MASTER OF SCIENCE
IN
ELECTRICAL ENGINEERING

DESIGN, IMPLEMENTATION, AND TESTING OF AN ASIC VLSI HIGH PERFORMANCE ARCTANGENT FUNCTION

Ronald Christopher Altmeyer-Captain, Canadian Army
B.Sc., Royal Roads Military College, 1993
Master of Science in Electrical Engineering-September 2002
Advisor: Douglas J. Fouts, Department of Electrical and Computer Engineering
Second Reader: Phillip E. Pace, Department of Electrical and Computer Engineering

This thesis documents the research, circuit design, and simulation testing of a VLSI ASIC which extracts phase angle information from a complex sampled signal using the arctangent relationship: $f = \tan^{-1}(Q/I)$. Specifically, the circuit will convert the In-Phase and Quadrature terms into their corresponding phase angle. The design specifications were to implement the design in CMOS technology with a minimum transistor count and ability to operate at a clock frequency of 700 MHz. Research on the arctangent function was performed to determine mathematical calculation methods and the CORDIC method was chosen to achieve the stated design specifications. MATLAB simulations were used to calculate and verify accuracy, and to implement Quine-McClusky logic minimization. T-SPICE netlists were generated and simulations were run to determine transistor and circuit electrical operation and timing. Finally, overall circuit logic functionality of all possible input combinations was completed using a VHDL simulation program.

KEYWORDS: Digital Image Synthesizer, DIS, VLSI, ASIC, CMOS, Inverse Tangent, Arctangent, Arc tangent, Atan, Atan2, Coordinate Rotation Digital Computer, CORDIC, Amplitude to Phase Conversion, In-phase, Quadrature, Quine-McClusky, VHDL, Tanner, MOSIS

CODING-SPREADING TRADEOFF IN CDMA SYSTEMS

Eduardo Bolas-Lieutenant, Portuguese Navy
B.S., Portuguese Naval Academy, 1994
Master of Science in Electrical Engineering-September 2002
Advisor: Tri T. Ha, Department of Electrical and Computer Engineering
Co-Advisor: Jan E. Tighe, Naval Information Warfare Activity
Second Reader: Jovan E. Lebaric, Department of Electrical and Computer Engineering

In this thesis the usage of low rate codes is investigated primarily to provide the total bandwidth expansion required for a CDMA system. Comparing different combinations of coding and spreading with a traditional DS-CDMA, as defined in the IS-95 standard, allows the criteria to be defined for the best coding-spreading tradeoff in CDMA systems. The analysis of the coding-spreading tradeoff is divided into two parts. The first part is dedicated to the study of the deterministic components of the problem. This includes the different factors with non-random behavior that the system's designer can determine. The processing gain, the code characteristics and the number of users are well-defined variables that can determine the overall performance and can consequently affect the tradeoff. The second part of the study is dedicated to analyzing different combinations of coding and spreading with no ideal channel estimation and interference reduction techniques. Small-scale fading channel conditions are emulated through Nakagami-m distribution. Large-scale path loss was incorporated through the extended Hata model while Lognormal shadowing considered the fluctuations on the received power at points with the same distance to the transmitter. The performance of different combinations of coding and spreading was assessed considering two cases: a worst-case scenario in which the mobile user was located at the corner of a hexagon cell in a seven-cell cluster and a more realistic scenario in which the user could be physically located anywhere in the cell, following a uniform probability distribution function. Furthermore, the improvement in

performance generated by interference reduction techniques, such as sectoring and power control is investigated.

KEYWORDS: Coding, Spreading, Low Rate Codes, Code-Spreading, Nakagami Fading, Lognormal Shadowing, CDMA, Wireless, Performance Analysis, Antenna Sectoring, Power Control

DELAY-BASED COMMUNICATION IN PACKET SWITCHED NETWORKS

Daniel B. Copeland-Lieutenant, United States Navy
B.S., The University of Texas at Austin, 1995
Master of Science in Electrical Engineering-September 2002
Electrical Engineer-September 2002
Advisor: John McEachen, Department of Electrical and Computer Engineering
Co-Advisor: R. Clark Robertson, Department of Electrical and Computer Engineering
Co-Advisor: Herschel H. Loomis, Jr., Department of Electrical and Computer Engineering

While a great deal of research has been done on traditional amplitude and frequency-based communication, much less research has been done on delay-based communications. This thesis explores using Packet Position Modulation (PkPM), a delay-based communication method in a packet switched network. Error mitigation in various timing channels is examined to determine the feasibility of PkPM in different networks. Synchronization issues that arise when packets are lost in the network are also explored. Java code was written to implement PkPM to allow flexibility in the testing methods. OPNET simulations are used to test PkPM in different network sizes with different traffic loads. Comparisons are also made to previously proposed methods for error mitigation in delay-based communications. Simulations show that the PkPM method proposed here gives reasonable throughputs with low error rates in a variety of networks.

KEYWORDS: Delay-Based Communication, Packet Position Modulation, Packet Switching, Timing Channels

TIME DELAY ESTIMATION OF A WIDEBAND SOURCE

William J. Diehl-Lieutenant Commander, United States Navy
B.A., Duke University, 1991
Master of Science in Electrical Engineering-September 2002
Advisor: Charles W. Therrien, Department of Electrical and Computer Engineering
Second Reader: Herschel H. Loomis, Jr., Department of Electrical and Computer Engineering

The problem of localization of wideband radio frequency (RF) sources is important in the fields of communications engineering, navigation and signals analysis. Time Delay Estimation using cross-correlation is one method of localization. In this thesis, a sample signal collection system is simulated. "Non-coherent" and "coherent" cross-correlation algorithms for time delay estimation are developed and tested. The algorithms are tested with varying levels of noise, different signal processing techniques, and various sources of interference. The algorithms are evaluated based on their ability to estimate the location of a randomly-placed Binary Phase Shift Keying (BPSK) source in a two-dimensional grid using intersections of hyperbolic lines of position.

This thesis shows that both the non-coherent and coherent cross-correlation algorithms are effective in locating BPSK signals. The non-coherent algorithm is more effective for the chosen test cases. The non-coherent algorithm is effective in high noise conditions. The algorithms are generally not effective in the presence of strong interference.

KEYWORDS: Time Difference of Arrival, Generalized Cross-Correlation, Maximum Likelihood, Localization

DIRECT-SEQUENCE SPREAD-SPECTRUM MODULATION FOR UTILITY PACKET TRANSMISSION IN UNDERWATER ACOUSTIC COMMUNICATION NETWORKS

Peter S. Duke-Lieutenant Commander, Canadian Navy
B.S., University of Calgary, 1985
Master of Science in Electrical Engineering–September 2002
Advisor: Roberto Cristi, Department of Electrical and Computer Engineering
Co-Advisor: Joseph Rice, Engineering Acoustics Chair

This thesis investigates the feasibility and performance of using Direct-Sequence Spread-Spectrum (DSSS) modulation for utility-packet transmission in Seaweb underwater wireless acoustic communications networks. Seaweb networks require robust channel-tolerant utility packets having a low probability of detection (LPD) and allowing for multi-user access. MATLAB code simulated the DSSS transmitter and receiver structures and a modeled channel impulse response represented the underwater environment. The specific modulation scheme implemented is direct-sequence, differentially encoded binary phase-shift keying (DS-DBPSK) with quadrature spreading. Performance is examined using Monte Carlo simulation. Bit error rates and packet error rates for various signal-to-noise ratios and channel conditions are presented and the use of a RAKE receiver, forward error-correction coding and symbol interleaving are examined for improving system performance.

KEYWORDS: Acoustic Communications, Underwater Communications, Underwater Networks, Undersea Warfare, Direct-Sequence Spread-Spectrum, Differential Binary Phase-Shift Keying, DSSS, DBPSK, DS/BPSK

QUANTIFYING THE DIFFERENCES IN LOW PROBABILITY OF INTERCEPT RADAR WAVEFORMS USING QUADRATURE MIRROR FILTERING

Pedro F. Jarpa-Captain, Chilean Air Force
B.S., Military Polytechnic Academy, 1998
Master of Science in Electrical Engineering-September 2002
Advisor: Phillip E. Pace, Department of Electrical and Computer Engineering
Co-Advisor: Herschel H. Loomis, Jr, Department of Electrical and Computer Engineering

Low Probability of Intercept (LPI) radars are a class of radar systems that possess certain performance characteristics causing them to be nearly undetectable by most modern digital intercept receivers. Consequently, LPI radar systems can operate undetected until the intercept receiver is much closer than the radar's target detector. The enemy is thus faced with a significant problem. To detect these types of radar, new direct digital receivers that use sophisticated signal processing are required. This thesis describes a novel signal processing architecture, and shows simulation results for a number of LPI waveforms. The LPI signal detection receiver is based on Quadrature Mirror Filter Bank (QMFB) Tree processing and orthogonal wavelet techniques to decompose the input waveform into components representing the signal energy in rectangular "tiles" in the time-frequency plane. By analyzing the outputs at different layers of the tree it is possible to do feature extraction, identify and classify the LPI waveform parameters, and distinguish among the various LPI signal modulations. Waveforms used as input signals to the detection algorithm include Frequency Modulated Continuous Wave, Polyphase Codes, Costas Codes and Frequency Shift Keying/Phase Shift Keying waveforms. The output matrices resulting from the most relevant layers of the QMFB tree processing are examined and the LPI modulation parameters are extracted under various signal-to-noise ratios.

KEYWORDS: Signal Processing, Digital Filters, LPI, LPI Radar Signals, Quadrature Mirror Filter Bank

A FIXED-POINT PHASE LOCK LOOP IN A SOFTWARE DEFINED RADIO
Michael T. Johannes-Captain, United States Marine Corps
B.A., College of the Holy Cross, 1995
Master of Science in Electrical Engineering-September 2002
Advisor: Tri T. Ha, Department of Electrical and Computer Engineering
Second Reader: Roberto Cristi, Department of Electrical and Computer Engineering

A software defined radio is a much more flexible platform than traditional, hardware implemented radios. By implementing radio functions in software, and putting those functions on a Field Programmable Gate Array (FPGA) chip, users will have the ability to download mission specific radio capabilities. This thesis examines a fundamental piece of the receiver, the Phase-Lock Loop (PLL), simulates a software PLL, and investigates the effects of fixed-point versus floating point mathematics required for an FPGA based PLL. With a fixed-point PLL simulator, figures of merit such as lock-time, lock range, and pull-in range are determined. Effects of the fixed-point error on the signal-to-noise ratio are also analyzed.

KEYWORDS: Software Radio, Phase-Locked Loop, Fixed-point Arithmetic, PLL

BOOTSTRAP BASED SIGNAL DENOISING
Hasan E. Kan-First Lieutenant, Turkish Army
B.S., Turkish Military Academy, 1996
Master of Science in Electrical Engineering-September 2002
Advisor: Monique P. Fargues, Department of Electrical and Computer Engineering
Co-Advisor: Ralph D. Hippenstiel, University of Texas
Second Reader: Roberto Cristi, Department of Electrical and Computer Engineering

This work accomplishes signal denoising using the Bootstrap method when the additive noise is Gaussian. The noisy signal is separated into frequency bands using the Fourier or Wavelet transform. Each frequency band is tested for Gaussianity by evaluating the kurtosis. The Bootstrap method is used to increase the reliability of the kurtosis estimate. Noise effects are minimized using a hard or soft thresholding scheme on the frequency bands that were estimated to be Gaussian. The recovered signal is obtained by applying the appropriate inverse transform to the modified frequency bands. The denoising scheme is tested using three test signals. Results show that FFT-based denoising schemes perform better than WT-based denoising schemes on the stationary sinusoidal signals, whereas WT-based schemes outperform FFT-based schemes on chirp type signals. Results also show that hard thresholding never outperforms soft thresholding; at best its performance is similar to soft thresholding.

KEYWORDS: Denoising, Bootstrap, Kurtosis

PERFORMANCE OF THE *IEEE 802.11A* WIRELESS LAN STANDARD OVER FREQUENCY-SELECTIVE, SLOW, RICEAN FADING CHANNELS
Chi-han Kao-Lieutenant Commander, Taiwan Navy
B.S., Chinese Naval Academy, 1989
Master of Science in Electrical Engineering-September 2002
Advisor: R. Clark Robertson, Department of Electrical and Computer Engineering
Second Reader: Roberto Cristi, Department of Electrical and Computer Engineering

With the rapidly growing demand for more reliable and higher data rate wireless communications, the *Institute of the Electrical and Electronics Engineers (IEEE) 802.11* working group approved a standard for 5 GHz band, wireless local area networks (WLAN) in 1999. This standard, *IEEE 802.11a*, supports data rates from 6 up to 54 Mbps, and uses orthogonal frequency division multiplexing (OFDM) for transmission in indoor wireless environments. This thesis examines the performance of the *IEEE 802.11a* standard for different combinations of sub-carrier modulation type and code rate and determines the signal-to-noise ratio required to obtain a probability of bit error P_b of 10^{-5}. The channel is modeled as a *frequency-selective,*

slow, Ricean fading channel with additive white Gaussian noise (AWGN). Contrary to expectations, for the combinations of sub-carrier modulation type and code rate utilized by the *IEEE 802.11a* standard, some of the higher data rate combinations outperform some of the lower data rate combinations. On the other hand, the results also show significant coding gain when applying *convolutional coding* with *Viterbi decoding*, and hence highlight the importance of forward error correction (FEC) coding to the performance of wireless communications systems.

KEYWORDS: *IEEE 802.11a* Standard, WLAN, OFDM, BPSK, QPSK, QAM, Probability of Bit Error, Frequency-selective Fading, Flat Fading, Fast Fading, Slow Fading, Ricean Fading, Rayleigh Fading, Viterbi Algorithm, Convolutional Code, Hard-decision Decoding, Soft-decision Decoding, Coding Gain

PERFORMANCE ANALYSIS OF A DIGITAL IMAGE SYNTHESIZER AS A COUNTER-MEASURE AGAINST INVERSE SYNTHETIC APERTURE RADAR

Fernando LeDantec-Lieutenant, Navy of Chile
B.S.S.E., United States Naval Academy, 1992
B.S.E.E., Naval Polytechnic Academy-Chile, 1995
Master of Science in Electrical Engineering-September 2002
Electrical Engineer-September 2002
Chairman of Committee: Phillip Pace, Department of Electrical and Computer Engineering
Committee Member: Douglas J. Fouts, Department of Electrical and Computer Engineering
Committee Member: David C. Jenn, Department of Electrical and Computer Engineering

This thesis is concerned with the development of a model to analyze a Digital Image Synthesizer (DIS) integrated circuit designed to create false target images to deceive Inverse Synthetic Aperture Radar (ISAR). The DIS is able to recreate the scattering effect of a moving target by using appropriate phase and gain modulations on an intercepted ISAR chirp signal before retransmitting it with the proper time delay. The DIS signal processing and the ISAR compression of the modulated return are modeled to examine the range-Doppler profile of a synthesized false target image. The image is representative of the image that would appear on an ISAR display. ISAR image quality is used to evaluate different DIS architectures and bit formats. Evaluation of the image quality is based on the deviation from an infinite resolution false target image. The results obtained from evaluating different DIS architectures indicate that the design is tolerant of significant quantization errors. The model is used to validate the architecture of the integrated circuit being fabricated. Finally, various different ISAR integration times and pulse repetition frequencies are used to confirm the integrity of the model.

KEYWORDS: Digital Image Synthesizer, DIS, Inverse Synthetic Aperture Radar, ISAR, Synthetic Aperture Radar, SAR, False Target

ELECTROMAGNETIC AIRCRAFT LAUNCH SYSTEM TECHNOLOGY SCALING FOR UNMANNED AERIAL VEHICLE LAUNCH TARGETED TOWARD THE ADVANCED LOGISTIC DELIVERY SYSTEM

Shawn W. McKee-Major, United States Marine Corps
B.S., United States Naval Academy, 1991
Master of Science in Electrical Engineering-September 2002
Co-Advisor: John G. Ciezki, United States Naval Academy
Co-Advisor: Robert W. Ashton, Department of Electrical and Computer Engineering
Second Reader: Sherif Michael, Department of Electrical and Computer Engineering

The United States Marine Corps' current doctrine centers on the concept of Operational Maneuver From the Sea (OMFTS). The MV-22 tilt-rotor aircraft and Advanced Amphibious Assault Vehicle are currently being developed in order to fulfill the operational requirements of this doctrine. The logistical requirement of supplying Marines ashore must also be addressed.

This thesis focuses on the initial design considerations for an Electromagnetic Aircraft Launch System (EMALS) to be used on an Advanced Logistic Delivery System currently being proposed by The

Innovation Center of The Naval Surface Warfare Center, Carderock Division. The launcher requirement is to propel a one thousand pound Unmanned Aerial Vehicle (UAV) to an altitude of 10,000 feet with no auxiliary power aboard the UAV.

Four major subsystems for the EMALS were considered. Three of the four subsystems have never been built to the desired specifications in terms of power and energy. Preliminary research into the basic operation and limitations of linear motors, power converters with associated switching devices, storage elements and control architecture was completed. From the preliminary research, a basic understanding of system limitations, system integration and design considerations was established. The design considerations were then presented in the context of an overall system engineering approach to establish a baseline for future design work.

KEYWORDS: ALDS, EMALS, OMFTS, Linear Induction Motor, Linear Synchronous Motor, Multilevel Converter, Cycloconverter, Energy Storage, Flywheel, Vector Control

A NOVEL APPROACH FOR THE SIMULATION AND MODELING OF STATE-OF-THE-ART MULTIJUNCTION SOLAR CELLS

Panayiotis Michalopoulos-Lieutenant, Hellenic Navy
B.S., Hellenic Naval Academy 1993
Master of Science in Electrical Engineering-March 2002
Master of Science in Computer Science-March 2002
Advisor: Sherif Michael, Department of Electrical and Computer Engineering
Second Reader: J. Bret Michael, Department of Computer Science
Second Reader: Todd Weatherford, Department of Electrical and Computer Engineering

In this thesis, a new method for developing realistic simulation models of advanced solar cells is presented. Several electrical and optical properties of exotic materials, used in such designs, are researched and calculated. Additional software has been developed to facilitate and enhance the modeling process. Furthermore, specific models of an InGaP/GaAs and of an InGaP/GaAs/Ge multi-junction solar cells are prepared and are fully simulated. The major stages of the process are explained and the simulation results are compared to published experimental data. Finally, additional optimization is performed on the last state-of-the-art cell, to further improve its efficiency. The flexibility of the proposed methodology is demonstrated and example results are shown throughout the whole process.

KEYWORDS: Solar Cell, Multijunction, Material Parameters, Tunnel Junction, Model, Simulation, Development, Silvaco

SMART ANTENNA APPLICATION IN DS-CDMA MOBILE COMMUNICATION SYSTEM

Kok Keng Ng-Civilian, Ministry of Defence (Singapore)
B.Eng., Nanyang Technological University, 1994
M.Sc., Nanyang Technological University, 1999
Master of Science in Electrical Engineering-September 2002
Advisor: Tri T. Ha, Department of Electrical and Computer Engineering
Co-Advisor: Jovan E. Lebaric, Department of Electrical and Computer Engineering

This thesis examines the use of an equally spaced linear adaptive antenna array at the mobile station for a typical Direct Sequence Code Division Multiple Access (DS-CDMA) cellular mobile communications system with forward error correction with soft decision decoding. The performance of a randomly positioned mobile terminal with a randomly orientated adaptive antenna array in the forward channel (base-station to mobile) of a multi-cell DS-CDMA system was analyzed and four performance boundaries were established. Using the more conservative optimized array antenna performance boundary for 2-, 3- and 4-elements linear array, the capacity and the performance of different cellular systems were compared. This was done under a range of shadowing conditions, with and without antenna sectoring at the base-station, and for various user capacities using Monte Carlo simulation.

Tapped-delay line (transversal filter) was further applied to each antenna element channel to allow frequency dependent amplitude and phase adjustment for broadband signals. The performance of a DS-CDMA cellular system with mobile terminal equipped with linear array and tapped-delay line is analyzed. It has been demonstrated that the optimization process has been extremely computational expensive and hence minimum taps should be used for practical consideration. The results illustrated that, in general, for a 2-element linear array system, 3-tap delay line would be sufficient to equalize the broadband signal while providing similar performance level of a narrowband adaptive array system. In the case of a 3-element linear-array system, 2-taps would suffice.

KEYWORDS: Mobile Communications System, Adaptive Antenna, Linear Array, DS-CDMA, Cellular System, Tapped-Delay Line

COMPARISON OF ANALYTIC AND NUMERICAL MODELS WITH COMMERCIALLY AVAILABLE SIMULATION TOOLS FOR THE PREDICTION OF SEMICONDUCTOR FREEZE-OUT AND EXHAUSTION

Derek Edwin Reeves-Lieutenant, United States Navy
B.S., Rochester Institute of Technology, 1997
Master of Science in Electrical Engineering-September 2002
Advisor: Ron J. Pieper, Department of Electrical and Computer Engineering
Co-Advisor: Sherif Michael, Department of Electrical and Computer Engineering

This thesis reports on three procedures and the associated numerical results for obtaining semiconductor majority carrier concentrations when subjected to a temperature sweep. The capability of predicting the exhaustion regime boundaries of a semiconductor is critical in understanding and exploiting the full potential of the modern integrated circuit. An efficient and reliable method is needed to accomplish this task. Silvaco International's semiconductor simulation software was used to predict temperature dependent majority carrier concentration for a semiconductor cell. Comparisons with analytical and numerical MATLAB-based schemes were made. This was done for both Silicon and GaAs materials. Conditions of the simulations demonstrated effect known as Bandgap Narrowing.

KEYWORDS: Silvaco, GaAs, Silicon, Freeze-out, Exhaustion, Intrinsic, Semiconductor, MATLAB, Bandgap Narrowing, Temperature Dependent

MOBILE USER OBJECTIVE SYSTEM (MUOS) HELMET MOUNTED UHF ANTENNA DESIGN AND HUMAN BODY EFFECTS

Stephen S. Schwarz-Major, United States Marine Corps
B.S., University of Missouri, 1989
Master of Science in Electrical Engineering-September 2002
Advisor: Jovan E. Lebaric, Department of Electrical and Computer Engineering
Second Reader: Richard W. Adler, Department of Electrical and Computer Engineering

The Mobile User Objective System (MUOS) is the U.S. Navy's next generation tactical communications satellite system. Computer simulations are used to determine a suitable, low profile antenna that conforms to the US ground troop Kevlar helmet and that operates from 243 MHz – 317 MHz. The electrical performance and Specific Absorption Rate (SAR) are used to determine the maximum Effective Isotropic Radiated Power (EIRP) for each configuration without exceeding Federal Communications Commission (FCC) SAR limits. Models include a two-arm spiral antenna in a nylon shell; the shell protects the antenna and improves low frequency performance through dielectric loading. Three configurations use a reflector, based upon Yagi-Uda antenna principles, to increase the radiation pattern front-to-back ratio and to reduce the reference impedance to the standard 50 ohms. All configurations have an EIRP of at least 0.5 W over a 120-degree beamwidth without exceeding the FCC SAR limits. Use of radio frequency shielding to further increase the EIRP is examined.

KEYWORDS: Human Body Effects, Specific Absorption Rate (SAR), Mobile User Objective System (MUOS), Satellite Communications, Dielectric Loading