# Electrical Engineering Department

CAPT Robert J. Voigt, USN
Chair

Research and scholarly activity are fundamental to the vitality and viability of any discipline. This is particularly applicable to electrical engineering, which is broadly based and rapidly expanding. Research helps both faculty and midshipmen keep abreast of advancing technology, and ultimately improves the effectiveness of the academic environment by encouraging a modern and relevant curriculum.

Funding for the department's research comes from the Naval Research Laboratory (NRL), the Naval Surface Warfare Center (NSWC), the Johns Hopkins University Applied Physics Laboratory (JHU/APL), and from within the Naval Academy. Research topics supported during the past year included modeling of underwater acoustic signals, microelectromechanical (MEM) switches, high performance optical communications, multilayer packaging of microwave devices, noninvasive probing of high performance microwave circuits, high power vacuum electronics, wireless communication of distributed shipboard sensors, computer controlled radio frequency (RF) data acquisition, simulation of optical fiber interferometric sensors, very low elevation antenna effects, adaptive error correction coding, and injury characterization using magnetic resonance imaging. This faculty research contributes directly to the fleet's operational capabilities, and provides relevant topics that benefit the professional as well as the academic development of our midshipmen.

## Sponsored Research

### Genetic Algorithms for Acoustical Signal Modeling/Detection

Researchers: Professor Delores M. Etter, Assistant Professor Robert W. Ives,
Associate Professor Louiza Sellami and CDR Thaddeus B. Welch, III, USN
Sponsor: Office of Naval Research (ONR)

In biological models of evolution, offspring inherit characteristics from each parent as a result of crossover operations within chromosomes. Additionally, random mutation, which occurs with low probability, introduces new characteristics to offspring. As systems evolve, a "survival of the fittest" competition yields more robust offspring because the characteristics that are passed on to new generations are those that support survival of the species. Genetic algorithms use similar operations of "crossover" and "mutation" on system parameters to create new models that, in general, have better performance than the parent models. This research program proposes to use genetic algorithms to develop robust models of underwater acoustic signals. We believe that this technique can be used to not only develop new models for given signals, but that the evolution process itself can be used to indicate when "new" characteristics, such as a new signal source, enter the signal space.

### Development of MEMS Microwave Switches

Researcher: Assistant Professor Samara L. Firebaugh
Sponsor: The Johns Hopkins University/Applied Physics Laboratory (JHU/APL)

Microelectromechanical (MEM) relays offer many potential advantages over solid-state switches for routing microwave signals, and could facilitate active aperture phased array systems (like the Aegis system) on small vehicles such as missiles or airplanes. They have much lower insertion loss, behave linearly over a wide operation range, and require little power for operation. The Johns Hopkins Applied Physics lab would like to develop a switch for operation at 10GHz, and then use this switch as a building block in more advanced systems. I began the investigation by writing a review of current work in the field and assessing how APL might contribute. There was some previous work at APL with one particular switch design, but the switch was not operational. This design was reviewed and the researcher developed an optical testing method for verifying whether the relay arm was moving as expected, which it was. The problem with the previous design was its high actuation

voltage, which led to problems with dielectric charging, and that it was implemented on a lossy substrate without adequate calibration standards. A second-generation device and packaging scheme is being developed, and the experimental apparatus is being improved. Once the switch is operational, they will be used in an investigation of the factors that affect lifetime and power handling capabilities, which are issues that currently limit the applicability of microelectromechanical relays in microwave applications.

## Advanced Packaging Applications

Researcher: Associate Professor Deborah M. Mechtel
Sponsor: The Johns Hopkins University/Applied Physics Laboratory (JHU/APL)

Wide bandwidth applications have driven the demand for optical waveguides and other components for the processing and transmission of information. Polymers are attractive materials for optical waveguides at both the chip and substrate levels because of their desirable electrical and optical properties as well as their ease of processing. We are developing a technique to simultaneously use polyimide as both a dielectric layer and an optical waveguide in the same multichip substrate structure. Our technique, using poled polymers, will permit electrical and optical interlayers to be formed simultaneously, thus allowing buried optical waveguide and electrical signal lines on the same multi-chip module (MCM-D).

We have also used a technique that employs a noninvasive, laser-based instrument to probe MCM structures fabricated with poled polyimide interlayer dielectrics and thin film metallizations on silicon carriers. The electro-optic interaction between the poled dielectric and the laser beam allows the strength of the internal fields within the MCM to be determined as a function of position. Electric field measurements and mappings can be useful in diagnosing module performance, locating sites of circuit shorts and opens, and determining the efficacy of field containment structures. The detection of electric fields in polyimide with buried circuit elements in multiple layers characteristic of MCM-D structures is being studied. Test systems of two dielectric layers with one metal interlayer are being studied.

The details of the poling and processing operations along with the mechanical, thermal, electrical, optical and electro-optic properties for both lightguide and dielectric layer applications are being examined.

## Design of a Wireless Sensor System/ Power Node Using MC68HC908 Microcontroller and the Bluetooth Communication Link

Researcher: Professor Antal A. Sarkady
Sponsor: Naval Surface Warfare Center, Carderock Division (NSWCCD),
Philadelphia, PA, Code 825, Henry Whitesel

A power node can be defined as an electronic system (or Box) that concentrates/formats information arriving from many sensors and takes appropriate control action when certain well-defined events occur. This power node is intended for machinery monitoring and advanced damage control applications on U.S. Navy ships. Typically, one or more power node is placed in a compartment and the nodes are interconnected/networked throughout the ship by Bluetooth wireless spread-spectrum type transmitters/receivers. These power nodes are powered by rechargeable batteries, operate at low average-power levels and have small physical size. An important property of this type system is the ease of shipboard installation (cabling is not required). This also allows rapid system reconfiguration. A particularly challenging network problem is to assure proper connectivity between nodes when the compartment doors are closed and fully closed and latched (*i.e.*, “dogged”).

An MC68HC908JL3 Microcontroller based power node was designed and prototype tested. This node uses four digital sensors, operates two 24V DC motors to control the action of two water-main valves. An abstract on this power node is being submitted to the 13$^{th}$ International Ship Control System Symposium scheduled in Orlando, Florida in April 2003.

### High Power Vacuum Electronics

Researcher: Assistant Professor James D. Zuber
Sponsor: Dr. Bruce Danly, Naval Research Laboratory (NRL),
Code 6840, Vacuum Electronics Branch

Since September 2001, and for the foreseeable future, the researcher will be conducting research at the Vacuum Electronics Branch of NRL (6840). Past work has involved the development of the gyrotron amplifier for applications ranging up to 94 GHz. There are two specific areas of interest. The first focuses on the development of the WARLOC 94 GHz radar currently being worked at NRL and at their Chesapeake Bay Detachment (CBD). The second specific area involves testing of the gyrotron traveling wave tube (TWT) amplifier. Both of these research efforts are being conducted under the guidance of Dr. Bruce Danly's High Power Devices Section within the Vacuum Electronics Branch.

## Independent Research

### Center for Adaptive Signal Processing Research

Researchers: Professor Delores M. Etter, Assistant Professor Robert W. Ives,
Associate Professor Louiza Sellami and CDR Thaddeus B. Welch, III, USN

The Electrical Engineering Department's Center for Adaptive Signal Processing Research will provide the U.S. Navy and the U.S. Marine Corp with leaders well versed in state-of-the-art digital signal processing (DSP) techniques. Whether these techniques are being used to operate and maintain the latest generation of DSP enhanced combat systems or to envision, specify, and design the next-generation of systems, the foundational material and the undergraduate research opportunities provided at the U.S. Naval Academy are invaluable to the fleet. Adaptive communication systems, cooperative systems behavior, moving and stationary target recognition, localization, tracking, and identification are but a few of the areas of interest in our Center.

## Trident Scholar Project

### Characterization of an Optical Self-Homodyne DPSK Receiver

Researcher: Midshipman 1/C Tarek S. Elmasry, USN
Advisers: Associate Professor R. Brian Jenkins and Associate Professor Deborah M. Mechtel
Sponsor: Office of Naval Research (ONR)

The goal of this project was to create a digital optical demodulator capable of processing information propagating at high data rates in an optical fiber. By processing data at higher rates the information capacity of the channel can be increased. Most demodulators in commercial applications utilized electrical systems. When an optical signal propagating in a fiber optic channel arrives at the receiver, the optical to electrical signal conversion can significantly slow down the processing speed. By optically processing the signal just before the electrical receiver, information can be transmitted at higher data rates. Many methods of building an optical demodulator have tried using different digital signal processing techniques. In this project a demodulator was designed for differential phase shift keyed (DPSK) data using self-homodyne coherent detection, without using a local oscillator. Local oscillators are often incorporated into coherent receivers to provide a phase reference for incoming data. By replacing the local oscillator with a 3-dB coupler and a delay line, the design of this receiver was simplified. In this configuration the incoming signal uses itself as the reference.

Past work on this topic has been mostly theoretical. This project went further by successfully testing a hardware model. Much of the experimental work concentrated on ensuring that constructive and destructive interference occurred in 3-dB couplers. The receiver setup was extremely sensitive to vibration. Experiments had to be performed on a floating table and the receiver had to be enclosed to give proper environmental isolation.

In addition to hardware testing of this receiver, computer simulation of the model was performed to determine required component parameters. It was found that the dominant limiting factor of the communication system was the linewidth of the laser. However, attenuation and receiver noises were also found to have pronounced effects on performance if they exceeded certain limits.

# Publications

## Journal (Refereed) Manuscripts

ETTER, Delores M., Professor (with Holland, C. J. and Grosh, J.), "Export Control of High-Performance Computing: Analysis and Alternatives," *Institute for Electrical and Electronic Engineering (IEEE) Computing in Science & Engineering*, pp. 24-31, May/June 2001.

High-performance computing (HPC) has historically played an important role in the ability of the United States to develop and deploy a wide range of national security capabilities, such as stealth aircraft, sonar arrays, and high-energy rocket fuels. Therefore it is critical that the US stay ahead technically in this important area. Export controls on computer hardware are one of several strategies used to ensure U.S. superiority in HPC. However, rapid advances in computer technology have limited the government's ability to prevent the export of HPC hardware to potential adversaries. In light of these concerns, the Deputy Secretary of Defense (Science and Technology) was asked to conduct a study to develop alternative export control strategies for HPC. This article summarizes the findings of this work completed in November 2000.

ETTER, Delores M., Professor, "A Glimpse into the Department of Defense (DOD) Science and Technology (S&T) Program," *The Bridge*, National Academy of Engineering, Volume 31, Number 2, pp. 11-16, Summer 2001.

As the U.S. Department of Defense (DOD) moves into the twenty-first century, its science and technology program faces significant challenges from several sources. In a changing world environment, asymmetric threats to our military and our country include chemical and biological warfare, nuclear proliferation, and information warfare (cyber warfare). New technologies are available globally, and we must expect that our adversaries will have access to many of them. Unrestricted access encourages a "run faster" strategy to try to maintain our technological edge. At the same time, economic realities require that DOD maintain a robust range of capabilities and use commercial systems and processes whenever possible.

FIREBAUGH, Samara L., Assistant Professor, Jensen, K.F., and Schmidt, M.A., "Miniaturization and Integration of Photoacoustic Detection," *Journal of Applied Physics*, Vol. 92, No. 3, August 2002, pp. 1555-1563.

Photoacoustic spectroscopy (PAS) is an absorption spectroscopy technique that is currently used for low-level gas detection and catalyst characterization. It is a promising technique for chemical analysis in mesoscale analysis systems because the detection limit scales favorably with miniaturization. This work focuses on the scaling properties of photoacoustic spectroscopy, and on the miniaturization of gas-phase photoacoustic detection of propane in a nitrogen ambient condition. The detection system is modeled with a transmission line analogy, which is verified experimentally. The model includes the effects of acoustic leaks and absorption saturation. These two phenomena degrade the performance of the photoacoustic detector and must be controlled to realize the scaling advantages of photoacoustic systems. The miniature brass cells used to verify the model employ hearing aid microphones and optical excitation from a mechanically-chopped, 3.39-mðm He-Ne laser, transmitted into the cells with an optical fiber. These cells are able to detect 10 ppm of propane in nitrogen (a signal level of ~ 1 Pa/W). We also describe the development of a miniaturized photoacoustic system formed by microfabrication. In this case, the pressure-driven deflection of the detection membrane is measured optically. These systems show that photoacoustic detection may be inappropriate for systems with large variations in gas concentration because of

absorption saturation and changing gas acoustic properties. Nevertheless, photoacoustic spectroscopy is a promising technique for the analysis of dilute mixtures in miniature chemical systems.

Ge, Y., Grossman, R.I., Udupa, J.K., Babb, J.S., Kolson, D.L., and McGOWAN, J.C., Captain (USN), "Magnetization Transfer Histogram Analysis of Gray Matter in Relapsing-remitting Multiple Sclerosis," *American Journal of Neuroradiology*, Vol. 22, pp. 470-475, 2001.

Gray matter may be affected by multiple sclerosis (MS), a white matter disease. Magnetization transfer ratio (MTR) is a sensitive and quantitative marker for structural abnormalities, and has been used frequently in the imaging of MS. In this study, we evaluated the amount of MTR of gray matter among patients with relapsing-remitting MS and healthy control subjects as well as the correlation between gray matter MTR abnormality and neurologic disability associated with relapsing-remitting MS. The MTR of gray matter significantly differed between patients with relapsing-remitting MS and healthy control subjects, suggesting that MS is a more diffuse disease affecting the whole brain, and neuronal damage accumulates in step with T2 lesion volume. Our finding of the relationship between gray matter MTR and EDSS indicates that measurement of gray matter abnormality may be a potentially useful tool for assessing clinical disability in MS.

Ge, Y., Grossman, R.I., McGOWAN, J.C., Captain (USN), and Udupa, J., "Magnetization Transfer Ratio Histogram Analysis of Normal Appearing Gray Matter and Normal Appearing White Matter in Multiple Sclerosis (MS)," *Journal of Computer Assisted Tomography (JCAT)*, Vol. 26, pp. 62-68, 2002.

The purpose of this work was to determine the extent of disease and disease severity in the conventional MR normal-appearing gray matter (NAGM) and white matter (NAWM) in patients with relapsing-remitting (RR) and secondary progressive (SP) multiple sclerosis (MS) utilizing quantitative magnetization transfer ratio (MTR) histogram analysis.Each of the RR and SP MS patient groups had significantly smaller MTR histogram mean values in NAGM and NAWM than the healthy subjects (p 0.0015). SP MS patients had a significantly lower first quartile and MTR histogram peak height for NAGM only (p 0.004) when compared with both RR MS patients and healthy subjects. The T2 lesion load had a modest negative correlation with MTR values in both RR and SP MS, but only in NAGM. Separate analysis of GM and WM MTR histograms may allow better detection of subtle damage and better understanding of the natural history of MS disease and ultimately the response to therapeutics.

McGOWAN, J.C., Captain (USN), "On the Use of Quantitative Magnetic Resonance (MR) Imaging," *American Journal of Neuroradiology*, Vol. 22, pp.1451-1452, 2001.

In addition to targeted investigations that might establish the usefulness of one or more quantitative magnetic resonance (MR) imaging measures for the assessment of disease state, there is a need for studies designed to connect the technical development of new methods with clinical application. Presently, a gap seems to exist between the physics-based development of some new techniques and the application in the study of disease, leading to sometimes-uncomfortable assumptions regarding the underlying process. Complete understanding of the physical relevance of, for example, fractional anisotropy or magnetization transfer ratio in normal-appearing white matter to the pathophysiology and progression of multiple sclerosis might be gained only by means of a comprehensive approach incorporating numerical modeling, phantom studies, animal research, and application in human subjects.

MECHTEL, Deborah M., Associate Professor, Charles, H.K., and Francomacaro, A.S., "The Use of Poled Polyimide Dielectric Layers in MDM-Ds With Integral Test and Light Guiding Capabilities," *Microelectronics Reliability*, Vol. 41(11), pp.1847-1855, 2001.

Non-invasive techniques for measuring electric field strengths in multichip module (MCM) substrates can be extremely important in determining ultimate module performance. Certain polymers such as polyimide exhibit an electro-optic response, after appropriate doping and poling, that permits direct measurement of the internal fields

with a laser probe. We have built MCM circuit structures using different electro-optic polyimides for the dielectric layer. We report thermal, electrical, optical and electro-optic properties for these dielectric layers. The optical properties of doped and poled polyimides make them attractive for building optical waveguides. We report results for poled polyimide use in both multiple layer structures and optical waveguide formation, and recommend processing guidelines. Using doped and poled polyimides may permit optical and electrical interlayers on the same thin-film multichip module (MCM-D).

Van Buchem, M.A., Steens, S.C.A., Vrooman, H.A., Zwinderman, A.H., McGOWAN, J.C., Captain (USN), Rassek, M., and Engelbrecht, V., "Global Estimation of Myelination in the Developing Brain on the Basis of Magnetization Transfer Imaging: A Preliminary Study," *American Journal of Neuroradiology*, Vol. 22, pp. 762-766, 2001.

In the developing brain, myelination occurs in an orderly and predetermined sequence. The aim of this study was to determine whether such changes can be tracked using volumetric magnetization transfer imaging. With age, all volumetric MTR parameters changed exponentially in a way that was best expressed by the function $y = a + b.\exp(-x/c)$ ($P < .0001$). The peak height of the MTR histogram was the parameter that changed most predictably and that continued to change for the longest period of time. With this preliminary study, we show that by using volumetric MTR analysis, it is possible to monitor changes in the developing brain, presumably the myelination progress. This method has a potential role for detecting myelination disorders in the pediatric population, for studying the natural history of these diseases, and for monitoring the effects of treatment.

Vite, C.H., McGOWAN, J.C., Captain (USN), Braund, K.G., Drobatz, K.J., Glickson, J.D., Wolfe, J.H., and Haskins, M.E., "Histopathology, Electrodiagnostic Testing, and Magnetic Resonance Imaging Show Significant Peripheral and Central Nervous System Myelin Abnormalities in the Cat Model of Alpha-mannosidosis," *Journal of Neuropathology and Experimental Neurology*, Vol. 60(8), pp. 817-827, 2001.

The purpose of this study was to characterize the peripheral nervous system (PNS) and central nervous system (CNS) myelin abnormalities in cats from a breeding colony with a uniform mutation in the gene encoding alpha-mannosidase. Progressively worsening neurological signs developed in affected cats that included tremors, loss of balance, and nystagmus. In the PNS, affected cats showed slow motor nerve conduction velocity and increased F-wave latency. Single nerve fiber teasing revealed significant demyelination/remyelination in affected cats. Mean G-ratios of nerves showed a significant increase in affected cats compared to normal cats. Magnetic resonance imaging of the CNS revealed diffuse white matter signal abnormalities throughout the brain of affected cats. Histology confirmed myelin loss throughout the cerebrum and cerebellum. Thus, histology, electrodiagnostic testing, and magnetic resonance imaging identified significant myelination abnormalities in both the PNS and CNS that have not been described previously in alpha-mannosidosis.

ZUBER, James D., Assistant Professor, Jensen, K.L., and Sullivan, T.E., "An Analytical Solution for Microtip Field Emission Current and Effective Emission Area," *Journal of Applied Physics*, Vol. 91, No. 11, pp. 9379-9384, June 2002.

Classical field emission theory relates the material work function and applied electric field at the emitter surface to tunneling current density, based upon the one-dimensional (1-D), planar Fowler-Nordheim (F-N) equation. The extension of this theory to non-planar, tip-anode geometries is complicated by the spatial variation of the electric field and resultant current density along the microtip surface. To relate this spatially dependent electric field to the applied voltage in this tip-to-plane geometry, experimenters have adopted empirically determined field enhancement factors (*i.e.*, $F=\beta V$) and emission area terms to explain quantitative measurements of microtip current. In this work, the nature of the field enhancement and area terms are defined analytically by employing an exact three-dimensional (3-D) electric field solution in prolate spheroidal coordinates and examining the relationship between total tip current and current density. The analytical and numerical results based on this model provide a physical context for understanding the validity of the generally used field enhancement factor $\beta$.

# Books

ETTER, Delores M., Professor (with Kuncicky, D.C.), *Introduzione a MATLAB*, APOCEO Publishing, 2001.

This is the Italian translation of *Introduction to MATLAB*, Second Edition, Prentice Hall Publishing, 1999, by Etter and Kuncicky.

ETTER, Delores M., Professor (with Kuncicky, D.C.), *Introduction to MATLAB*, Sankaido Publishing Company, 2001.

This is the Japanese translation of *Introduction to MATLAB*, Second Edition, Prentice Hall Publishing, 1999, by Etter and Kuncicky.

ETTER, Delores M., Professor, (with Ingber, J.A.), *Engineering Problem Solving in C++: An Object Based Approach*, Prentice Hall Publishing Company, 2002.

Engineers use computers to solve a variety of problems ranging from the evaluation of a simple function to solving a system of nonlinear equations. C++ has become the language of choice of many engineers and scientists not only because it has powerful commands and data structure, but also because it can easily be used for system-level operations. Since C++ is a language that a new engineer is likely to encounter in a job, it is a good choice for an introduction to computing for engineers. Therefore this text was written to introduce engineering problem solving along with the fundamental capabilities of C++.

# Review Articles, Magazines and Book Chapters

ETTER, Delores M., Professor, "Defense Science and Technology," *AAAS Science and Technology Policy Yearbook 2002*, Chapter 18, pp. 167-181.

This chapter describes how the Department of Defense Science and Technology Program first determines what it must accomplish to meet the needs of the warfighter and, then, implements those goals by developing needed technology.

ETTER, Delores M., Professor, (with Steinhardt, A. and Stoner, S.), "Least Squares Adaptive Processing in Military Applications," *Institute for Electrical and Electronic Engineering (IEEE) Signal Processing Magazine*, Vol. 19, No. 3, pp. 66-67, May 2002.

This article is an extension of a presentation made to celebrate the awarding of the Franklin medal to Dr. Bernard Widrow in April 2001. In it, we reflect on the impact of Dr. Widrow's work on military applications. His least squares adaptive processes have enhanced the performance of a range of systems. Many of these applications have long-term potential for spin-off in civilian areas, most notably communications and remote sensing.

ETTER, Delores M., Professor, "Cognitive Readiness: An Important Research Focus for National Security," *Converging Technology for Improving Human Performance*, Kluwa Academic Publishers, pp.330-337, 2003.

Cognitive readiness is a critical research area for the Department of Defense. Soldiers must not only be ready physically for the myriad of roles that they have in the world today, but they must also be ready cognitively. This cognitive readiness extends from handling stress and sleep deprivation, through training "anytime, anyplace," through additional information provided by augmented reality, and through real-time physical monitoring during operations. This range of cognitive readiness requires a serious investment in research covering a wide range of areas. This paper will present some of the focus of existing research, and present some of the paths for future research in this area as it applies to national security.

McGOWAN, J.C., Captain (USN), "Magnetic Resonance Imaging and Magnetization Transfer" in Advances in Imaging and Electron Physics, (P.W. Hawkes, ed.), Academic Press, Oxford 118, pp.1-83, 2001.

# Patent

U.S. Patent No. 6,271,671 (issued on August 7, 2001 to Deborah M. Mechtel, Associate Professor) for an invention entitled "Multi-Chip Module Testability Using Poled-Polymer Interlayer Dielectrics".

> The present invention improves multi-chip module (MCM) testability by employing a non-invasive, laser-based instrument to probe the MCM structures fabricated with poled polyamide interlayer dielectrics and thin film metallizations on silicon carriers to detect on-substrate electric field strength.

# Conference Proceedings

ESTES, D.R.J., (Class of 2001 Trident Scholar), WELCH, T.B., III, Commander (USN), SARKADY, A.A., Professor, and Whitesel, H., "*Shipboard Radio Frequency Propagation Measurements for Wireless Networks,*" Military Communications Conference, Vienna, VA, October 2001 (CD-ROM).

> This paper discusses several in-hull RF propagation studies on board one decommissioned and several active Naval ships in the 0.8 – 2.5 GHz range. During these tests, it was repeatedly demonstrated that radio signals propagate from one compartment to another even when the watertight doors (hatches) are shut and sealed. In fact, signals have been received across several bulkheads. Results indicate approximately 20 dB of attenuation is associated with transmission through a bulkhead/watertight door. It has also been found that the wireless channel aboard Naval vessels does not show good correspondence with a Ricean channel. Finite element modeling of a shipboard compartment has been performed and supports the hypothesis that rubber door gaskets and other non-conductive structures may be the source of bulkhead penetration/leakage. For comparison, ultra-wideband channel measurements within the hull of a ship have also been taken. These measurements will be used to characterize the propagation within a single compartment as well as through a sealed bulkhead/watertight door.

ETTER, Delores M., Professor (with Coffey, M.), "Multiresolution Analysis on Bounded Domains for the Design of Biorthogonal Wavelet Bases," *Institute for Electrical and Electronic Engineering (IEEE) Transactions on Signal Processing*, Vol. 50, No. 3, pp. 501-519, 2002.

> An axiomatic approach to biorthogonal multiresolution analyses on bounded domains is presented. The intervalized MRA leads to a generalized framework within which one can construct biorthogonal wavelet transforms, including many constructions presented in the literature to date. The framework also leads naturally to algorithms for calculating and constraining pertinent properties of both the discrete filters and their corresponding continuous basis functions. Construction of wavelet analyses within the new framework is then illustrated with the design of a basis specifically tailored to reduce the boundary artifacts induced by some wavelet transforms used in image processing.

ETTER, Delores M., Professor, Wright, C.H.G., WELCH, T.B. III, Commander (USN), and MORROW, M.G., Lieutenant Commander (USN), "A Systematic Model for Teaching DSP," *Institute for Electrical and Electronic Engineering (IEEE) International Conference on Acoustics, Speech, and Signal Processing*, Orlando, FL, May 2002. (CD-ROM)

> While many DSP topics are difficult for undergraduates to internalize, appropriate demonstrations and laboratory experiences have been shown to be very helpful. This paper describes a highly successful pedagogical model the authors have developed which includes theory, demos, lab exercises, and real-time DSP experience using MATLAB and the Texas Instruments C6711 digital signal processing starter kit.

ETTER, Delores M., Professor, Wright, C.H.G., WELCH, T.B. III, Commander (USN), and MORROW, M.G., Lieutenant Commander (USN), "Teaching Hardware-Based DSP: Theory to Practice," *Institute for Electrical and Electronic Engineering (IEEE) International Conference on Acoustics, Speech, and Signal Processing*, Orlando, FL, May 2002. (CD-ROM)

The authors have developed a teaching model which includes theory, demonstrations, lab exercises, and real-time DSP experience using MATLAB and the Texas Instruments C6711 digital signal processing starter kit. This paper describes specific demonstrations that can be used as part of this model.

ETTER, Delores M., Professor, Wright, C.H.G., WELCH, T.B. III, Commander (USN), and MORROW, M.G., Lieutenant Commander (USN), "Teaching DSP: Bridging the Gap from Theory to Real-Time Hardware," *American Society for Engineering Education (ASEE) Conference*, Albuquerque, NM, June 2001. (CD-ROM)

Many digital signal processing (DSP) topics are difficult for undergraduates to internalize, but studies have shown that demonstrations and laboratory experiences can facilitate the process. In the past, many barriers existed to including real-time DSP hardware in an undergraduate curriculum. This paper describes a pedagogical model the authors have developed which includes theory, demos, lab exercises, and real-time DSP experience using MATLAB, C, and real-time DSP hardware that overcomes the barriers. Experiences using this model have been very successful.

MORROW, M.G., Lieutenant Commander (USN), WELCH, T.B., III, Commander (USN), and Wright, C.H. G., "An Introduction to Hardware-Based DSP Using winDSK6," *American Society for Engineering Education (ASEE) Conference*, Albuquerque, NM, June 2001. (CD-ROM)

Today there is a global need for engineers who are DSP literate. To help educate the next generation of DSP engineers, several powerful and highly versatile DSP boards designed for educational use are offered. The problem with most of these systems is that they lack user- friendly software to demonstrate the capabilities of the DSP boards. Some of the software packages shipped with these devices have a very steep learning curve, while other packages are still DOS or command line based. Today's students may be hesitant to approach these impediments to learning without significant motivation. To allow a student's first hardware based DSP experience to be a positive one, software tools must be provided that are affordable, easy to install, attention getting, Windows-based, and feature rich. This paper discusses winDSK6, an object-oriented application program that meets all of these requirements.winDSK6 seamlessly interfaces with and programs the complete TMS3206xxx family of DSP Starter Kits (DSKs). Its features include, talk-through (with full CODEC parameter control), oscilloscope, spectrum analyzer (both the traditional display and waterfalling spectrogram), notched filter, arbitrary waveform generation, DTMF generation (with repeating speed-dial), Karplus-Strong string algorithm, 5 band graphic equalizer, audio effects, guitar synthesizer, and a DSK confidence test. The authors freely distribute this software for educational, non-profit use.

Rice, J.L., and WELCH, T.B., III, Commander (USN), "Real-time Data Acquisition of Physiological Signals For an Instrumentation Course," *American Society for Engineering Education (ASEE) Conference*, Albuquerque, NM, June 2001. (CD-ROM)

The United States Naval Academy offers an instrumentation course for non-electrical engineering majors, which takes advantage of the PC plug-in data acquisition (DAQ) boards and PC software (MATLAB). In this course, several lab exercises were developed for the undergraduate study of physiological signals. This includes electrocardiography (ECG) and electromyography (EMG) signals. With the advent of real-time data acquisition and signal processing technology, it is now much easier to develop instrumentation lab experiments for student use. The current hardware and software enables our students to achieve highly accurate measurements, perform time domain and frequency domain analysis, and store the data for subsequent use, analysis, and design. This paper discusses some of the methods developed for implementing these labs. We believe our techniques have greatly enhanced the ease of teaching and learning these important topics in instrumentation.

Wage, K.E., Buck, J.R., WELCH, T.B., III, Commander (USN), and Wright, C.H.G., "The Continuous-Time Signal and Systems Concept Inventory," *Institute for Electrical and Electronic Engineering (IEEE) International Conference on Acoustics, Speech, and Signal Processing*, Orlando, FL, May 2002. (CD-ROM)

This paper describes the development of a continuous-time signals and systems concept inventory (CT SSCI) exam. The CT SSCI exam has twenty-five multiple choice questions and is designed to assess students' understanding of core concepts in undergraduate signals and systems. The questions require little or no computation, and contain distractors, or incorrect answers, that capture common student misconceptions. This paper discusses the list of concepts covered by the exam, reviews test results for the first version of the CT SSCI, and describes the question design strategy. A study to evaluate version 2.0 of the exam is underway at four campuses, and this paper reports preliminary results from that study. question writing strategy, the ongoing study evaluating the exam on four campuses, and preliminary results from that study.

WELCH, T. B., Commander (USN), Field, C.T., and, Wright, C.H.G., "A Signal Analyzer for Teaching Signals and Systems," *American Society for Engineering Education (ASEE) Conference*, Albuquerque, NM, June 2001. (CD-ROM)

Music and computers continue to fascinate today's students. This powerful and sometimes addicting combination can also provide for a tremendous opportunity to enhance the understanding of the time and frequency domain relationships routinely discussed in a *Signals and Systems* course. This paper discusses a MATLAB-based program that allows for simultaneous signal analysis in the time and frequency domains. The program is menu-driven and very easy to learn and use.

WELCH, T.B., III, Commander (USN), Emessiene, B.A., and Cassadine, D.N., "Measured Effects of the Human Body on Ultra-wideband (UWB) Signal Propagation in an Indoor Environment," *Annual Symposium on Wireless Personal Communications*, Blacksburg, VA, pp. 85-94, June 2002.

Ultra-wideband (UWB) communication systems were investigated for their ability to operate in dense multipath environments. While a great deal of time and effort has been spent characterizing both the indoor and outdoor UWB channels, the effects of human body interaction with a close proximity UWB antenna remains largely unexplored. Performance measurements of two different commercially available UWB antennae in various indoor multipath environments were conducted. Comparisons of the measurement results using the diamond-dipole antenna indicate that while the human body creates a deep null (23.6 dB) in a light multipath environment, this null is drastically reduced (6.8 dB) in a dense multipath environment. Measurements using the newer BroadSpec antennae did not exhibit a similar effect unless the antenna was severely shadowed.

ZUBER, James D., Assistant Professor, and Jensen, Kevin L., "Modeling Device Performance and Feature Variation in Microtip Field Emitters," *Electrochemical Society Proceedings of the 2nd International Symposium on Cold Cathodes*, Vol. 2002-18, pp. 211-227, November 2002.

A theoretical model for vacuum field emission that applies to real three-dimensional (3-D) microtip emitters has been developed. This model provides electric field variation along the microtip surface, an analytical solution for current density, a basis for defining effective emission area and tip current, and a framework for addressing the current deviations due to fabrication process variability. Array current and frequency response can be analyzed by treating the local tip radius as a random variable and using a probabilistic model to calculate expected values. The results of these statistical analyses highlight the importance of tip radius uniformity in FEA operation, demonstrate its quantitative effect, and reveal an analytical basis for which the Rayleigh probability density function may be a good model for tip radius variation. The quantification of tip radius variation and the geometrical characterization of individual tips are critical to device modeling where emission characteristics are paramount.

# Presentations

ETTER, Delores M., Professor, "Nanoscience Research for Advanced Technology," National Institute of Standards and Technology (NIST) Workshop on Nanostructure Science, Metrology, and Technology, Gaithersburg, MD, 5 Sept 2001. (Keynote presentation)

ETTER, Delores M., Professor, "A Vision for the Future – Smaller Smarter Systems," 2001 Sidney Parker Memorial Lecture, Asilomar Conference on Signals and Systems, Monterey, CA, 5 Nov 2001.

ETTER, Delores M., Professor, "Technology for Smaller and Smarter Systems," Colorado School of Mines, Golden, CO, 7 Nov 2001. (Invited seminar)

ETTER, Delores M., Professor, "Cognitive Readiness: An Important Research Focus for National Security," National Science Foundation (NSF) Workshop on Converging Technology for Improving Human Performance, Arlington, VA, 3 Dec 2001. (Plenary presentation)

ETTER, Delores M., Professor, "Department of Defense (DoD) Science and Technology (S&T) Community in Crisis," Presentation to the Naval Research Advisory Committee on the Science and Technology Community in Crisis, Arlington, VA, 6 Dec 2001.

ETTER, Delores M., Professor, Science and Technology Panel Moderator, National Defense Industrial Association (NDIA) Symposium on Defense Science and Technology, Charleston, SC, 7 Feb 2002.

ETTER, Delores M., Professor, "Life's Surprises," School of Engineering, Southern Methodist University, 18 May 2002. (Commencement address)

ZUBER, James D., Assistant Professor, "Modeling Device Performance and Feature Variation in Microtip Field Emitters," Second International Symposium on Cold Cathodes, 201st Meeting of The Electrochemical Society in Philadelphia, PA, 14 May 2002. (Abstract # 452)