MASTER OF SCIENCE
IN
ELECTRICAL ENGINEERING

DESIGN OF AN 8 x 8 NON-BLOCKING CROSSPOINT SWITCH IN GaAs TWO-PHASE DYNAMIC FET LOGIC

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Computer resources on military and telecommunications satellites are being over-tasked more than ever before, and the increasing shift to onboard signal processing will only compound the problem in the future. Space-based multiprocessor computer systems linked by high speed interconnect networks offer one possible solution to this ever-expanding problem. Fallium arsenide (GaAs) integrated circuits using metal-semiconductor field effect transistors (MESFSTs) offer very high speed operations, reduced power consumption, and inherent radiation tolerance, which make them ideally suited to the harsh space environment.

The design, simulation and layout of an 8 x 8 non-blocking crosspoint switch implemented in GaSa two-phase dynamic FET logic (TDFL) is presented in this thesis. The design of the TDFL crosspoint switch design that uses GaAs direct-coupled FET logic (DCFL). Design specifics of working with GaAs are presented first, followed by detailed descriptions of the DCFL and TDFL crosspoint switches, and finally, an analysis of the advantages and disadvantages of dynamic logic over static logic is presented.

The TDFL crosspoint switch presented here could easily be modified to serve as a one gigabit per second serial interconnect for future space-based multiprocessor computer systems.

KEYWORDS: GaAs, Gallium Arsenide, Crosspoint Switch, TDFL, Two-phase Dynamic FET Logic

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

ANALYSIS OF FINITE PHASED ARRAYS ON SHAPED GROUND PLANES

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The objective of this thesis is to evaluate the performance of an array antenna when this is installed on an complex structure, such as those that have unusual edge contour, curved surfaces, and mixed material composition. A dipole is used as the basic array element to study the effect of various changes in the array design parameters on the gain and sidelobe level. Data is generated using a computational electromagnetics code based on the method of moments. Among the issues addressed are the curvature of the array ground plane and shaping the ground plane edges to reduce wide-angle sidelobes.

KEYWORDS: Arrays, Radiation Pattern

DoD KEY TECHNOLOGY AREA: Electronics

OBJECT RECOGNITION USING 2D SENSORS AND AUTONOMOUS VEHICLE NAVIGATION ISSUES

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This research deals with the problem of extracting features from an image using wavelets and then using these features to recognize objects present in the image. This technique is applied to recognition of Unexploded Ordnance (UXO) objects. However, the concepts described here can be extended to recognition of other objects such as ships, missiles and aircrafts.

This work is performed as part of an ongoing effort to develop an autonomous vehicle capable of detecting UXOs.

KEYWORDS: Image Recognition, Unexploded Ordnance, Wavelets, Neural Networks, Motion Control

DoD KEY TECHNOLOGY AREAS: Computing and Software, Electronic Warfare, Modeling and Simulation, Ground Vehicles

THE MACH-ZEHNDER COUPLER

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This thesis is the second in a series which investigates the possibility of creating a code-shift-keying (CSK) optical receiver using single-mode 2x2 couplers and fiber optical delay lines to construct Mach-Zehnder couplers which comprise the main building block of the CSK receiver. There were two main goals of this thesis research. The first was to investigate design and construction modifications which would lower the system loss of a previously designed Mach-Zehnder coupler. As a result of this research, the system loss was reduced from 10.5 dB to 3.3 dB by changing the design to eliminate an unnecessary stage and by replacing several mechanical connections with fusion splices. The second goal was to find a method to measure the inherent phase shift of a 2x2 fiber optical coupler. Two separate methods were developed and implemented, and a third previously developed method was used to verify the results. All three methods provided experimental values between 145° and 149°. This thesis develops the theory that explains the discrepancy between the measured values and the ideal value of 180° for the inherent phase shift

KEYWORDS: Fiber Optic Receiver, Mach-Zehnder Coupler, Interferometry

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

ANALYSIS AND DESIGN OF RETROREFLECTORS

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The enhancement of the radar cross section (RCS) of specific bodies above their normal cross section has several military and civilian applications (e.g., sailboats and decoys). This enhancement is achieved by the use of retroreflectors. Retroreflectors are simple geometric conducting structures that concentrate the reflected wave back in the direction of incidence. They are capable of producing a high RCS over a wide range of aspect angles.

This thesis examines the RCS performance of various common retroreflector geometries. The study is performed using two computational electromagnetic simulation codes: a method of moments code and a physical optics code. The contour plots of RCS are presented for different geometries as a function of frequency. For retroreflectors composed of flat plates, the plate shape is varied to determine the affect of the plate size and profile on the RCS.

KEYWORDS: RCS, Retroreflector

DoD KEY TECHNOLOGY AREA: Electronic Warfare

CALIBRATION AND EVALUATION OF WATER SPEED INDICATOR AND COMPASS FOR THE SMALL AUTONOMOUS UNDERWATER VEHICLE NAVIGATION FILTER

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There are three major thrusts to this thesis. The first was to design and build a device to measure ground speed for testing the position estimating capabilities of the Small Autonomous Navigation System (SANS) filter. The ground tests consisted by placing the SANS unit on a golf cart and maneuvering it along a known track. The speed sensing device uses a bicycle wheel attached to the golf cart along with an appropriate time to speed software conversion.

The next problem was to determine if the existing paddle wheel in use would be accurate enough for the SANS to conduct underway tests. To perform this, a mechanism had to be built to channel water and measure its speed while allowing the paddle wheel to be in the flow.

Finally, the electronic compass was found to have heading dependent errors, thus a test was designed to determine its deviation. This was performed by swinging the compass using a transit aligned with its axis. This established a deviation table that was inserted into the SANS code, further refining its directional capabilities.

As a final test for determining the effectiveness of the calibrated inputs, tests were conducted that showed that the SANS filter is capable of obtaining 3 meter accuracy with no Global Positioning Update for an excess of two minutes. This is well beyond the initial goals set for the system.

KEYWORDS: Small Autonomous Navigation System, SANS, Global Positioning

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Modeling and Simulation

DEVELOPMENT OF AN ACOUSTIC TRANSIENT ANALYSIS USER INTERFACE FOR DETECTION AND TARGET LOCALIZATION

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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 acoustic transient detection and analysis. This module allows an operator to view time domain data from various sensors, record time of arrival data for a transient, and use the times from various buoys to calculate target position using a Time Difference of Arrival (TDOA) algorithm. The algorithm provides a closed form solution of target position and transmission time based on Time Difference of Arrival data. The accuracy of this solution depends on the accuracy of the time of arrival measurements, the accuracy of the sensor positions, and the sensor geometry. This work presents the development of the user interface using Microsoft Visual C++ as the implementation language, the development of the TDOA algorithm, and the testing of the various parts of the Transient Analysis module in a stand-alone Windows 95 application.

KEYWORDS: Transient, TDOA, Beartrap

DoD KEY TECHNOLOGY AREAS: Computing and Software, Sensors

FREQUENCY REUSE THROUGH RADIO FREQUENCY (RF) POWER MANAGEMENT IN SHIP-TO-SHIP DATA NETWORKS

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A proposed U.S. Navy ship-to-ship, line-of-sight, high-data-rate communication system is analyzed. Because of the limited bandwidth available in the UHF band, it is desired to reuse a frequency channel at the shortest possible range. By limiting the radiated power to the minimum required to establish a desired quality of service, the channel can be reused at considerably shorter ranges than when the transmitter output power is fixed to the maximum available. Frequency reuse, however, introduces the problem of cochannel interference which degrades system performance.

A computer simulation was developed to determine the bit error rate (BER) of a QPSK system in a Ricean fading channel with one cochannel interferer. The simulation generates plots of energy per bit to one-sided noise power spectral density ratio $(E_b IN_o)$ versus BER. Simulation results are used to compute the minimum range (R) at which the channel can be reused while maintaining an average BER of 10^{-6}. The results show that even when no power control is used the channel can be reused at a range, R, of approximately 45 kilometers. This range can be reduced to less than 20 kilometers if an interfering ship can reduce its output power by 30 dB.

KEYWORDS: Radiated Power Control, Frequency Reuse, Cochannel Interference, Ship-to-Ship Data Networks, Reuse Range, QPSK, BER, Fading Channel

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

OPNET IMPLEMENTATION OF SPREAD SPECTRUM NETWORK FOR VOICE AND DATA DISTRIBUTION

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This thesis presents an OPNET model and simulation of a single cell wireless communications system within a proposed expeditionary warfare communications network. The focus of this thesis is to model and implement data and voice traffic generation, slotted ALOHA medium access control protocol, and direct sequence spread spectrum code division multiple access (CDMA) mechanisms in OPNET. The RF channel is modeled as both a Rayleigh fading channel and a non-fading noise limited channel. Simulation results evaluating the induced BER and multiple access implementation are presented.

KEYWORDS: OPNET, CDMA, Spread Spectrum, Slotted ALOHA, Medium Access Control, Expeditionary Warfare Communications

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

PHOENIX AUTONOMOUS UNDERWATER VEHICLE (AUV):NETWORKED CONTROL OF MULTIPLE ANALOG AND DIGITAL DEVICES USING LONTALK

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The purpose of this thesis is to simplify analog and digital device control inside the *Phoenix* autonomous underwater vehicle (AUV). *Phoenix* is required to process many data information streams associated with a variety of different sensors. Real-time processing is required both for input sensing and for output directing. As presently configured, hardware devices aboard the *Phoenix* are manually connected and configured using parallel ports, serial ports, analog-to-digital (A/D) and digital-to-analog (D/A) controller hardware. Current hardware control within *Phoenix* connects all devices individually to a single computer. This approach is cumbersome, error-prone and does not scale.

This project investigates the feasibility of using Echelon LonWorks hardware and LonTalk protocol as a faster and scalable networked robot control system. LonWorks/LonTalk is a flexible A/D D/A hardware networking technology that provides reliable communication, decentralized topology with no single point of failure, easy extensibility, excellent throughput, and interoperability for a wide variety of hardware.

This project builds and tests a prototype LonTalk network that connects all *Phoenix* devices. This network demonstrates the capability of using LonWorks to control various types of hardware and support rapid component integration onboard the *Phoenix*. Successful demonstration of a LonTalk solution eliminates a critical barrier to *Phoenix* progress and makes robot execution much more robust.

KEYWORDS: Autonomous Underwater Vehicle, AUV, Networked Control, LonWorks Technology, LonTalk, LonBuilder

DoD KEY TECHNOLOGY AREAS: Computing and Software, Surface/Under Surface Vehicles-Ships and Watercraft