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 our 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 U. S. Naval Academy. Research topics supported during the past year included high performance fiber optic communications, multilayer packaging of microwave devices, noninvasive probing of high performance microwave circuits, wireless communication of distributed shipboard sensors, computer controlled RF data acquisition, a simulator for optical fiber interferometric sensors, very low elevation antenna effects, adaptive error correction coding, and injury characterization using magnetic resonance imaging. 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

Simulation and High Speed Dispersion Managed Fiber Communications

Researcher: Assistant Professor R. Brian Jenkins
Sponsor: Naval Research Laboratory (NRL), Irl N. Duling, III

High performance communication on optical fiber is necessary to meet the bandwidth demands of modern telecommunication and computing systems. Fiber optic links that operate near 100 Gb/s are influenced by linear and nonlinear phenomena. Hence, solitons are often used, and the links require high-speed transmitters and receivers as well as amplification, filtering, and dispersion management. The design and optimization of such links can be difficult and expensive without numerical simulation. In this project, we modeled a broadband fiber optic communication link that operates at 100 Gb/s using solitons (1-2 picoseconds in width) and dispersion management techniques. For the system being built at NRL, some issues that were addressed included the impact optical add-drop multiplexing on solitons that have traversed a dispersion managed link, as well as a comparison of dense and standard dispersion management techniques.

Advanced Packaging Applications

Researcher: Associate Professor Deborah M. Mechtel
Sponsor: 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 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.

The Assessment of Radio Frequency Propagation in Ex-USS America

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

A distributed shipboard sensor system currently is in a design stage at the Naval Surface Warfare Center, Carderock Division, Philadelphia PA, Henry Whitesel, Code 825. This system is intended for machinery monitoring and advanced damage control applications on U.S. Navy ships. An individual “smart “ sensor consists of a transducer, microcomputer, a spread-spectrum receiver for input control and spread-spectrum transmitter for output control. These “smart” sensors are powered by a rechargeable battery, operate at low power levels (approximately 1mW) and have small physical size (size of a credit card). An important property of these sensors is the ease of shipboard installation (cabling is not required). This also allows rapid sensor reconfiguration. Large numbers of distributed “smart” sensors are linked (using spread spectrum transmitters and receivers), forming a wireless communication network with display terminals located at strategic shipboard locations.

A computer controlled RF data acquisition system was configured and calibrated in the summer of 2000. The RF data acquisition system is comprised of a 30 mW RF transmitter (tunable in the 0.9 GHz to 2.5GHz frequency range), a Spectrum Analyzer (with sensitivity of 1uV in this same frequency range) and a Laptop computer (used for Spectral data logging).

This RF data acquisition system was used in the summer of 2000 to collect 60 spectral data (in 0.9 GHz to 2.5 GHz frequency range) from the Ex-USS AMERICA (CV66) located in Philadelphia, PA.

The RF data set was included in the Trident Research project of Midshipman 1/C Daniel R.J. Estes, USN.

Independent Research

Simulator for the Creation of Signals Like Those from 3x3 Optical Fiber Interferometric Sensors

Researcher: CDR Charles Cameron, USN

Three by three optical fiber interferometric sensors have been found to permit a huge dynamic range in a wide variety of sensing applications. The cost of good-quality 3 x 3 optical fiber couplers remains high, however. The goal of the research is to investigate the effect of deviations of the couplers from the ideal on demodulation of signals recovered from sensors which use them. Since a particular sensor incorporating only one or possibly two such couplers and replacing them is difficult, exploring this variation using a simulator is attractive. The simulator will be built using a combination of digital electronic and microprocessors. It will generate three output signals of varying offset, amplitude, and phase.

Early design work led to a theoretical exploration of the effects of imperfections in the 3 x 3 couplers. This work requires the solution to a very difficult differential equation. In late 2000, it was solved with the assistance of Mathematica. However, the form of the solution is too complex to be comprehended. Current efforts are directed at simplifying the expression and investigating its interpretation and implications.

Trident Scholar Project

Assessment of Radio Frequency Propagation in a Naval Shipboard Environment

Researcher: Midshipman 1/C Daniel R.J. Estes, USN
Advisers: Professor Antal A. Sarkady and CDR Thaddeus B. Welch, III, USN

In this project, data was collected aboard decommissioned and active ships to characterize the wireless channel on combat ships and to attempt to determine the effect of bulkheads and hatches in the information path. Both narrowband and ultra wideband techniques were used to demonstrate and measure transmissions through the shipboard environment. Each bulkhead attenuated the test signal roughly 20dB.

Computer modeling of the bulkhead supported the hypothesis that the radio energy is propagating through the non-conductive structures within the bulkhead (such as hatch seals) rather than through the steel.

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Publications

Journal (Refereed) Manuscripts

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

BACKGROUND AND PURPOSE: 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.

METHODS: We obtained fast spin-echo dual-echo and magnetization transfer (with and without MT saturation pulses) images from eighteen patients with relapsing-remitting MS and 18 age-matched healthy control subjects. Gray matter was segmented using a semiautomated system. Gray matter MTR histogram parameters, Kurtzke Expanded Disability Status Scale (EDSS), total T2 lesion volume, and gray matter volumes were obtained for statistical analysis.

RESULTS: A significant difference was found in gray matter MTR between patients with relapsing-remitting MS and healthy subjects (mean and median). Gray matter MTR histogram normalized peak heights in patients inversely correlated with EDSS ($r = -0.65$, $P = .01$). There was also an inverse correlation between mean MTR of gray matter and total T2 lesion volume.

CONCLUSION: 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.

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*, accepted for publication.

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, which 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. Thermal, electrical, optical and electro-optic properties are reported 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).

McGOWAN, Joseph C., Captain (USN), Haskins, M.E., Wenger, D., and Vite, C., "Investigating Demyelination in the Brain in a Canine Model of Globoid Cell Leukodystrophy (Krabbe Disease) Using Magnetization Transfer Contrast," *Journal of Computer Assisted Tomography*, 24(2), pp.316-321, 2000.

This study was designed to examine the use of quantitative magnetization transfer imaging in naturally occurring globoid cell leukodystrophy (GLD) in the Cairn terrier. Methods A model of GLD was established via a breeding colony and a total of 7 animals were studied with magnetization transfer imaging (MTI), including two dogs with GLD, one of which underwent whole-body irradiation (725 cGy) and bone marrow transplant from a genotypically normal littermate. The remaining dogs served as untreated, irradiated, and unirradiated controls. Results Region of interest (ROI) analysis of the MTI showed a decrease in MT ratio in the internal capsule of the untreated/affected dog compared with age-matched controls but revealed similar results in the two other study animals. On MT contour plotting, inside-to-out gradients of MTR mimicked the demyelination pathology of the disease in the untreated/affected dog. Conclusions MT contour plotting demonstrated patterns of MT abnormality in the untreated/affected dog that were consistent with histopathology, establishing a clear relationship between pathology-proven demyelination and MTR as well as a striking contrast to the patterns of radiation damage.

McGOWAN, Joseph C., Captain (USN), Berman, J.I., Lavi, E., Ford, J.C., and Hackney, D., "Characterization of Experimental Spinal Cord Injury with Magnetization Transfer Histograms," *Journal of Magnetic Resonance Imaging*, 12, pp.247-254, 2000.

This study was designed to characterize the severity of tissue damage in experimental spinal cord injury using magnetization transfer (MT) histogram analysis. 7 Sprague-Dawley rats were subjected to laminectomy and standard weight-drop injury to the spinal cord (4 rats at 15 cm drop-height, and 3 rats at 2.5 cm). Three control animals underwent laminectomy without weight-drop. After sacrifice, the animals were scanned at 1.9T with a pulsed off-resonance MT technique. Following MR imaging the cords were embedded in paraffin and sectioned into 5-micron sections for semi-quantitative histopathological analysis. Composite histograms were generated using data spanning an axial distance of 3 cm centered on the injury site. MT histogram parameters, such as the amount of tissue with statistical correspondence to normal white matter, were highly predictive of histopathological results, including myelination state and neurofilament damage. Less correlation with edema was observed, suggesting that the technique was most sensitive to true tissue alteration.

Sinson, G., Bagley, L.J., Cecil, K.M., Torchia, M., McGOWAN, Joseph C., Captain (USN), Lenkinski, R.E., McIntosh, T.K., and Grossman, R.I., "Magnetization Transfer Imaging and Proton Magnetic Resonance Spectroscopy in the Evaluation of Axonal Injury and Correlation with Clinical Outcome in Traumatic Brain Injury," *American Journal of Neuroradiology*, in press, 2001.

BACKGROUND AND PURPOSE: Current imaging does not permit quantification of neural injury after trau-

matic brain injury (TBI) and therefore limits both the development of new treatments and the appropriate counseling of patients concerning prognosis. We evaluated the utility of magnetization transfer ratio (MTR) and proton MR spectroscopy in identifying patients with neuronal injury after TBI.

METHODS: Thirty patients with TBI (21-77 years old; mean age, 42 years; admission Glasgow Coma Scale (GOS) scores 3-15; mean score, 11) were studied on a 1.5-T system with magnetization transfer imaging and MR spectroscopy of the splenium. Magnetization transfer imaging was also performed in the brain stem in all patients, and other areas of the brain were sampled in one patient. The splenium of the corpus callosum and brain stem were studied because these are often affected by diffuse axonal injury. Scans were obtained 2 to 1129 days after injury (median, 41 days). MTR was considered abnormal if it was more than 2 SD below normal. Proton MR spectroscopy was used to calculate the N-acetylaspartate (NAA)/creatine (Cr) ratio. GOS was determined at least 3 months after injury.

RESULTS: In 10 patients with a GOS of 1 to 4, the mean NAA/Cr was 1.24 ¦ 0.28; two of these patients had abnormal MTR in normal-appearing white matter (NAWM). In 20 patients with a GOS of 5, the mean NAA/Cr was 1.53 ¦ 0.37 ($P < .05$); four of these patients had abnormal MTR in NAWM. MTR abnormalities in NAWM were identified in six patients, but these changes did not correlate with GOS or MR spectroscopy changes.

CONCLUSION: MTR and MR spectroscopy can quantify damage after TBI, and NAA levels may be a sensitive indicator of the neuronal damage that results in a worse clinical outcome.

Vite, C.H. and McGOWAN, Joseph C., Captain (USN), "Magnetization Transfer Imaging of the Canine Brain," *Veterinary Radiology and Ultrasound*, in press, 2001.

Magnetic resonance (MR) imaging is a sensitive, non-invasive method for identifying brain structure and pathology. In conventional MR imaging, various pulse sequences are used to emphasize spin-lattice (T1) and spin-spin (T2) relaxation properties of hydrogen protons in order to provide contrast between adjacent brain structures. Tissue contrast may also be generated by employing pulse sequences sensitive to blood flow and to diffusion of water protons. Administration of intravenous paramagnetic agents, such as gadolinium, which shorten T1 and T2 relaxation times of adjacent protons, is also performed to increase contrast on MR images. Magnetization transfer (MT) imaging is a method whereby contrast is generated by imaging the effect on signal intensity of the exchange of magnetization between protons in structural macromolecules and protons in water (Wolff et al 1991; Wolff et al 1989). In effect, MT imaging examines the non-water components of the tissue through the effects they have on protons in water (Mc Gowan 1999). Contrast present in MT images may be used qualitatively to improve the sensitivity for the detection of lesions, and, quantitatively, via the magnetization transfer ratio, MTR, to examine the effect of pathology on observed magnetization transfer contrast (MTC).

This paper reviews the theory of magnetization transfer imaging, it applications, and provides an example of its use in examining the white matter tracts of the canine brain.

WELCH, T.B., III, Commander (USN), MORROW, M.G., Lieutenant Commander (USN) and Wright, C.H.G., "Teaching Practical Hands-On DSP with MATLAB and the C31 DSK," *Computers in Education Journal*, Vol. 11, number 2, Apr-Jun 2001.

A graphically oriented MATLAB program, written by the authors, facilitates teaching real-world DSP concepts such as quantization of digital filter coefficients that occur in fixed-point processors. While many universities own, or plan to buy, the inexpensive floating-point TMS320C31 DSKs for pedagogical reasons, this MATLAB program fully supports that decision by allowing filter coefficient quantization effects to be demonstrated using either fixed-point or floating point filtering algorithms on a single DSP device. This program eliminates the need to purchase expensive specialized software programs or additional DSP hardware. The program described in this paper provides an interactive graphical user interface, which communicates directly with the DSK, and demonstrates in real-time how both coefficient quantization and filter implementation affect filter performance. All of this is accomplished without the need for tedious programming of the DSK. The latest version of the software allows the floating-point TMS320C31 to directly implement the fixed-point filtering algorithm. This enhancement represents a considerable cost and timesavings for both the student and professor since only one type of digital signal processor is required.

Technical Reports, Book Reviews and Book Chapters

McGOWAN, Joseph C., Captain (USN), "The Physical Basis of Magnetic Resonance Spectroscopy" in Magnetic Resonance Spectroscopy in Multiple Sclerosis, (Filippi, M. and Arnold, D., ed), Springer-Verlag, 2000.

McGOWAN, Joseph C., Captain (USN), "Optimization and Standardization of Magnetic Resonance Spectroscopy Techniques for Multicentre, Longitudinal, Multiple Sclerosis Studies," in Magnetic Resonance Spectroscopy in Multiple Sclerosis, (Filippi, M. and Arnold, D., ed), Springer-Verlag, 2000.

McGOWAN, Joseph C., Captain (USN), "Magnetic Resonance Imaging and Magnetization Transfer," in Advances in Imaging and Electron Physics, (P. Hawkes, ed), Academic Press, in press, 2001.

T.B. WELCH, III, Commander, (USN), Walker, M.J., and Foran, R.A., *"Very Near Ground RF Propagation Measurements and Analysis,"* Wireless Personal Communications, Channel Modeling and Systems Engineering, Kluwer Academic Press, AH Dordrecht, The Netherlands, pp.1-9, 2000.

> We analyze and measure the effects associated with placing a cordless phone antenna, with three different orientations, very near the ground (3 - 28 cm). A significant decrease in signal strength occurs when a user falls from the sitting position to the prone position. As much as a 12 dB decrease in signal strength can occur. This information, if available to an injured cordless phone user, could allow for a successfully completed 911 call.

WATERSTON, J., Midshipman 1/C, WOOTEN, E. C. K., Assistant Professor, BENNETT, W.E., Associate Professor and WELCH, T.B, III, Commander, (USN), *"Development and Implementation of an Adaptive Error Correction Coding Scheme for a Full Duplex Communication Channel,"* Wireless Personal Communications, Channel Modeling and Systems Engineering, Kluwer Academic Press, AH Dordrecht, The Netherlands, pp.229-237, 2000.

> This paper investigates via simulation, the bit error probability (BEP) associated with a variable redundancy coding scheme operating in a wireless environment. Within a slowly varying (flat fading) Rayleigh channel, this algorithm provides increased throughput over fixed coding implementations. From a family of BCH codes of the same block length (n = 63), a code with appropriate redundancy is chosen depending on the receiver's estimation of the current conditions experienced by the channel. Two different decision techniques are compared. The first method statistically evaluates the receiver's input and calculates the signal to noise ratio (E_b/N_o), while the second method observes the number of corrected errors in recent decoded blocks. Once deciding to modify the correction ability of the code, the decoder transmits the decision to the encoder over a low bandwidth feedback channel, allowing the correction ability to be changed on a block-by-block basis. This algorithm is implemented in software, and therefore can be optimized for many real world communications systems. The low cost of the high-speed microprocessors and DSPs allow for the development of a robust adaptive coding system in hardware. The results are compared against fixed coding implementations and show that the adaptive process maintains a better efficiency of information rate while keeping the bit error probability near the level obtained by maximum encoding.

Conference Proceedings

He, X., El-Leithy, N., SELLAMI, Louiza M., Assistant Professor, and Newcomb, R.W., "An Adjustable CMOS Load Line for Nonlinear Circuits," *Proceedings of the 43rd IEEE Midwest Symposium on Circuits and Systems*, Lansing MI, August 8-11, 2000. (CD-ROM)

> A five-transistor nonlinear load line circuit is presented for use in analog CMOS circuit design. The load line can be adjusted by an external voltage, possibly dynamically, to fit the situation. In this paper the load line circuit is

presented along with design equations and an example of its use in the realization of a neural type cell. Other uses are in relaxation oscillator and chaos generator design.

JENKINS, R. B., Assistant Professor and FIELD, C.T., Assistant Professor, "Practical Circuit Design in an Elementary Circuit Theory Lab," *Proceedings of the 2000 American Society for Engineering Education (ASEE) Annual Conference*, Session 2532, St. Louis, MO, June 2000.

A course in elementary circuit analysis is a common requirement in an electrical engineering curriculum. The course traditionally emphasizes fundamental DC and AC circuit theory concepts for resistive and reactive components and may introduce operational amplifiers. To provide a rationale for learning the theoretical concepts required in the course, we have restructured our laboratories to 1) motivate students through greater emphasis on the practical merit of the fundamentals; 2) insure conceptual integration with course; the labs are not merely fun, they reinforce fundamental concepts; 3) emphasize design using practical components. In this paper we discuss four different designs that were done in the laboratory that support the goals listed above.

MARTIN, Richard L., Professor, and MORROW, Michael G., Lieutenant Commander, (USN) and WELCH, Thaddeus B., III, Commander, (USN), "Development of an Instructor Station for Electrical Engineering Laboratories," *Proceedings of the 2000 American Society for Engineering Education (ASEE) Annual Conference*, St. Louis, MO, June 19-22, 2000.

An individually laboratory-based Centralized Signal Distribution System has been developed to provide known signals in labs for undergraduate core electrical engineering and technology courses. The system consists of a general purpose PC running LABVIEW software which controls three Arbitrary Waveform Generators. LABVIEW, a graphical programming language, allows easy programming of the instruments. The source code for LABVIEW looks like a flowchart, while the user interface appears on the monitor as the front panel of a virtual instrument. The presently developed system is programmed to provide basic signals for introduction to signal waveform analysis and oscilloscope operation, phase-locked waveforms of integrally related frequencies for digital applications, AM and FM signals for elementary communications experiments, and frequency sweeps for testing of analog transfer functions. Signal parameters such as DC offset, frequency, phase, amplitude, waveform, and modulation may be readily changed by the lab instructor.

MARTIN, R.L., Professor, MORROW, Michael G., Lieutenant Commander, (USN) and WELCH, T.B., III, Commander, (USN), "Development of an Instructor Station for Electrical Engineering Laboratories," *Proceedings of the 2000 American Society for Engineering Education (ASEE) Annual Conference*, St. Louis, MO, June 19-22, 2000. (CD-ROM)

An individually laboratory-based Centralized Signal Distribution System has been developed to provide known signals in labs for undergraduate core electrical engineering and technology courses. The system consists of a general purpose PC running LABVIEW software which controls three Arbitrary Waveform Generators. LABVIEW, a graphical programming language, allows easy programming of the instruments. The source code for LABVIEW looks like a flowchart, while the user interface appears on the monitor as the front panel of a virtual instrument. The presently developed system is programmed to provide basic signals for introduction to signal waveform analysis and oscilloscope operation, phase-locked waveforms of integrally related frequencies for digital applications, AM and FM signals for elementary communications experiments, and frequency sweeps for testing of analog transfer functions. Signal parameters such as DC offset, frequency, phase, amplitude, waveform, and modulation may be readily changed by the lab instructor.

MORROW, Michael G., Lieutenant Commander, (USN), WELCH, T.B., III, Commander, (USN), Wright, C.H.G., and York, G.W.P., "Demonstration Platform for Real-Time Beamforming," *International Conference on Acoustics, Speech, and Signal Processing*, Salt Lake City, UT, May 2001.

DSP topics such as real-time beamforming are more easily taught to undergraduates if appropriate demonstrations and laboratory experiences are available. This paper describes a real-time DSP beamforming educational platform based around MATLAB and the Texas Instruments C6211 digital signal processing starter kit. Classroom uses of this platform are discussed; the software is available at http://www.usna.edu/EE/links/ee_links.htm.

MORROW, Michael G., Lieutenant Commander, (USN), WELCH, T.B., III, Commander, (USN), Wright, C.H.G, and York, G.W.P., "Teaching Real-time Beamforming with the C6211 DSK and MATLAB," *Digital Signal Processing Solutions Conference*, Houston, TX, August 2000. Published on the web at http://www.ti.com/sc/docs/general/dsp/festproceedings/fest2000/educator.htm.

This paper describes our efforts to teach hardware-based beamforming at the undergraduate level. A DSP based beamformer is at the heart of numerous military systems, including active and passive sonars, RF direction finding equipment, and phased-array radars. While the military has needed engineers capable of designing and enhancing these and other systems, civilian applications of these same technologies have recently made beamforming an important topic for many engineers. High interest topics include E911 mobile position location, space division multiple access (SDMA), cellular/PCS base station antenna design, and low Earth orbit (LEO) satellite communications within a densely packed constellation. Beamforming is routinely discussed in a course on multidimensional signal processing but an actual hardware system to design or enhance is often not available. The use of powerful software, such as MATLAB, to simulate the geometries and techniques necessary to learn about beamforming has become standard. However, proceeding beyond MATLAB simulation to a real-time hardware implementation has been impeded by a very expensive and abrupt transition, in terms of both cost and the learning curve of unfamiliar systems and software. By developing a software bridge between MATLAB and the C6211 DSK, we make it possible to smoothly and incrementally transition from simulation to full hardware implementation, all while retaining the impressive capabilities of the MATLAB display engine. Using this approach, students can develop and enhance their own sonar system. Initially, a student works with MATLAB generated data files to develop an understanding of various beamforming techniques. Then, they proceed to non-real-time processing of actual data acquired directly into MATLAB from the DSK, then incrementally move the processing into C code running on the DSK, and finally, using MATLAB only for display of the real-time results. The software development cycle of algorithm and display development in MATLAB, followed by real-time implementation with a C6X DSK, can be iterated as many times as the semester will allow. The paper describes in detail the software and inexpensive multichannel ADC daughtercard that facilitate this pedagogical process. The software is freely distributed by the authors for educational use.

Moskowitz, M.T., SELLAMI, Louiza M., Assistant Professor, and Newcomb, R.W., "A Switched Current Mode Real Ear-Type Lattice," *Proceedings of the 42nd IEEE Midwest Symposium on Circuits and Systems*, pp. 660-663, New Mexico, August 1999.

Switched current circuits are used here to design real degree-one discrete time lattices for use in modeling the inner ear portion of ear-type networks. This lattice is characterized as an electrical two-port system and is, therefore, described by a transfer scattering matrix relating input and output signals. This matrix is degree-one and requires only one delay function, which we realize with a switched current circuit. This circuit uses a new sampling switch that substantially reduces the distortion occurring due to the clock feed through in conventional MOS based switches. PSpice simulation results are included to support the theory.

Moskowitz, M.T., SELLAMI, Louiza M., Assistant Professor, and Newcomb, R. W., "Current Mode Standard Lattice Filter for Use in Complex Ear-Type Networks," *Proceedings of the 43rd IEEE Midwest Symposium on Circuits and Systems*, Lansing MI, August 8-11, 2000. (CD-ROM)

An inner ear degree-two cochlea section, which encompasses complex transmission zeros, is realized in hardware. In doing this, standard complex two-port filters are extracted to form real four-port networks. A new digital switched current circuit is used with improved clock-feed through delay portions. A complex lattice portion is simulated in both Spice and Matlab with accurate results.

Moskowitz, M.T., SELLAMI, Louiza M., Assistant Professor, Newcomb, R.W., and Rodellar, V., "Current Mode Realization of Ear-Type Multi-sensors," *Proceedings of the IEEE Symposium on Circuits and Systems*, Sidney (Australia), Vol. II, pp. 285-288, May 2001.

We present a MEMS switched current mode circuit that realizes a multi-ear type system in which a novel sensor acts as a pressure transducer for input to cochlear-type processing. Z-transform computations of fluid motion in the tubules of the cochlea are realized with switched current lattice cascade. Also, we describe how an array of MEMS-SI circuits can be placed for use as a multi-sensor, intended for sound-beam forming in an n-aural hearing system.

Saistan, M.A., Moskowitz, M.T., Rodellar, V., SELLAMI, Louiza M., Assistant Professor, and Newcomb, R.W., "A Digitally Implementable Ear-Type Lattice," *Proceedings of the 43rd IEEE Midwest Symposium on Circuits and Systems*, Lansing MI, August 8-11, 2000. (CD-ROM)

The internal auditory system emits slightly detectable signals (known as Kemp echoes) in response to a stimulus. This response has been reproduced via a cascade of two-port lattices and has been previously simulated with analog amplifiers. This paper presents a digital implementation scheme using fixed-point, two's complement arithmetic with the word length and decimal precision based on generic parameters. The advantages are in the accuracy and cancellation of initial cycle oscillations due to initial conditions normally present in both numerical and continuous implementations.

WELCH, T.B., III, Commander, (USN), et. al., *"Near Ground RF Propagation Measurements," Annual Symposium on Wireless Personal Communications*, Blacksburg, VA, June 2001.

Using a forward control channel from a nearby cellular base station, the effect on signal strength and Rician k factor were measured as a function of antenna elevation. Realistic antenna and head orientations were maintained throughout the various elevations. These measurements were taken in an attempt to model a wireless user in the standing, sitting, and lying positions. Measurements included the effects of head shadowing and of blocking the signal's specular component with a conductive screen. There is a significant decrease in signal strength as a user drops from a standing to a lying position. This decrease in signal strength can be up to 10 dB. The shadowing effects of a simulated human head were generally less than 3 dB. The conductive screen decreased the average signal strength by approximately 20 dB, with a corresponding drop in the Rician k factors.

WELCH, T.B., III, Commander, (USN), MORROW, Michael G., Lieutenant Commander, (USN) and Wright, C.H.G., *"An Inexpensive Software Tool for Teaching Real-Time DSP,"* October 2000, Signal Processing Education Workshop, Hunt, TX. Published on the web at http://spib.rice.edu/SPS/SPS_prevconf.html.

An innovative program that bridges the pedagogical gap between software and hardware aspects of DSP education for all age levels is described. Examples of the program's capabilities are given. Graphically based programs such as this, which provide real-time results and also ease the introduction of DSP hardware for students, may help increase the number of students interested in DSP as an area of concentration.

WELCH, T.B., III, Commander, (USN), "An Open-ended Design Project for a First Communications Course," *Proceedings of the 2000 American Society for Engineering Education (ASEE) Annual Conference*, St. Louis, MO, June 19-22, 2000. (CD-ROM)

The United States Naval Academy offers a junior level communications systems course that includes a significant amount of hardware design. A signals and systems class is the prerequisite for this course, during which the necessary fundamentals are developed to allow for an immediate discussion of higher order modulation schemes. The open-ended design project deals with designing, building, and testing a 16-QAM communications link. This project allows for a significant amount of design experience prior to starting the traditional senior-year design sequence.

WELCH, T.B., III, Commander, (USN), ZIVI, E.L, Assistant Professor, FIELD, C.T., Assistant Professor and Rice, J.L., "Real-time Data Acquisition in a Signals and Systems Course," *Proceedings of the 2000 American Society for Engineering Education (ASEE) Annual Conference*, St. Louis, MO, June 19-22, 2000. (CD-ROM)

A sophomore or junior level course entitled *Signals and Systems* or *Linear Systems Theory* is contained within almost every electrical engineering program in the country. The United States Naval Academy offers a junior level *Signal and Systems* course that includes a significant amount of hands-on lab time. This course is taught in a 2-2-3 format. The availability of both PCs and DAQ software that allow for seamless introduction of real-world data into the MATLAB workspace has facilitated this process. This paper discusses some of the lab exercises that are used in this course. These lab experiments have allowed our students to see immediate applicability for the theory and skills that they are learning in class.

WELCH, T.B., III, Commander (USN), MORROW, Michael G., Lieutenant Commander, (USN), and Wright, C.H.G., "Teaching Practical Hands-On DSP with MATLAB and the C31 DSK," *Proceedings of the 2000 American Society for Engineering Education (ASEE) Annual Conference*, St. Louis, MO, June 19-22, 2000. (CD-ROM)

A graphically oriented MATLAB program written by the authors facilitates teaching real-world DSP concepts such as quantization of digital filter coefficients that occur in fixed-point processors. While many universities have or plan to buy the inexpensive floating-point TMS320C31 DSKs for pedagogical reasons, this MATLAB program fully supports that decision by allowing filter coefficient quantization effects to be demonstrated using either fixed-point or floating point filtering algorithms on a single DSP device. This program eliminates the need to purchase expensive specialized software programs or additional DSP hardware. The program described in this paper provides an interactive graphical user interface, which communicates directly with the DSK, and demonstrates in real-time how both coefficient quantization and filter implementation affect filter performance. All of this is accomplished without the need for tedious programming of the DSK. The latest version of the software allows the floating-point TMS320C31 to directly implement the fixed-point filtering algorithm. This enhancement represents a considerable cost and timesavings for both the student and professor since only one type of digital signal processor is required.

WELCH, T.B., III, Commander (USN) and Ziemer, R.E., "Equal-Gain Combining of Multichannel DPSK in Doppler-Spread Rician Fading," *IEEE Transactions on Vehicular Technology*, Volume 49, number 5, pp.1846-1855, September 2000.

A method for computing the bit error probability (BEP) of multichannel differentially coherent phase-shift keying with equal gain combining in a Doppler spread Rician fading is given. It is based on Gauss-Chebyshev quadrature integration of the moment generating function of the decision statistic at the combiner output. The method allows nonuniform power delay profiles for the received multipath rays. Applications to multicarrier spread spectrum modulation and spread spectrum with RAKE reception systems are discussed. It is found that for moderate values of the Rician *K*-factor (ratio of specular to diffuse fading signal power) an optimum order of diversity exists whereas, for large *K*-factors, diversity does not improve performance.

Presentations

HARDING, David S., Associate Professor, "Enhancement of a Core Electrical Engineering Course Using WebCT," American Society for Engineering Education (ASEE) Annual Conference, St. Louis, MO, June 2000.

JENKINS, R.B., Assistant Professor, and FIELD, C.T., Assistant Professor, "Practical Circuit Design in an Elementary Circuit Theory Lab," American Society for Engineering Education (ASEE) Annual Conference, St. Louis, MO, June 2000.

MARTIN, Richard L., Professor, and MORROW, Michael G., Lieutenant Commander (USN) and WELCH, Thaddeus B., III, Commander (USN), "Development of an Instructor Station for Electrical Engineering Laboratories," American Society for Engineering Education (ASEE) Annual Conference, St. Louis, MO, June 2000.

McGOWAN, Joseph C., Captain (USN), **"**Fast Spin Echo Imaging, MR Physics and Techniques for Clinicians," International Society of Magnetic Resonance in Medicine (ISMRM)," Glasgow, Scotland, April 23, 2001.

WELCH, T.B., III, Commander (USN), "Near Ground RF Propagation Measurements," Annual Symposium on Wireless Personal Communications, Blacksburg, VA, June 2001.

WELCH, T.B., III, Commander (USN), "Demonstration Platform for Real-Time Beamforming," International Conference on Acoustics, Speech, and Signal Processing, Salt Lake City, UT, May 2001.

WELCH, T.B., III, Commander (USN), "An Inexpensive Software Tool for Teaching Real-Time DSP," Signal Processing Education Workshop, Hunt, TX, October 2000

WELCH, T.B., III, Commander (USN), "Teaching Real-time Beamforming with the C6211 DSK and MATLAB," Digital Signal Processing Solutions Conference, Houston, TX, August 2000

WELCH, T.B., III, Commander (USN), "An Open-ended Design Project for a First Communications Course," American Society for Engineering Education (ASEE) Annual Conference, St. Louis, MO, June 2000.

WELCH, T.B., III, Commander (USN), "Teaching Practical Hands-On DSP with MATLAB and the C31 DSK," American Society for Engineering Education (ASEE) Annual Conference, St. Louis, MO, June 2000.

WELCH, T.B., III, Commander (USN), "Real-time Data Acquisition in a Signals and Systems Course," American Society for Engineering Education (ASEE) Annual Conference, St. Louis, MO, June 2000.