Gateways," Masters Thesis, Naval Postgraduate School, December 2000.

Lam, W., "Meeting SIGINT Constraints in IP Telephony," Masters Thesis, Naval Postgraduate School, March 2001.

Mullin, S., "Vulnerabilities in Multiprotocol Label Switching," Masters Thesis, Naval Postgraduate School, March 2001.

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

SECURITY VULNERABILITIES OF WIRELESS PROTOCOLS

John McEachen, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: Perform research into the internal protocols of wireless computer networks and identify vulnerabilities associated with their standard implementation. Examine use of cellular-based protocols such as Mobitex and CDPD for data communications. Begin investigation into the interface of wireless networks with landline IP networks in the interest of examining upcoming technologies such as WAP and IP telephony.

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. Work on this project began in December 2000. This project already has identified several denial of service issues in the IEEE 802.11 control and management functions.

PUBLICATION:

McEachen, J.C. and Braswell, B., "Vulnerabilities in Control and Management Functions of IEEE 802.11Wireless LANs," Naval Postgraduate School Technical Report, NPS-EC-01-001, February 2001.

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

KEYWORDS: 802.11, ATM, Wireless, LAN, High Speed Networking, Ad-hoc Networking

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

John McEachen, Assistant Professor
Department of Electrical and Computer Engineering
Sponsor: National Security Agency

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

SUMMARY: This project uses the OPNET Modeler network simulation tool to perform computer simulation of radio frequency (RF) environments where wireless LANs may be implemented. The most significant result of this project has been the development of a high-fidelity model of the IEEE 802.11a high-speed WLAN. This model will be release to the public in March 2001. Issues relating to receiver sensitivity and performance in noisy environments were also examined. Modeling includes analysis of Ad-hoc networks as well.

PUBLICATION:

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

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

KEYWORDS: 802.11, ATM, Wireless, LAN, High Speed Networking, Ad-hoc Networking

RADIATION HARDENED SPACE BASED ELECTRONIC DEVICES AND SOLAR CELLS

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, InP and Multi-junction cells. To investigate annealing methods for 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 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 2nd International Conference on Modeling and Simulation of Microsystems*, San Juan, PR, April 1999.

THESES DIRECTED:

Lee, R.D., "The Design, Simulation, and Fabrication of a VLSI Digitally Programmable GIC Filter," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Electronics, Environmental Quality

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

NULKA FOT&E TEST PLAN DEVELOPMENT AND TECHNICAL SUPPORT

Phillip E. Pace, Associate Professor
Department of Electrical and Computer Engineering
Kenneth Davidson, Professor
Department of Meteorology
Sponsor: Commander Operational Test and Evaluation Force

OBJECTIVE: In order to evaluate the EW effectiveness of the Nulka/MK53 decoy launch system, Follow-On Test and Evaluation (FOT&E) exercises at sea must be conducted using captive-carry seekers, and test ships conducting both live NULKA firings as well as hovering the NULKA rocket with the use of a helicopter. Command Operational Test and Evaluation Force (COMOPTEVFOR) is the Navy's independent test agent responsible for developing the test requirements and test procedures. They also perform the analysis of the field test data to determine the degree of the NULKA's effectiveness. This technical support contract enabled consultation with COMOPTEVFOR to aid in the design of the test requirements and procedures as well as guide the decision for the necessary tools needed for the post-test analysis.

SUMMARY: Through several meetings at COMOPTEVFOR, the group was able to lay down a specific test plan that exercised the NULKA's EW capability. The test involved multiple ships at sea, several NULKA rounds for live fire, several captive-carry threat seekers (NRL's P-3) and plans for a helicopter to hover the rocket at various positions.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics

KEYWORDS: Nulka/MK53, Decoy Launch System

AN OPTIMUM SENSOR NETWORK CONFIGURATION

Phillip E. Pace, Associate Professor
Department of Electrical and Computer Engineering
Sponsors: Naval Air Systems Command and Johns Hopkins University

OBJECTIVE: This project provides support to the Airborne Electronic Attack (AEA) Analysis of Alternatives (AoA) Modeling and Simulation effort in the area of sensitivity analysis of the solutions evolved by NRL's Airborne Reactive Electronic Warfare Simulation (ARES). This network-centric analysis is to determine the robustness in the derived measures of effectiveness or sensitivity to system failures or variances in performance parameters. In addition, a sensitivity analysis is performed to test the vulnerability of solutions to the environment (e.g., threat intensity, terrain, IADS, etc.).

SUMMARY: This work continues the investigation of using the ARES to determine an optimum sensor/jammer network configuration for the suppression of enemy air defense (SEAD) using the classified RT4, RT2 scenarios. This involves evaluating the sensitivity of the Measures of Effectiveness (MOEs) to small perturbations in the optimal solution (as derived by the genetic algorithm in ARES). For example, a trade space for RT4, RT2 might involve four EA-6Bs, two Global Hawk unmanned aerial vehicles (UAVs), and six Miniature Air Launched Jammers (MALJs). After the ARES genetic simulation, the optimum answer could be: three EA-6Bs with ICAP 3 receivers but with an increase in sensitivity (e.g., by 10 dB), two Global Hawks with receivers having –90 dBm sensitivity and a MALJ with a specific X-band jammer onboard. The derived measures of effectiveness (MOE) might be for example: total tracking time by early warning radars = 20 s and total Surface-to-Air Missile (SAM) engagements = 20. A perturbation of the solution (e.g., no Global Hawk UAVs) is prepared and several vignettes are run for both RT2, RT4 to investigate the effect on the MOEs. This in turn will demonstrate the robustness of the MOEs to perturbations from the optimal solution. The tasks involved with this effort include running the RT4, RT2 distributed scenarios with conventional ARES (no genetic algorithms) to verify solutions and corresponding MOEs and then changing one or more parameters in the scenario solution and rerunning ARES to investigate the sensitivity of the derived MOEs to these changes.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics

KEYWORDS: Network-Centric, Analysis of Alternatives, Airborne Electronic Attack, EA-6B, Unmanned Aerial Vehicles, Suppression of Enemy Air Defense

NAVY SURFACE ANTI-SHIP CRUISE MISSILE THREAT SIMULATOR VALIDATION WORKING GROUP

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

OBJECTIVE: The objective of this proposal is to provide technical leadership to the Navy Surface Anti-Ship Cruise Missile Threat Simulator Validation Working Group. Three types of simulations are currently being validated by the SVWG for use in test and evaluation. These include (a) radio frequency missile hardware simulators, (b) infrared missile hardware simulators and (c) computer models of missile seekers and related electronics.

SUMMARY: To insure that each ASCM simulator accurately represents the associated threat missile, OPNAV (N912) established the Navy-Unique ASCM Simulator Validation Working Group (SVWG). Three types of simulations are currently being addressed by the SVWG for use in EW test and evaluation (OPEVAL). These include (a) radio frequency hardware simulators, (b) infrared hardware simulators and (c) computer models. The duties for the SVWG chairman include coordinating with the Navy's Simulator Validation Coordinator, the NRL ENEWS Program Manager and other Navy commands (e.g., Commander, Operational Test and Evaluation Force) to prioritize the simulator validations for N912 approval. Additional responsibilities include coordinating with the Office of Naval Intelligence for threat data review and convening the SVWG as an independent and unbiased reviewer for all of the validation reports.

PUBLICATIONS:

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*, to be published.

Pace, P.E. and Zulaica, D.P., "A Relative Targeting Architecture for Test Range Visualization in Captive-Carry Missile Simulator Experiments: USS Peterson-Nulka Test Results (July 9, 1998)," Naval Postgraduate School Technical Report, NPS-EC-00-006, 3 May 2000.

PRESENTATIONS:

Pace, P.E., "SVWG Organizational Chart and Validation Plan," presented at the N9 Threat ASCM Simulator Validation Working Group, Naval Research Laboratory, 1 February 2000.

Pace, P.E., "The SVWG Charter – A Proposal," presented at the N9 Threat ASCM Simulator Validation Working Group, Naval Research Laboratory, 1 February 2000.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics

KEYWORDS: Hardware-in-the-Loop, Threat Missile Simulators, Infrared, Computer Missile Simulation

DIGITAL TARGET IMAGING ARCHITECTURES

Phillip E. Pace, Associate Professor
Douglas J. Fouts, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The technical objective of this research is twofold. The *first* objective is to quantify the system-level implementation tradeoffs of a digital, programmable imaging architecture to generate realistic false target signatures against high resolution imaging radars, including synthetic aperture radar (SAR) and inverse SAR (ISAR), using all-digital techniques and modern digital radio frequency memory (DRFM) technology. The *second* objective is to design, fabricate and test an all digital target-imaging device capable of generating *large* false targets using wideband chirp signals of any duration to provide a new, superior radio frequency (RF) decoy capability.

SUMMARY: To generate the target and its motion, the user will program the *target extent*, the *amplitude* characteristics and the *motion profile* of each scatterer within the image on a pulse-to-pulse basis. The imaging device will reduce both the noise of the repeated signal and the size of such a system over prior analog technology with a significant cost reduction. The all-digital design will permit real-time alteration of operating parameters, permitting rapid and adaptive shifting among different types of large targets. It is expected that the device will be transitioned into the AN/SLY-2 (AIEWS) Increment-2 in order to generate structured false targets including any target motion or movement required for time-critical platform protection. In this first year we investigate the system-level tradeoffs and design a new programmable

imaging architecture able to generate high-fidelity target images that have a realistic size (e.g., 512 range bins).

PUBLICATIONS:

Pace, P.E., Ekestorm, S., Karow, C., and Fouts, D., "An All-Digital Image Synthesizer for Countering High-Resolution Imaging Radars," Naval Postgraduate School Technical Report, NPS-EC-00-005, 24 February 2000.

Pace, P.E., Fouts, D.J., Ekestorm, S., and Karow, C., "Digital Iimage Synthesizers for Countering High-Resolution Imaging Radar," *IEEE Transactions on Aerospace and Electronic Systems*, in review.

PRESENTATIONS:

Pace, P.E., Ekestorm, S., Karow, C., Fouts, D., "All-Digital Image Synthesizer for Countering High Resolution Imaging Radars -- Progress Report FY99/00," presented at the TTCP-Technical Program 3, Naval Research Laboratory, Washington, D.C., 12 January 2000.

Pace, P.E., Ekestorm, S., Karow, C., Fouts, D., "All-Digital Image Synthesizer for Countering High Resolution Imaging Radars - Progress Report FY99/00," presented at Code 5740 - Ships Self-Defense, Naval Research Laboratory, Washington, D.C., 13 January 2000.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics

KEYWORDS: Imaging Decoys, Inverse Synthetic Aperture Radar, Counter-Targeting, Counter-Terminal, Digital Radio Frequency Memories, DRFM

ROBUST SYMMETRICAL NUMBER SYSTEMS

Phillip E. Pace, Associate Professor
David C. Jenn, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: The objective of this research is to investigate new symmetrical number systems and their application to electronic engineering systems.

SUMMARY: Both an optimum symmetrical number system (OSNS) and a robust symmetrical number system (RSNS) have been investigated. The RSNS has an inherent performance advantage over the OSNS design since the encoding errors due to several comparators changing at one time is eliminated (Gray code properties). Applications investigated include high-speed folding analog-to-digital converters (ADCs) and phase-sampled direction finding antenna architectures. Symmetrical number system preprocessing is used to decompose the amplitude analyzing (folding ADC) or spatial filtering (DF antenna) operation into a number of parallel sub-operations (moduli) that are of smaller computational complexity. A much higher resolution is provided after the N different moduli are used and the results of thee low precision sub-operations are recombined. By incorporating the OSNS or RSNS preprocessing concept, the performance of the system can be analyzed exactly. The OSNS gives the maximum dynamic range while the RSNS reduces considerably, the number of possible encoding errors. Simulation results for an RSNS ADC are reported as well as experimental results for a prototype OSNS and RSNS direction finding system.

PUBLICATIONS:

Pace, P.E., Styer, D., and 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*, Vol. 47, No. 5, May 2000, pp. 462-467.

Pace, P.E., Styer, D., and Ringer, W.D., "An Optimum SNS-to-Binary Conversion Algorithm and Pipelined Field Programmable Logic Design," *IEEE Transactions on Circuits and Systems—II: Analog and Digital Processing*, Vol. 47, No. 8, Aug. 2000, pp. 736-745.

Pace, P.E., Wikersham, D., Jenn, D., York, N., "High-Resolution Phase Sampled Interferometry Using Symmetrical Number Systems," *IEEE Transactions on Antennas and Propagation*, 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 Symmetrical Number System Encoding," *Proceedings of the IEEE International Conference on Phased Array Systems and Technology*, Dana Point, CA, 22 May 2000, pp. 169-172.

PATENT:

Pace, P.E., Styer, D., "Wideband Undersampling Digital Receiver," Naval Postgraduate School, U.S. Patent 6,031,879, 29 February 2000.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Electronics

KEYWORDS: Asymmetrical Number System, Direction Finding Antennas, Folding Analog-to-Digital Converter, Gray Code Property

PHOTONIC SAMPLING ARCHITECTURES FOR MICROWAVE SIGNAL COLLECTION AND ANALYSIS

Phillip E. Pace, Associate Professor
John P. Powers, Distinguished Professor
Department of Electrical and Computer Engineering
Sponsors: Defense Advanced Research Projects Agency and Naval Postgraduate School

OBJECTIVE: The objective of this research is the experimental investigation of a photonic sigma-delta architecture for high-speed sampling and digitization of RF and microwave signals. Our photonic sigma-delta ADC uses a mode-locked laser to oversample an input signal at two Mach-Zehnder interferometers. A fiber lattice accumulator is embedded within a feedback loop around a single-bit quantizer to spectrally shape the quantization noise to fall outside the signal band of interest. Decimation filtering is applied to the quantizer output to construct the input signal with high resolution.

SUMMARY: A single-bit, first-order, electro-optical sigma-delta modulator for use in wideband digital antennas was designed, constructed and experimentally tested. The construction and experimentation of the modulator was in two parts: the signal oversampling subsystem and the fiber lattice accumulator. A pulsed 1550-nm laser diode source was used to optically sample the RF antenna waveform. Performance characteristics of this subsystem were compared with the results of a computer simulation. A comparator circuit was designed and constructed in order to drive the signal accumulation in the fiber lattice in the proper direction. Before constructing the fiber lattice, the phase modulator and the semiconductor optical amplifier were characterized. The results of the characterization of the phase modulator determined the appropriate output voltage required by the comparator circuit. The characterization test of the optical amplifier established the correct operating range required for a monotonic linear response of the fiber lattice accumulator. Finally, a 4-port fiber lattice accumulator was constructed using a phase modulator, a semi-conductor optical amplifier, a pair of variable-ratio directional couplers and a delay loop equal to the pulse repetition interval of the sampling laser. The directional coupler coupling coefficients were matched with the gain of the optical amplifier to produce a monotonic response of the fiber lattice accumulator. Experimental results for the sigma-delta architecture were taken. Correct accumulation in the fiber lattice was not achieved since the linewidth of the laser diode was too broad. In addition, the need for a piezo-electric transducer for adaptively adjusting the optical cavity length was identified.

PUBLICATION:

Pace, P.E., Bewley, S.A., and Powers, J.D., "Fiber Lattice Accumulator Design Considerations for Optical Sigma-Delta Analog-to-Digital Converters," *Optical Engineering*, Vol. 39, No. 6, June 2000, pp. 1517–1526.

PRESENTATION:

Gillespie, W.U., Powers, J.P., and Pace, P.E., "Design and Experimental Evaluation of an Integrated Optical Sigma-Delta Modulator for Wideband Digital Antennas," presented at the DARPA/MTO 2000 RF Lightwave Integrated Circuits, Cincinnati, OH, 16 October 2000.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Sensors, Sigma-Delta, Sampling, Electro-Optic, Photonics, Electronics

ELECTRONIC WARFARE ADVANCED TECHNOLOGY STUDIES

R. Clark Robertson, Professor
Ron Pieper, Visiting Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Air Warfare Center-Aircraft Division and Naval Postgraduate School

OBJECTIVE: The objective of this project was to determine the conditions for which the aim-point of an infrared (IR) missile on a "hot" aircraft is 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 tends to track on and aims for the "hottest" part of the target within the unobscured field-of-view (FOV), tracking performance depends 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 changes as functions of both the aspect of attack and the 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. The effectiveness of flare countermeasures depends 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.

PRESENTATION:

DeLeo, N.C., Pieper, R., and Robertson, C., "Infrared Missile Aim-Point Modeling and Flare Countermeasure Effectiveness," presented at PMA-272, Patuxent River, MD, 6 June 2000.

THESIS DIRECTED:

DeLeo, N.C., "Infrared Missile Aim-Point Modeling and Flare Countermeasure Effectiveness," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare

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

MISSILE AIM-POINT SENSITIVITY

R. Clark Robertson, Professor
Ron Pieper, Visiting Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Air Warfare Center-Aircraft Division and Naval Postgraduate School

OBJECTIVE: The objective of this study is to continue and elaborate on the aim-point study previously performed on the F15E using the F/A-18-E/F as a platform. The behavior of the aim-point of an IR missile can be simulated using a program developed by SAIC for the F15E aim-point study. Various questions addressed in the previous aim-point study will again be addressed, but the focus in this study will be on the F/A-18-E/F aircraft.

SUMMARY: Aircraft survivability under conditions of a missile attack depends to a large extent on the tracking performance of the missile. Through the use of computer programs such as MOSAIC and SPIRITS, various aspect dependent scenarios will be studied. The SPIRITS package allows for full imaging information at the seeker. The dependence of the aim-point on conditions such as aspect and aircraft signature levels, both with and without IRCM, will be examined. At least three surface-to-air missile threats, the Stinger Basic, the SA16, and the SA18, will be tested with the F/A-18-E/F. In addition, selected air-to-air missiles will also be tested with the F/A-18-E/F. A check will be made to determine if the aim-point is sensitive to the aspect angle between missile and aircraft and the effect of IRCM as a function of aim-point. A preselected combination of ranges and aspects will be used to define the initial experiment under typical operating conditions taken between minimum rated thrust and afterburner without IRCM. The aim-point during the flyout and chase scenario will be monitored as well as the aim-point for the initial lock-on. We will then examine the effectiveness of IRCM for various dispense locations. For example, if IRCM is dispensed with the intent of defeating a missile aimed at the engine or plume, but the missile is actually aimed at the aircraft nose, what is the effect on IRCM as compared with IRCM designed to be in the field-of-view (FOV) of the missile aim-point? Also examined will be missile range effects as a function of the threat FOV.

This project is new for FY01, but is likely to be canceled prior to completion due to the lack of support for this research by the IW curriculum.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare

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

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 for testing of signal classification algorithms.

SUMMARY: This work continued in 2000 with the focus on testing the Higher-Order Cyclostationary-Based Classifier (HBC). One student performed comprehensive testing on the classification performance of several types of digital modulated signals. A follow-on student focused on a particular problem area (BPSK) and performed further testing and analysis.

THESES DIRECTED:

Cadenazzi, M.P., "Performance Analysis of the Higher-Order Cyclostationary-Based Classifier," Masters Thesis, Naval Postgraduate School, March 2000.

Bailey, B.K., "Performance and Space Borne Application Analysis of the Higher-Order Cyclostationary-Based Classifier," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Other (Signal Processing)

KEYWORDS: Signal Classification, Higher Order Cyclostationarity

BEARTRAP POST-MISSION ANALYSIS SYSTEM

Murali Tummala, Professor
Charles W. Therrien, Professor
LCDR Robert Barsanti, USN, Military Instructor
Department of Electrical and Computer Engineering
Sponsor: Air Anti-Submarine Warfare Systems Program Office (PMA-264D)

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: Focus this year was on delivering a final product to the sponsor. A beta-zero version of S2K was delivered to the sites this year. We expect to phase out the project in year 2001 with the final delivery of the system. During 2000, an HTML help system was developed to provide online help for the S2K system. In a software engineering effort, the EMST tracker was redesigned at a schematic level to develop an object-oriented architecture. The focus of this effort was to provide a means for compensating the tracker solution for biases introduced by drifting sonobuoy sensors. Towards this goal, a model of the expected sensor motion was developed and the parameters of this model were estimated using the same Maximum A-Prior (MAP) algorithm that estimates the target motion. Further studies on the estimation and discrimination of time delay of arrival were undertaken.

PUBLICATIONS:

Barsanti, R., Tummala, M., and Therrien, C., "Enhanced Multi-Segment Tracker," Naval Postgraduate School Technical Report, NPS-EC-00-009, 3 July 2000.

Barsanti, R. and Tummala, M., "Passive Target Tracking with Uncertain Sensor Positions," *Proceedings 34th Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, 29 October–1 November 2000.

THESES DIRECTED:

Tidwell, B.S., "Toward an Object Oriented Architecture for the Enhanced Multi-Segment Tracker (EMST)," Masters Thesis, Naval Postgraduate School, March 2000.

McCabe, E.D. and Stone, C.D., "Development of the Beartrap Post Mission Processing System 2000 (S2K) HTML Help Project," Masters Thesis, Naval Postgraduate School, June 2000.

Bennett, G.H., "Acoustic Transient TDOA Estimation and Discrimination," Masters Thesis, Naval Postgraduate School, September 2000.

OTHER:

A beta version of the software was delivered to multiple Beartrap sites in Summer 2000 and Version 1.0 of the software is scheduled for release during the Spring quarter of 2001.

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

WIRELESS NETWORKS FOR MOBILE AD HOC ENVIRONMENTS

Murali Tummala, Professor
Department of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To develop graduate level course materials for wireless networks with emphasis on software defined radio principles and in support of the digital modular radio program. As part of the work, also investigate the mobile ad hoc routing protocols for use in the DMR program.

SUMMARY: The effort to develop materials for a course on wireless networks and software-defined radio is ongoing. There are no textbooks available. Also, the materials are spread among several areas of specialty: wireless engineering, networking, software engineering, radio engineering, and signal processing. During the course of development of the course materials, we investigated the routing protocols for mobile ad hoc networks: zone routing protocol and adaptive on-demand distance vector protocol.

PUBLICATION:

Shea, K.M., Ives, R., and Tummala, M., "Performance Evaluation of the Zone Routing Protocol for Tactical Wireless Networks," Proceedings 34th Asilomar Conference on Signals, Systems and Computers, Pacific Grove, CA, November 2000.

THESES DIRECTED:

Shea, K.M., "Simulation and Performance analysis of the Zone Routing Protocol for Tactical Mobile Ad Hoc Networks," Masters Thesis, Naval Postgraduate School, September 2000.

Theriot, T.P., "Simulation and Performance Analysis of the Ad Hoc On-demand DistanceVector Routing Protocol for Tactical Mobile Ad Hoc Networks," Masters Thesis, Naval Postgraduate School, December 2000.

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

KEY WORDS: Ad-hoc Wireless Networks, Software Defined Radio, Joint Tactical Radio System, Digital Modular Radio

ULTRA WIDEBAND ELECTROMAGNETIC MEASUREMENTS/ ULTRA WIDEBAND ANTENNA DEVELOPMENT

Capt J. Scott Tyo, USAF, Military Instructor
Department of Electrical and Computer Engineering
Sponsor: Air Force Research Laboratory

OBJECTIVE: To develop sensors and measurement strategies for use in ultra-wideband (UWB) microwave measurements, and to develop antennas for transmitting short-pulse signals.

SUMMARY: UWB electromagnetics involves the generation and radiation of electromagnetic transients on the order of 100 picoseconds in duration. These signals have instantaneous bandwidths of more than two decades. Conventional sensors and deconvolution strategies do not work with such large bandwidth signals. Under this project, several novel sensors were developed that minimize the need for deconvolution. These sensors work by optimizing their responses in the time domain, ignoring late-time effects that occur after the measurement of interest is over. In this way, the sensor can be used with almost no correction for short times. To help with the development of sensors and antennas for these applications, a study of the effect of aperture shape on antenna performance was also conducted.

PRESENTATIONS:

Tyo, J.S., "Optimal Feeds for 4-Arm IRAs, Ultra-Wideband, Short-Pulse Electromagnetics," presented at EUROEM 2000, Edinburgh, Scotland, 1-3 June 2000.

Tyo, J.S. and Buchenauer, C.J., "Compact Sensors for Time-Domain Measurements," presented at EUROEM 2000, Edinburgh, Scotland, 1-3 June 2000.

DoD KEY TECHNOLOGY AREAS: Sensors, Directed Energy Weapons

KEYWORDS: Ultra-Wideband Electromagnetics, UWB Metrology

ULTRA-WIDEBAND ANTENNA ARRAY ANALYSIS

Capt J. Scott Tyo, USAF, Military Instructor
Department of Electrical and Computer Engineering
Sponsor: Center for Reconnaissance Research

OBJECTIVE: Investigate the design of ultra-wideband (UWB) array antennas for use in time-domain and broadband CW applications, including the development of concepts for dual-polarization capable UWB arrays. Validate modeling studies with experimental analysis of prototype arrays

SUMMARY: The initial phase of the investigation involved numerical analysis of candidate UWB array elements for beam shape characteristics. The analysis was completed using the finite-difference time domain computational electromagnetics method and the results compared favorably with experimental studies conducted previously. Small arrays of TEM horns were analyzed both numerically and experimentally, and the performance of the elements in and out of arrays was comparable. The steer ability of timed arrays was experimentally demonstrated in receiving mode for small collections of elements. Future work in this effort will include analysis of dual-polarization elements, time-domain beam forming, and element-to-element interactions.

THESIS DIRECTED:

Rutherford, S., "Combat Systems, Use of UWB Radar for Human Heart and Respiration Rate Localization," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Sensors, Directed Energy Weapons

KEYWORDS: Ultra-Wideband Array Antenna, UWB, Dual Polarization

POLARMITERIC IMAGERY FOR REMOTE SENSING

Capt J. Scott Tyo, USAF, Military Instructor
Department of Electrical and Computer Engineering
Sponsor: Unfunded

OBJECTIVE: To improve the design of optical imaging polarimeters by maximizing SNR and minimizing the effect of experimental uncertainty.

SUMMARY: Imaging polarimetry requires simultaneous measurement of polarimetric information at as many as 10^6 pixels across a scene. The fewer measurements that are necessary to reconstruct the angle, degree, and ellipticity of polarization, the more suitable the method is for real-time applications. However, making fewer measurements increases susceptibility to detection noise and systematic errors associated with optical element misalignment and miscalibration.

The optimal polarimeter configurations for rotating compensator and variable retardance polarimetry were derived under this project. By choosing appropriate measurement strategies, SNR in reconstructed

images could be improved by as much as 15 dB without improving the quality of the optics used to make the measurement. Additionally, the effect of element misalignment was quantified, and strategies to mitigate these effects were developed.

PUBLICATIONS:

Tyo, J.S., "Noise Equalization in Stokes Parameter Images Obtained Using Variable Retardance Polarimetry," *Optical Letter* 25, pp. 1198-1200 (2000).

Tyo, J.S., "Improvement of the Point-Spread Function in Scattering Media by Polarization Difference Imaging," *Journal of the Optical Society of America* 17, pp.1-10 (2000).

Tyo, J.S., "Considerations in Polarimeter Design," *SPIE* Vol. 4133 Polarization Measurement and Analysis III, D.B. Chenault, M.J. Duggin, W.G. Egan, and D.H. Goldstein, eds., pp. 65-74, *SPIE*, Bellingham, WA, 2000.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Polarimetry, Polarimetric Imagery, Remote Sensing

SILVACO TOOLS DEVELOPMENT FOR RADIATION EFFECTS

Todd Weatherford, Assistant Professor
Andrew Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsor: Naval Surface Warfare Center-Crane

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

SUMMARY: Work in 2000 has focused on modeling recombination effects in Metal-Oxide-Semiconductor structures and charge trapping in buried oxides. Results in the MOS structure simulations correlated to charge yield in oxide layers, but correlation was poor for recombination in silicon regions. Buried oxide simulations continued to model multi-edge SOI MOSFETs for back channel leakage. Effort discovered limitations in the oxide transport models which was later corrected.

THESES DIRECTED:

Gaskey, G., "Transient Response to Single Event Upset in Silicon-on-Insulator Field Effect Transistors," Masters Thesis, Naval Postgraduate School, March 2000.

Lake, V., "Modeling Total Dose Radiation Effects in a Multi-Edge SOI MOSFET," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Electronics, Materials, Processes and Structures, Modeling and Simulation, Other (Silicon-on-Insulator)

KEYWORDS: Solid-State Electronics, Semiconductors, Radiation Hardening

TIME RESOLVED SINGLE EVENT EFFECT STUDIES IN SOI

Todd Weatherford, Assistant Professor
Andrew Parker, Research Associate
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 0.25um and 0.11um semiconductor process 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. Circuit simulations were performed to predict temporal measurements.

PUBLICATION:

Weatherford, T.R., Whitaker, J.F., and Keast, C., "In-situ Time-Resolved Voltage Transients Measured in CMOS/SOI Inverters," submitted to the IEEE Natural Space and Radiation Effects Conference, July 2001.

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

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

NEUTRON SINGLE EVENT EFFECT STUDIES

Todd Weatherford, Assistant Professor
Andrew Parker, Research Associate
Department of Electrical and Computer Engineering
Sponsors: Navy Strategic Systems Program Office

OBJECTIVE: Initially to examine semiconductor device degradation effects related to neutron irradiation, redirected to study radiation effects on photo detectors.

SUMMARY: Investigated the variance in photo detector responsivity in InGaAs diodes to displacement damage. Radiation tests were performed at UCB's cyclotron and NPS' LINAC. Results showed the commercially available photo detectors were unacceptable for mission requirements. Device modeling, simulation and destructive analysis was performed to understand the failure mechanisms.

THESIS DIRECTED:

Kalowsky, J., "Radiation Effects in InGaAs P-I-N Photodiodes," Masters Thesis, Naval Postgraduate School, December 2000.

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

KEYWORDS: Semiconductors, Opto-Electronics, Radiation Effects, Indium Gallium Arsenide

HIGH PERFORMANCE SEI DEMONSTRATION

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

OBJECTIVE: To support Specific Emitter Identification (SEI) data collection and initiate software code development using SEI DSP algorithms for the High Performance SEI Processor Demonstration.

SUMMARY: Key MOP (Modulation On Pulse) SEI deficiencies were identified. In an unclassified form, current SEI deficiencies include:

- Limited performance against radars with modern modulations. Current techniques cannot handle important emitters that contain small MOP signals from fundamental accuracy limitations, SNR limitations and other factors.

- Average SEI rate ~ XX% (unsatisfactory!) and requires high SNR conditions and pulse averaging for even conventional radars.

- SEI not performed at low SNR conditions.
- Current SEI Database limited by signal -selection, signal fidelity and data processing accuracy, and contains mostly navigation radars with few modern modulation radars. Also, database transportability, from platform to platform, is an issue.

- Current SEI system uses architecture and design developed 20 years ago with some technology improvements.

- Tonal interferences (internal and external) strictly limit current SEI system performance.

- A SEI system based on precision parameter measurements of conventional Radar parameters will not handle Modern Modulation Radars because of agile parameter conditions. Emitter ambiguities and ID errors cannot be resolved with these conventional techniques.

Enemy radar systems and targeting systems utilize coherent radars with modern modulations (frequency agility, PRF agility and other), that our ELINT systems need to defeat or neutralize in conventional military and peacekeeping missions. High Performance SEI techniques must effectively process these radar emitters on a single pulse basis. Also, unambiguous ID of radars associated with civil targets is an increasingly important element of counter-terrorism.

Emitters with modern modulations (agile frequency, agile PRF or PRI, nearly identical classical parameters, frequency coded, phase coded, etc.) are not effectively processed by current techniques. In particular, ELINT systems utilizing classical parameters for sorting and SEI/ID functions are very successful against radars with fixed classical parameters, but have limited success against radar emitters with modern modulations.

Navy EW and ELINT systems have known SEI performance limitations. For example, the Navy JETS Program has identified critical performance limitations, which include ambiguities and SEI/ID deficiencies, as well as problems with unacceptable incidents of fratricide, poor ID performance at low SNRs, lower than desired platform survivability, and operating range performance limitations.

The proposed High Performance SEI Processor will overcome key SEI problems and have the following characteristics:

- Uniquely identify modern radar systems with complex modulations and agile parameter variations that cannot be handled with current SEI techniques.

- Improve SEI rates at lower SNR conditions and use single pulse processing. Tonal interferences will not significantly degrade performance.

- Provide unambiguous ID of civil platform radars of high interest.
- SEI Database is transportable from platform to platform.
- SEI cards will utilize, as much as possible, economical COTS hardware and software technologies.
- Reduce friendly fratricide incidents for a variety of peacetime and wartime scenarios.

SEI technical performance demonstrations were performed using radar emitter collected by the Naval Research Laboratory. DSP algorithms and software were developed for SEI processing and to establish ground truth on the contaminated NRL database. SEI assessments were performed.

In an unclassified summary, DSP SEI results were above 90% correct ID and exceeded SNR performance expectations by at least 3 dB. All project performance goals were exceeded. The sponsor is continuing this work in FY01 for ELINT deinterleavers.

THESIS DIRECTED:

Free, M., "Performance Assessment of an Intrapulse Technique to Identify and Deinterleave Radar Signals," Master's Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Targeting)

KEYWORDS: SEI, ID, RF Rreceiver, MOP Signal Extraction, Parameter Extraction

CURRENT AND PROPOSED DATALINKS FOR NAVAL AVIATION TIME CRITICAL STRIKE

Lonnie A. Wilson, Research Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Chief of Naval Operations (N88)

OBJECTIVE: The objective is to survey and assess current and proposed datalinks for Naval aviation time critical strike.

SUMMARY: Network Centric Warfare requires target information and data flow from sensors to command and control centers for decisions and then target information and data flow to shooters in a timely fashion for successful military strike operations. Datalinks can provide RTIC (Real Time Information to the Cockpit) strike information and paths for target information and data flow capabilities between sensor platforms, command platforms and shooter platforms. Broadcast modes, if implemented, can shorten RTIC time line.

Datalink capabilities, limitations (to include data throughput and transmission ranges), availability and deficiencies will be determined for Navy assets (surveillance, maritime patrol and fighter aircraft, ship and unmanned aircraft), joint assets, and national assets. Current and proposed datalinks considered are:

1. Air to ship data links – for E-2C, EA-6B, F/A-18, F-14, P-3, S-3, EP-3, unmanned aircraft, UAVs, ships and others
2. Air to air data links – between air platforms
3. Joint data links – between air and surface platforms
4. National data links – overhead to surface and air platforms
5. Link 16 / JTIDS for all of the above.

Datalink information is obtained from Navy / contractor product developers. Link 16 / JTIDS, as well as, Link 11, Link 4, CEC, CDL, TCDL, AWW-13, IDM Modem, FTI and other new datalinks are being considered.

Link-16 Datalink information was summarized in a "handbook" format for reference use. Link-16 Datalink information was submitted for sponsor review in December 2000. Other datalink information will be added to the handbook in FY01.

DoD KEY TECHNOLOGY AREAS: Other (Communications)

KEYWORDS: Sensors, Datalinks, IW, Command and Control Centers, Shooters and Network Centric Warfare, Strike, Surveillance, Communications

AEA AIRCHITECTURE AND PLATFORM MIXES

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

OBJECTIVE: The objective is to perform top-level analysis of AEA (Advanced Electronic Attack) Architecture and Platform Mixes and identify key capabilities and needs to support the OSD AEA EA-6B follow-on studies.

SUMMARY: Expected EA-6B service life is through 2015 – 2020 requiring a follow-on platform or platform mix to the ICAP III upgrade expected to IOC in 2004. These efforts will use the EA-6B ICAP III as a baseline to build a future Electronic Attack (EA) capability to accomplish the SEAD role and other Information Operation missions. This core tactical capability includes radar jamming, communication jamming, hard-kill capabilities, and connectivity to ISR and off board assets. The expected result will be a platform mix utilizing available technology to develop a system of systems to provide future EA capabilities.

AEA candidate air vehicles can be manned or unmanned, performing either the dedicated AEA role or having AEA capability as part of their multi-mission capability. The nature of AEA support requires detailed knowledge of the supported air, ground and sea forces and emerging warfighter concepts in Information Operations (IO).

The fundamental goal of the AEA is to find the most mission capable, cost effective solution to tactical aviation requirements for electronic warfare (EW) support. The initial requirement is driven by the necessity to replace an aging EA-6B airframe.

The architecture and preliminary design were completed for a digital ES (Electronic Support) receiver and processor for the AEA application. Technical performance improvements and new operational performance capabilities were identified. The AEA Technical Working Group has agreed to develop the digital EC receiver along with high performance DSP with Specific Emitter Identification. NPS participated and supported the AEA Technical Working Group, the Digital Receiver Focus Group and the SEI Focus Group.

A new digital match filter concept was developed and demonstrated for the high performance detection and processing of LPI radar signals. This new LPI Receiver and DSP processing gain exceeded 36 dB for an LPI signal with 38 dB. Conventional EW receivers would have little or no capability against this LPI emitter.

THESIS DIRECTED:

Christie, K., "Low Probability of Intercept Radar Detection Techniques for Advanced Electronic Support Systems," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare

KEYWORDS: EW, EA, Architecture, F-18G, UAV, UCAV, IW, Radar, Strike, and Surveillance

WIRELESS DAMAGE CONTROL COMPUTER NETWORKS

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

OBJECTIVE: To test and evaluate data rate, range, and interoperability of IEEE 802.11b compliant wireless LAN product components for submarine damage control communications.

SUMMARY: Wireless LAN components rated at 2 Mbps were used in the Memphis test conducted in August 1999. Since the Memphis test, wireless LAN components rated at 11 Mbps were made available by Lucent and Aironet in the fourth quarter of 1999. This project conducted testing of 11 Mbps WLAN components on the campus at the Naval Postgraduate School (NPS) in Monterey, California. The actual measured throughput of both the Lucent Technologies WaveLAN Turbo and the Aironet Turbo DS components rated at 11 Mbps was 2.0 to 4.5 Mbps depending on test condition. Even though the actual data rates were discouraging when compared to the specification rates of 11 Mbps, there is a more than 100% increase in data rates when compared to the previous generation of products rated at 2 Mbps. The actual range measurements were in line with those specified by vendors.

THESIS DIRECTED:

McConnell, R.J., "Testing and Evaluation of Shipboard Wireless Network Components," Masters Thesis, Naval Postgraduate School, March 2000.

OTHER:

Yun, X., "Test and Evaluation of 11 Mbps Wireless LAN Componets," project report submitted to NAVSEA PMS450T2, March 2000.

Yun, X., "Submarine Wireless LAN (SWLAN) Project Overview," presented to Commander Submarine Force, U.S. Atlantic Fleet, Norfolk, VA, April 2000.

Yun, X., "Software Prototyping for DC Communication Applications," project report submitted to NAVSEA PMS450T2, September 2000.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications

KEYWORDS: Damage Control, Wireless Computer Networks

MOTION TRACKING USING INERTIAL SENSORS

Xiaoping Yun, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Chief of Naval Operations (N6) and U. S. Army Research Office

OBJECTIVE: To develop a hybrid inertial/magnetic body tracking system for use in a networked virtual environment.

SUMMARY: As an off-shoot of our previous effort on autonomous underwater (AUV) inertial navigation system research, a hybrid inertial/magnetic body tracking system for use in a networked virtual environment was initiated. Toward this goal, a quaternion-based attitude filter based upon Gauss-Newton iteration and an orthogonal quaternion theorem was developed. This filter continuously corrects for drift and tracks without singularities. Simple, but effective algorithms for calculating sensor null points and scale factors and for determining the limb segment/sensor offsets have also been devised. These offsets allow efficient animation of a human model using world reference orientation data in quaternion form. Differential weighting of sensor data reduces the effects of magnetic field disturbances. In experiments, arms, legs, and the human torso have been tracked in real-time using an inertial/magnetic body tracking

system, which includes three prototype MARG sensors. Preliminary simulation work has also been completed on a reduced order Kalman filter designed for body tracking.

PUBLICATION:

Yun, X., Backmann, E.R., and Arslan, S., "An Inertial Navigation System for Small Autonomous Underwater Vehicles," *Proceedings of 2000 IEEE International Conference on Robotics and Automation*, San Francisco, CA, 24-28 April 2000, pp. 1781-1786.

THESES DIRECTED:

Marins, J.L., "An Extended Kalman Filter for Quaternion-Based Attitude Estimation," Masters Thesis, Naval Postgraduate School, Sep. 2000.

Arslan, S., "Testing and Evaluation of the Small Autonomous Underwater Vehicle Navigation System (SANS)," Masters Thesis, Naval Postgraduate School, March 2000.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: INS, GPS, AUV, Navigation Kalman Filter

REDUCED CREW SIZE METEROLOGY USING WIRELESS LANs AND WEARABLE PCs

Xiaoping Yun, Associate Professor
Department of Electrical and Computer Engineering
Sponsor: Naval Warfare Assessment Center

OBJECTIVE: To investigate the Reduced Crew Size (RCS) Metrology using WLANs and wearable computers.

SUMMARY: Working with the Measurement Science Directorate (MSD) of the Naval Warfare Assessment Station (NWAS), feasibility of developing a general-purpose calibration system using wearable computers and wireless LANs was studied. In particular, a prototype of pressure calibration system has been developed. The prototype system was demonstrated at NAVSEA Philadelphia on 19-21 September 2000 and was well received by the NAVSEA Philadelphia staff.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Metrology, Wireless LAN, Wearable Computer

EVALUATION OF DEINTERLEAVER ALGORITHMS

Lawrence J. Ziomek, Professor
Department of Electrical and Computer Engineering
Sponsor: National Security Agency

OBJECTIVE: In order for the Naval Postgraduate School (NPS) Cryptologic Research Laboratory (CRL) to create it's own "generic testing environment" so that it can independently evaluate the effectiveness of various pulse-train deinterleaver algorithms, it is necessary to develop mathematical models and computer simulations of waveforms that are due to the superposition (interleaving) of *N* different, transmitted pulse trains at a receiver. 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 pulse-train 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: General time-domain and frequency-domain mathematical models for *N* different transmitted pulse trains have been derived. Each pulse train is allowed to have its own number of pulses, carrier frequency, and total duration. In addition, each pulse within a given pulse train is allowed to have different amplitude scaling factors, amplitude-modulating and angle-modulating functions, and pulse lengths if desired. 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. General time-domain and frequency-domain mathematical models for the random received signal have also been derived. The received signal is modeled as being equal to the superposition (interleaving) of *N* different, transmitted 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. Work also began on studying in detail two new pulse-train deinterleaver algorithms that appeared very recently in the open literature. The first algorithm computes what I refer to as the interleaved-pulse-train (IPT) time-of-arrival (TOA) spectrum and the second algorithm computes what I refer to as the interleaved-pulse-train (IPT) cross-correlation detector (CCD) function. Both algorithms claim to be able to provide estimates of the total number of emitters (individually transmitted pulse trains) present in an IPT measured at a receiver, and estimates of the corresponding PRIs by only processing the time-of-arrivals (TOAs) of the individual pulses. Both algorithms claim to be able to handle staggered as well as uniform pulse trains. Four FORTRAN computer programs were also written. The first program generates computer simulated time-series data corresponding to an IPT measured at a receiver. The second program can generate either TOA data only, corresponding to each pulse in an IPT measured at a receiver, or pulse parameter vectors (pulse descriptor words) for an IPT measured at a receiver. At present, each pulse parameter vector contains the following information: 1) type of amplitude modulation used, 2) type of angle modulation used, 3) center frequency, 4) pulse amplitude, 5) TOA, 6) pulse length, 7) phase shift (if PSK is used), 8) frequency shift (if FSK is used), 9) swept bandwidth (if LFM is used), and 10) either up-chirp or down-chirp information (if LFM is used). The third and fourth computer programs compute the IPT TOA spectrum and the IPT CCD function, respectively, by processing TOA data.

OTHER:

Ziomek, L.J., “A Mathematical Model of Interleaved Pulse Trains,” Naval Postgraduate School, ECE Department, Cryptologic Research Laboratory, 3 March 2000, 24 pp.

Ziomek, L.J., “An Initial Review of the Interleaved-Pulse-Train Time-Of-Arrival Spectrum,” Naval Postgraduate School, ECE Department, Cryptologic Research Laboratory, 26 April 2000, 21 pp.

Ziomek, L.J., “An Initial Review of the Interleaved-Pulse-Train Cross-Correlation Detector Function,” Naval Postgraduate School, ECE Department, Cryptologic Research Laboratory, 26 September 2000, 13 pp.

Four FORTRAN computer programs were written

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Modeling and Simulation

KEYWORDS: Interleaved Pulse Trains, Pulse-Train Deinterleaver Algorithms, Measures of Effectiveness