MASTER OF SCIENCE
IN
ELECTRICAL ENGINEERING

CONSTRUCTION AND MEASUREMENT OF AN ACTIVELY MODE-LOCKED SIGMA LASER

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The direct digitization of microwave signals of interest would allow rapid computer processing and analysis. Current analog-to-digital converters (ADCs) are bandwidth limited and electronic warfare systems must down-convert the signal before digitization causing a loss of information. Optical ADCs can directly digitize frequencies greater than 10 GHz using wideband integrated optical interferometers (folding ADCs). A critical component of the optical folding ADC is the pulsed laser used for sampling the wideband signal. The amplitude-modulated pulses become the discrete samples of the analog signal. Limiting factors in an optical ADC are the pulsewidth, the pulse rate, and the jitter noise of the optical pulse train. Mode-locked lasers provide pulse rates and pulsewidths suitable for high bandwidth applications.

In this thesis a mode-locked sigma laser was constructed using fiber-optic, electro-optic, and microwave components. The theory of mode-locking, laser construction, output measurements, and sampling applications are discussed in detail. The mode-locked sigma laser demonstrated a pulse repetition frequency of 16 GHz, pulsewidth of 7.2 picoseconds, amplitude noise less than 1%, temporal jitter of 386 femtoseconds, and the ability to be harmonically mode-locked at twice the modulation frequency using only 200 mW of diode pump power in the optical amplifier. The analysis shows that this laser can be used in an optical ADC to sample a 6.44 GHz signal at 7 bits, 3.22 GHz at 8 bits, or 1.61 GHz at 9 bits of resolution.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Other (Photonics)

KEYWORDS: Mode-Locked Laser, Sigma Laser, Erbium-Doped Fiber Amplifier, Optical Sampling, Analog-to-Digital Conversion, Amplitude Noise, Phase Noise, Temporal Jitter Noise, Timing Uncertainty

DENOISING OF ACOUSTIC SIGNALS USING WAVELET/WIENER BASED TECHNIQUES

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This thesis investigates the use of combined Wavelet decomposition and Wiener filtering for the removal of noise from underwater acoustic signals. Several Wavelet/Wiener based denoising techniques are presented and their performances compared. Performances of the denoising algorithms are compared to those of Wiener filter and wavelet thresholding implementation and demonstrate that Wavelet/Wiener based methods are also a viable tool for the denoising of acoustic data under more restrictive conditions.

DoD KEY TECHNOLOGY AREAS: Sensors, Electronic Warfare

KEYWORDS: Acoustic Signals, Wavelets, Wiener Filter, Denoising, Aliasing

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ARCHITECTURAL DEVELOPMENT AND PERFORMANCE ANALYSIS OF A PRIMARY DATA CACHE WITH READ MISS ADDRESS PREDICTION CAPABILITY

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This work is part of an ongoing effort to bridge the cycle-time gap between high-speed processing units and lower-speed main memories through the use of memory hierarchies. Cache memory exploits the principle of locality by providing a small, fast memory between the processor and the main memory. The Predictive Read Cache (PRC) further improves the overall memory hierarchy performance by tracking the data read miss patterns of memory accesses, developing a prediction for the next access and prefetching the data into the faster cache memory. The PRC has been proven to significantly improve system performance when acting as a second-level cache. The purpose of this thesis is to simulate the effectiveness of the PRC as a first-level cache in the memory hierarchy using the same simulator developed to prove the effectiveness of the PRC as a second-level cache.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Predictive Read Cache, Address Prediction, Memory Bandwidth, Memory Latency, Cache Memory, Memory Systems

SINGLE-EVENT ANALYSIS OF AlInAs/GaInAs/InP HETEROJUNCTION BIPOLAR TRANSISTORS

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For many of today's spaceflight programs, spacecraft and spacecraft designers are being pushed to utilize enabling and emerging technology in order to meet performance constraints in small-volume and low-power, low-cost spacecraft. These newer technologies must be evaluated to meet the performance requirements of spacecraft, especially for the smaller, low-cost satellite programs. AlInAs/GaInAs heterojunction bipolar transistors (HBTs) grown on InP substrates are emerging as an alternative HBT technology to the more widely used GaAlAs/GaAs HBTs for high performance and low-power integrated-circuit applications. However, these technologies may be vulnerable to single-event effects in the space environment. Recent testing at the University of Michigan at Ann Arbor has shown that HBT circuits are sensitive to single-event effects (SEEs). This thesis examines the effects of cosmic ray induced charge collection on AlInAs/GaInAs HBT by utilizing Silvaco's Virtual Wafer Fabrication software to design and simulate electrical properties of transistors. Two-dimensional computer simulations were performed to determine why the InP HBT is sensitive to charge collection events; whether charge collection is occurring across base-collector or base-emitter junctions; and what is causing the radiation sensitivity. Computer simulations are performed using Atlas® device simulation software created by Silvaco International, Inc®. The simulation results are compared to actual SEU test data.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Manufacturing Science and Technology, Electronics

KEYWORDS: Heterojunction Bipolar Transistor, Single-Event Upsets, Indium Phosphide, Aluminum Indium Arsenide, Gallium Indium Arsenide

FREQUENCY DEPENDENCE OF SINGLE EVENT UPSETS IN GALLIUM ARSENIDE METAL SEMI-CONDUCTOR FIELD EFFECT TRANSISTORS

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Single event upsets (SEUs) are the result of high-energy particles passing through transistors in electronic circuits, causing errors in flip-flops and memory circuits. Gallium Arsenide (GaAs) Metal Semiconductor Field Effect Transistors (MESFETs) are desirable for space systems due to their lower power consumption at higher frequencies. However, they are more prone to errors from high-energy particles in the space environment. The goal of this research was to explore the temporal aspects of SEUs in GaAs MESFETs to determine the causes of variation in upset rates with frequency. By performing two-dimensional simulations of inverter circuits, the fundamental building blocks of electronic storage elements, a more accurate simulation of SEUs is possible, providing greater insight into the circuit response to particle strikes as transient signals are applied. This thesis develops doping profiles to match electrical characteristics of both conventional and radiation-tolerant MESFETs using Low-Temperature grown GaAs (LTGaAs). Techniques are developed to incorporate multiple transistors in 2-D simulations, more accurately replicating circuit responses. Finally, it is shown that the response to SEUs depends on the timing of the particle strike in relation to the signal transient, resulting in a varying error rate as a function of circuit frequency.

DoD KEY TECHNOLOGY AREAS: Electronics, Modeling and Simulation

KEYWORDS: GaAs, MESFET, SEU, Transient, Frequency Dependence

CLASSIFICATION OF UNDERWATER SIGNALS USING WAVELET-BASED DECOMPOSITIONS

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This thesis investigates the application of wavelet decompositions to classification applications. Two feature extraction tools are considered: Local Discriminant Bases (LDB) scheme and Power method. Several dimension reduction schemes including a newly proposed one called the Mean Separator Neural Network (MSNN) are discussed. Two types of classifiers are investigated and compared: Classification Trees (CT) and Back-Propagation Neural Network (BPNN). Classification experiments conducted on synthetic and real-world underwater signals show that: 1) the power feature extraction method is more robust to time synchronization issues than the LDB scheme is; 2) the MSNN scheme is a successful dimension reduction scheme that may be used with both LDB and Power feature extraction methods; and 3) the BPNN is a more powerful classifier than CT as it has fewer constraints than CT in partitioning the feature input space.

DoD KEY TECHNOLOGY AREAS: Sensors, Electronic Warfare

KEYWORDS: Classification, Wavelet Decomposition, Local Discriminant Bases (LDB), Dimension Reduction, Classification Trees (CT), Back-Propagation Neural Network (BPNN), BCM

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ACOUSTIC NOISE REMOVAL BY COMBINING WIENER AND WAVELET FILTERING TECHNIQUES

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This thesis investigates the application of Wiener filtering and wavelet techniques for the removal of noise from underwater acoustic signals. Both FIR and hR Wiener filters are applied in separate methods which involve the filtering of wavelet coefficients which have been produced through a discrete wavelet decomposition of the acoustic signal. The effectiveness of the noise removal methods is evaluated by applying them to simulated data. The combined Wiener wavelet filtering methods are compared to traditional denoising techniques which include Wiener filtering and wavelet thresholding methods.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors

KEYWORDS: Wavelet Analysis, Wiener Filtering, Denoising, Acoustic Signals

FEATURE-BASED LOCALIZATION IN SONAR-EQUIPPED AUTONOMOUS MOBILE ROBOTS THROUGH HOUGH TRANSFORM AND UNSUPERVISED LEARNING NETWORK

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As we approach the new millennium, robots are playing an increasingly important role in our everyday lives. Robotics has evolved in industrial and military applications, and unmanned space exploration promises the continued development of ever-more-complex robots. Over the past few decades, research has focused on the development of autonomous mobile robots—robots that can move about without human supervision. This brings with it several problems, however, specifically the problem of localization. How can the robot determine its own position and orientation relative to the environment around it?

Various methods of localization in mobile robots have been explored. Most of these methods, however, assume some a priori knowledge of the environment, or that the robot will have access to navigation beacons or Global Positioning Satellites. In this thesis, the foundations for feature-based localization are explored. An algorithm involving the Hough transform of range data and a neural network is developed, which enables the robot to find an unspecified number of wall-like features in its vicinity and determine the range and orientation of these walls relative to itself. Computation times are shown to be quite reasonable, and the algorithm is applied in both simulated and realworld indoor environments.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Autonomous Mobile Robots, Hough Transform, Localization, Nomad Scout Mobile Robot, Competitive Neural Networks, Data Clustering

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

AN INTEGRATED INS/GPS NAVIGATION SYSTEM FOR SMALL AUVS USING AN ASYNCHRONOUS KALMAN FILTER

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A Small AUV Navigation System (SANS) is being developed at the Naval Postgraduate School. The SANS is an integrated INS/GPS navigation system composed of low-cost, small-size components. It is designed to demonstrate the feasibility of using a low-cost Inertial Measurement Unit (IMU) to navigate between intermittent GPS fixes.

This thesis presents recent improvements to the SANS hardware and software. The 486-based ESP computer used in the previous version of SANS is now replaced by an AMID 586DX133 based PC/104 computer to provide more computing power, reliability and compatibility with PC/104 industrial standards. The previous SANS navigation filter consisting of a complementary constant gain filter is now aided by an asynchronous Kalman filter. This navigation filter has six states for orientation estimation (constant gain) and eight states for position estimation (Kalman filtered). Low-frequency DGPS noise is explicitly modeled based on an experimentally obtained autocorrelation function. Ocean currents are also modeled as a low-frequency random process. The asynchronous nature of DGPS measurements resulting from AUV submergence or wave splash on the DGPS antennas is also taken into account by adopting an asynchronous Kalman filter as the basis for the SANS software. Matlab simulation studies of the asynchronous filter have been conducted and results documented in this thesis.

DoD KEY TECHNOLOGY AREA: Electronics, Sensor

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

IMPLEMENTATION OF A MULTIPLE ROBOT FRONTIER-BASED EXPLORATION SYSTEM AS A TESTBED FOR BATTLEFIELD RECONNAISSANCE SUPPORT

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Future military battlefields will see smaller forces responsible for ever increasing geographical areas. In addition, future conflicts will occur more often in urban or built-up areas. Both of these trends argue for some type of augmentation for initial reconnaissance, continued observation, and control of lines of communication and other key terrain features. Multisensor systems, mounted on a variety of robotic platforms, can provide this type of battlefield support where it is needed most. However, before costly decisions concerning the details of such systems can be made, basic research needs to be conducted regarding their most effective composition and utilization.

Prior to this time all multiple robot studies at this institution had only taken place in simulated environments. This thesis implements a real-world multiple robot system that uses a technique known as frontier-based exploration to explore and map a laboratory or office environment. In doing so, many previously hidden aspects of multiple robot systems, unnoticeable in simulation-only studies, become evident. The results developed here are compared to results obtained elsewhere involving other robotic platforms. This research lays the foundation for future research involving multiple robots interacting as a system in a real-world environment and acting towards a common or shared goal.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors, Other (Robotics)

KEYWORDS: Robotics, Multiple Robots, Sensor Fusion, Battlefield Reconnaissance

DEVELOPMENT OF A NARROWBAND ZOOM PROCESSING CAPABILITY USING COMMERCIAL PROCESSORS

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This work is part of an ongoing effort to integrate the separate BEARTRAP post mission analysis tools into a system residing in a Microsoft Windows environment. This new integrated system will contain software modules designed to replace the array of diverse processing systems currently being used for BEARTRAP post mission analysis. This thesis develops the module responsible for narrowband zoom processing. This module allows an operator to view high resolution frequency domain data from various sensors using heterodyning and decimation techniques with processing performed by either a desktop personal computer processor or commercial digital signal processing boards. This work presents the development of the narrowband bandwidth determination and decimation sequence algorithms, the development of the heterodyning and narrowband processing using Microsoft Visual C++ as the implementation language, and the testing of the various parts of the Narrrowband Pretrack module in a stand-alone Microsoft Windows application.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Sensors

KEYWORDS: DSP, Narrowband, BEARTRAP

PERFORMANCE ANALYSIS OF NONCOHERENT DIFFERENTIAL PHASE SHIFT KEYED WITH VARIOUS DIVERSITY COMBINING TECHNIQUES OVER A RICIAN FADING CHANNEL

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The error probability analysis of a noncoherent differential phase shift keyed (DPSK) receiver employing diversity combining techniques is performed. It is assumed that the system operates over a frequency non-selective, slowly fading Rician channel.

This thesis analyzes equal gain combining (EGC), selection combining (SC) and post detection selection combining (PDSC). The first two diversity combining techniques are widely used in communication systems, while PDSC is a new technique. Previous analysis of the EGG and the SC techniques shows that the EGC technique has a better performance than the SC technique in a Rayleigh fading channel. In this thesis, the effect on the performance of a noncoherent DPSK receiver using the diversity combining techniques for Rician fading is examined. It is shown that the PDSC technique provides a performance that is better than the SC but worse than the EGC technique. The PDSC technique allows a relatively simple receiver structure independent of the number of diversity branches.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Rician Fading Channel, Diversity Combining Techniques, Equal Gain Combining (EGG), Selection Combining (SC), Post Detection Selection Combining (PDSC).

ESTIMATING THE ACOUSTIC MODAL ARRIVALS USING SIGNALS TRANSMITTED FROM TWO SOUND SOURCES TO A VERTICAL LINE HYDROPHONE ARRAY IN THE 1996 SHELFBREAK PRIMER EXPERIMENT

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During the 1996 multi-institutional Shelfbreak PRIMER experiment, low frequency sound sources were moored on the continental slope south of Cape Cod. These sources transmitted phase encoded tomography signals which were monitored by vertical-line hydrophone arrays moored on the continental shelf. The measured signals were processed for the acoustic modal arrivals and their variability in time. The processing entailed pulse compression, coherent averaging, local sound-speed profile updates and an application of the Chiu-Miller-Lynch model-based modal beamforming technique. In this thesis, the signal processing procedure is discussed and the modal arrival estimates are examined. The model-based estimates are found to be of high quality, with all propagating modes individually resolved. This unambiguous separation of the high modes cannot be achieved using simple least-squares techniques because of under sampling. The temporal variability of the modal amplitudes and travel times are found to be related to ocean processes that are unique to the shelf-slope littoral environment.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Acoustics, Array, Mode, Processing

DETECTION AND CLASSIFICATION OF DIGITAL COMMUNICATION SIGNALS USING SECOND- AND HIGHER-ORDER CYCLOSTATIONARY FEATURES (PART I/II) (U)

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Conventional detection and classification techniques with regards to digital communications rely primarily on one or a combination of the following: Knowledge that a single known signal is present or absent, a *priori* knowledge of modulation parameters of multiple possible signals; energy or power measurements; temporal or spectral feature measurement. Though these techniques are successful in many instances, they are severely limited in significant additive white Gaussian noise (AWGN) and co-channel interference. By processing the signals as cyclostationary, a new set of features can be obtained that remain uniquely identifiable in the presence of strong noise and other signals. Two such signal processing approaches are tested here. The Automatic Signal Classifier (ASC) exploits second-order cyclostationarity via the spectral correlation function (SCF), while higher-order cyclostationarity (HOCS) is exploited via the temporal cumulant function (TCF) in the HOCS-Based Classifier (HBC). These detection and classification algorithms demonstrate a signal-selectivity property that renders them inherently more tolerant to noise and interference in a series of tests conducted first with simulated digital communications and secondly with actual transmitted digital communications.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Sensors

KEYWORDS: SIGINT, Signal Processing, Cyclostationary, Spectral Correlation, Temporal Cumulants

PERFORMANCE ANALYSIS OF NONCOHERENT DIFFERENTIAL PHASE SHIFT KEYINGUSING POST-DETECTION SELECTION COMBINING OVER A RAYLEIGH FADING CHANNEL

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In this thesis, the performance analysis of a noncoherent Differential Phase Shift Keying (DPSK) receiver using Post-Detection Selection Combining techniques over a Rayleigh fading channel is investigated. Post-Detection Selection Combining (PDSC) is evaluated and compared to Equal Gain Combining (EGC) and Selection Combining (SC), the two common diversity techniques discussed in the literature. Numerical results obtained for Post-Detection Selection Combining are compared to Selection Combining and Equal Gain Combining. The Post-Detection Selection Combining method is shown to be superior to the Selection Combining method but inferior to Equal Gain Combining method for a non-coherent DPSK receiver operating over a Rayleigh fading channel.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Rayleigh Fading Channel, Diversity Combining Techniques, Equal Gain Combining (EGC), Selection Combining (SC), Post-Detection Selection Combining (PDSC)