

# MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

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## TRANSMISSION OF LOW-BIT-RATE MPEG-4 VIDEO SIGNALS OVER WIRELESS CHANNELS

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The objective of this thesis is to study the performance of the MPEG-4 video coding standard in the presence of highly erroneous media, such as a wireless channel. MPEG-4 treats video sequences as a collection of objects rather than a collection of frames. A Matlab encoder that conforms to this approach is built for compressing raw video signals at various compression rates. A two-state Markov channel was used to simulate a wireless channel that introduces errors in the video bitstream and a decoder that utilizes error concealment techniques to hide these errors from the user was used to reconstruct the video sequence. The error resilient tools that the MPEG-4 standard provides to enhance the robustness in the presence of errors were simulated and proven to be advantageous compared to methods used in previous standards (MPEG-2, H.263, etc.). At the decoder, the use of error concealment techniques significantly enhanced the quality of the reconstructed video in high bit error rate environments.

**KEYWORDS:** MPEG-4, Video, Communications, Wireless Channels, Error Resilience, Error Concealment

## INCREASING PROMPT RESPONSE FROM IMPULSE RADIATING ANTENNA BY APERTURE SHAPING

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In order to improve the prompt response from an impulse radiating antenna (IRA) a number of studies have suggested controlling the spatial distribution of the aperture fields by changing the feed arm angle. Other work has suggested that proper shaping of the aperture can further enhance the radiated signal for a given feed structure. This paper shows how the radiated prompt response can be maximized for a given feed arm configuration by shaping the aperture to eliminate fields orientated in the wrong direction.

The percent increase in the prompt radiated electric field for a 200  $\Omega$  IRA with a ideally shaped aperture compared to a standard circular aperture ranged from 0.42% to 39.94% depending on the input electrode angle. For the most common electrode angles of 45° and 60° the increases are 6.00% and 16.63% respectively.

**KEYWORDS:** Ultra Wideband Electromagnetics, Time Domain Electromagnetics, Impulse Radiating Antennas, Wideband Antennas

## ELECTRICAL ENGINEERING

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### PROTOTYPE SYSTEM FOR DETECTION AND PROCESSING OF IEEE 802.11B SIGNALS

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As the use of wireless networks exponentially increases, the military is deciding the direction it should take with wireless technology. Wireless networks introduce flexibility, yet also introduce increased risk due to exploitation of physical layer vulnerabilities. Currently the commander has no means to view wireless traffic throughout his command. A rogue Access Point can jeopardize an otherwise secure network. This research focuses on developing a prototype system that will allow the commander to detect and process WLAN signals in real time. The prototype system was developed using commercial software and hardware components that can be upgraded and enhanced as the industry standard changes. The research includes the methodology used in selecting the commercial software and hardware components. In addition substantial testing results are included that outline the conditions under which the prototype will be able to receive and process 802.11b WLAN signals. The measured data is compared to radio frequency propagation models, and a simple formula to determine if a signal can be detected is presented. The research concludes with recommendations on how to successfully employ the system in an operational environment.

**KEYWORDS:** Wireless Local Area Networks, IEEE 802.11, Propagation, Detection, WLAN Signal Processing, Information Operations, Exploitation

### CHARACTERIZATION OF RADIATION DEGRADATION ON INDIUM

#### GALIUM ARSENIDE PHOTODIODES

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Since photodetectors are currently incorporated into a wide variety of military applications that require radiation hardness, the effect of neutron irradiation on the device's operating characteristics are of interest. In particular, the dependence of the device radiation response on the energy of the irradiating particle must be known so that predictions can be made about expected device operation in a radiation environment. The first goal of this research is to experimentally determine the displacement damage of off the shelf Epitaxx ETX 100 series InGaAs PIN photodiodes after being subjected to various fluence levels of proton and electron radiation environments so future modeling of equivalent devices can be performed. Secondly, this research will determine the applicability of published NIEL values to Epitaxx ETX 100 series photodiodes by calculating a 90 MeV electron fluence that will produce an equivalent displacement damage from a known 55 MeV proton fluence.

**KEYWORDS:** Displacement Damage, Electronics, InGaAs,  $\text{In}_{1-x}\text{Ga}_x\text{As}_y\text{P}_{1-y}/\text{InP}$ , NIEL, Non-ionizing Energy Loss, Photodetectors, Photodiodes, Radiation Effects

# ELECTRICAL ENGINEERING

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## JPEG2000 IMAGE COMPRESSION AND ERROR RESILIENCE FOR TRANSMISSION OVER WIRELESS CHANNELS

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This thesis examines the compression performance of the JPEG2000 standard for image transmission over noisy channels. Other features of the standard, such as error resilience and region of interest, have been studied and their effectiveness tested on several images. The JPEG2000 still image compression standard has provided higher compressions performance with lower distortion and better image quality than JPEG. JPEG2000 has the capability to define regions of interest of any shape and size and code the selected regions with a higher fidelity than the rest of the image. Compressed image data is transmitted over a noisy wireless channel based on Gilbert-Eliot model, which simulates both isolated and burst errors. JPEG2000 error resilient tools are used to allow the decoder to detect and conceal errors introduced in the channel. The results indicate up to 10 dB improvement in the peak signal to noise ratio when these tools are used.

**KEYWORDS:** Wavelet Analysis, Discrete Wavelet Transform, JPEG2000, Forward Error Correction (FEC), Automatic Repeat Request (ARQ), Markov Channel Model

## DEVELOPMENT OF A NAKAGAMI-LOGNORMAL MODEL FOR A CELLULAR CDMA FORWARD CHANNEL

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In this thesis, the performance of the forward channel of a DS-CDMA cellular system operating in a Nakagami-fading, Lognormal-shadowing environment is analyzed. Given the upper bound of bit error probability with FEC and including all the appropriate losses and interference terms, the bit error probability in various fading and Lognormal shadowing conditions is computed in two ways; firstly, by setting up a statistical model and secondly, by Monte Carlo simulations. The results predicted by the two methods take into account that the intended user is located at the corner of the hexagon of a seven-cell structure (worst case scenario). Furthermore, in order to obtain more realistic and accurate results, the user's distribution is incorporated in the cell and finally fast power control is applied to overcome the Lognormal shadowing effects.

**KEYWORDS:** Nakagami Fading, Lognormal Shadowing, CDMA, Forward Channel Model, Wireless, Performance Analysis, Antenna Sectoring, Sum Distribution, Power Control

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## ELECTRICAL ENGINEERING

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### PERFORMANCE ANALYSIS OF ADAPTIVE ANTENNA WITH CHANNEL CODING AND RAKE RECEIVER

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The presence of co-channel interference in a cellular system limits the system capacity. In order to meet the ever-growing demand of high data rates with the limited spectrum available, system designers are exploring new ideas to increase the system capacity. This thesis addresses the use of adaptive antenna arrays with coding and RAKE receivers to increase the system capacity by rejecting the interference and improving the output signal-to-interference-plus-noise ratio (SINR). Analytical expressions for the cumulative distribution function (CDF), the probability density function (PDF) and the Bit Error Rate (BER) have been derived for the adaptive antenna array employing BPSK signal and channel coding over a flat Rayleigh fading channel. These expressions are given in term of eigenvalues of the system based on an approximation of the characteristic function for the output SINR. We assume that the antenna branches are uncorrelated and that power gains for all the antenna branches are equal. Comparison with published results shows that the derived expressions are accurate even though they are based on an approximation for the characteristic function of the output SINR. The analytical results also show that by using forward error correction (FEC), substantial coding gains can be achieved and the system performance greatly enhanced. Furthermore, in a multipath environment, signals exhibit distinct fading statistics due to different propagation paths over which they travel and a RAKE receiver can be used to combine the useful information obtained from the resolvable multipath components and thus improve the overall signal-to-noise ratio. Analytical expressions for PDF and BER for an adaptive antenna array with RAKE receiver have also been derived.

**KEYWORDS:** Wireless, Performance Analysis, Rayleigh, RAKE Receiver, Convolutional Codes, Adaptive Antenna Arrays

### ON THE CAPACITY OF A CELLULAR CDMA SYSTEM REVERSE CHANNEL

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In this thesis, the reverse channel model for a seven-cell cluster DS-SS-SSMA cellular communications system operating in a slow-flat Nakagami fading and lognormal shadowing environment is developed. The aforementioned system uses imperfect power control to combat the near-far effect and the lognormal shadowing. Forward error correction is applied by using convolutional encoding and soft decision decoding. The probability of bit error is estimated by using a Gaussian approximation, sectoring antennas and a rake receiver at the base station in order to enhance the system's performance.

The performance of the system is examined under several values of the standard deviation of lognormal shadowing and the power control error for various numbers of users and values of the Nakagami-m variable by using simulations.

Finally, a barrage noise jammer will be introduced and its effect seen in the performance of the cellular communication system for a specific value of  $\frac{E_b}{N_0}$ .

**KEYWORDS:** Reverse Channel Cellular Communications

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## **ELECTRICAL ENGINEERING**

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### **TRIPLE MODULAR REDUNDANT (TMR) MICROPROCESSOR SYSTEM FOR FIELD PROGRAMMABLE GATE ARRAY (FPGA) IMPLEMENTATION**

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Major integrated circuit manufacturers including Intel and AMD have stopped producing radiation tolerant devices in favor of consumer electronics devices. The consequence is low availability and high cost for radiation tolerant microprocessors coincident with performance falling generations behind readily available non-tolerant microprocessors commonly referred to as Commercial-Off-the-Shelf (COTS) microprocessors.

Field Programmable Gate Arrays (FPGAs) are generic logic devices that can be programmed to mimic any conceivable logic network. FPGAs are readily available in both radiation tolerant and non-tolerant versions. The purpose of this thesis is to present a Triple Modular Redundant (TMR) microprocessor design as a System-on-a-Chip (SOC) for FPGA implementation with the goal of providing reliable microprocessor operation in radiation environments.

This research presents a cost sensitive alternative to improve microprocessor performance and reliability in radiation environments. Specifically, it presents the use of soft-core microprocessors in FPGA SOC implementation as a viable avenue to put COTS-like performance into space applications. Through the development presented, additional system reliability is incorporated through the use of a SOC design and through improvements to the basic voter circuit for TMR applications. System reliability is further improved through the development of a system level error vector to uniquely identify Single-Event-Upsets and indicate the presence of multiple errors. Finally, the system is "fit-tested" to validate the viability of a SOC microprocessor FPGA implementation using 32-bit RISC microprocessors.

**KEYWORDS:** Fault Tolerant Computing, Triple Modular Redundancy (TMR), Commercial-off-the-Shelf (COTS) Devices, Single Event Upsets (SEU), Field Programmable Gate Array (FPGA)

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

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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

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## ELECTRICAL ENGINEERING

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### **TIMING-BASED COMMUNICATIONS FOR PACKET NETWORKS**

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In a communications channel based on the timing of information, noise is introduced by any delay of the information as it is transmitted across a network. This thesis examines this noise by measuring the deviation of timing differences between packets as they are transmitted across local and wide area networks. Parameters affecting these timing differences are analyzed and techniques are studied which may improve the reliability of transmitting information embedded in these packet timing differences.

**KEYWORDS:** Steganography, Cryptography, Timing Channels

### **MASK LAYOUT OF AN ASIC FOR GENERATING FALSE TARGET RADAR IMAGES**

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The mask layout library that will be used to create the Digital Image Synthesizer (DIS) Application Specific Integrated Circuit (ASIC) is presented. The mask layout of a single range bin modulator and a group of 8 range bin modulators, together with the clock distribution network and power distribution network, are discussed and illustrated. Models used to simulate the power distribution network are presented. The capacitive and resistive effects of the metal layers used for interconnects and power distribution are investigated and the results of these studies are also presented.

As a result of this research, the DIS layout library has been completed and verified. The mask layout of the range bin was found to not have any problems with respect to power distribution.

**KEYWORDS:** Digital Image Synthesizer, DIS, Inverse Synthetic Aperture Radar, ISAR, Synthetic Aperture Radar, SAR, Countermeasure, ASIC, Chip Design, Mask Layout

### **A DCT-BASED IMAGE WATERMARKING ALGORITHM ROBUST TO CROPPING AND COMPRESSION**

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Digital watermarking is a highly evolving field, which involves the embedding of a certain kind of information under a digital object (image, video, audio) for the purpose of copyright protection. Both the image and the watermark are most frequently translated into a transform domain where the embedding takes place. The selection of both the transform domain and the particular algorithm that is used for the embedding of the watermark, depend heavily on the application. One of the most widely used transform domains for watermarking of still digital images is the Discrete Cosine Transform domain. The reason is that the Discrete Cosine Transform is a part of the JPEG standard, which in turn is widely used for storage of digital images. In this research a unique method for DCT-based image watermarking is proposed. In an effort to achieve robustness to cropping and JPEG compression an algorithm is developed for rating

the 8×8 blocks of the image DCT coefficients taking into account their embedding capacity and their spatial location within the image. The experiments show that the proposed scheme offers adequate transparency, and works exceptionally well against cropping while at the same time maintains sufficient robustness to JPEG compression.

**KEYWORDS:** Digital Image Watermarking, JPEG Compression, Discrete Cosine Transform

**MINIMIZATION OF SOFs FOR BI-DECOMPOSABLE FUNCTIONS AND  
NON-ORTHODOX/ORTHODOX FUNCTIONS**

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A logical function  $f$  is AND bi-decomposable if it can be written as  $f(X_1, X_2) = h_1(X_1)h_2(X_2)$ , where  $X_1$  and  $X_2$  are disjoint. Such functions are important because they can be efficiently implemented. Also many benchmark functions are AND bi-decomposable. Surprisingly, the minimal sum of products (MSOP) of  $f$  is not always obtainable by finding the MSOP of  $h_1$  and  $h_2$  and applying the law of distributivity. However, a special class of functions called orthodox functions, introduced by Sasao and Butler [1], do have this property. This thesis focuses on orthodox functions, and the remaining non-orthodox functions. It is shown how to build up non-orthodox functions from orthodox functions on fewer variables. An algorithm is presented for generating families of non-orthodox functions. A test program is developed to test the results of the proposed algorithm and also other programs are developed to conduct experiments with both orthodox and non-orthodox functions. Results are presented that represent the first steps toward completely characterizing bi-decomposable functions that can be efficiently implemented.

**KEYWORDS:** Bi-decomposable Functions, Orthodox Functions, Non-orthodox Functions, Disjoint Bi-decomposition, Minimum Sum-of-Products, Espresso

