MASTER OF SCIENCE
IN
SYSTEMS ENGINEERING

SIGNAL SYNTHESIS WITH DYNAMICALLY-CHANGED POWER SPECTRAL DENSITY IN A SOFTWARE DEFINED RADIO TRANSMITTER

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The objective of this thesis is to synthesize signals with a dynamically changing power spectral density, in a Software Defined Radio (SDR) transmitter, utilizing the most appropriate channels, modulation schemes, and transmission rates for communication, based on the noise profile (AWGN plus interferences) of the link, in order to achieve performance within some predefined acceptable levels. The objective is obtained by simulation.

KEYWORDS: Software Defined Radio, RF Section, IF Section, Baseband Section, Dual Quad Programmable Digital-Down-Converter, Dual Quad Programmable Digital-Up-Converter, Analog-to-Digital Converter, Digital-to Analog Converter, Controller, Data Buffer, Interpolation Filter, Decimation Filter, Shaping Filter, CIC Filter, FIR Filter, Root Raised Cosine FIR Filter, Filter Compute Engine, Channel Capacity, MPSK Modulation, Intersymbol Interference

PERFORMANCE EVALUATION OF THE AN/USQ-146 JAMMER OVER UNCODED SLOW FH/MFSK MILITARY COMMUNICATION SYSTEMS AND THE IEEE 802.11A WIRELESS LAN COMMERCIAL COMMUNICATION STANDARD

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On the modern battlefield communication is critical. Individual units require a steady flow of accurate information between headquarters and field units to remain effective. Just as important, denying the enemy the same needs of communicating with the help of electronic countermeasures (ECM), is essential to success. Communications jamming and surveillance are critical to achieve information superiority. This thesis evaluates the performance and capabilities of one of the most advanced devices that detects, analyzes, and denies enemy signals: the Rockwell Colins AN/USQ-146 transportable communication jammer. The jammer's best strategy varies with respect to the modulation technique that the hostile communication system uses. As the theoretical analysis and the simulation results indicated, the AN/USQ-146 jammer achieves its best performance over a FH/MFSK system when it selects the repeat multitone jamming strategy. However, when the hostile communication system is the IEEE 802.11a wireless local area network (WLAN) system, the AN/USQ-146 (Rubicon II) jammer must select the partial-band jamming strategy with $p = 0.1$. The results of the theoretical analysis and the simulation modeling of the specific jammer for all types of jamming in manual spot and repeat modes over FH/MFSK military communication systems and new advanced wireless standards, such as the IEEE 802.11a, can be used as guidelines to select the most effective jamming strategy for the specific type of hostile waveform encountered.

KEYWORDS: Battlefield Communication, Electronic Countermeasures, AN/USQ-146 Transportable Communication Jammer, Jamming Strategy

REFRACTIVE CONDITIONS OF AMAZON ENVIRONMENT AND ITS EFFECTS ON GROUND AND AIRBORNE RADAR AND ESM SYSTEMS

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This is a study of abnormal refractive layer occurrence over the Amazon region and possible effects on radar and ESM systems, ground or airborne based. Climatologic data from three stations in that region are analyzed using computations from the Global Tropospheric Experiment (GTE), soundings and satellite imagery. The GTE data provide monthly occurrences and seasonality of atmospheric ducts and superrefractive layers. Further, individual soundings from the March-June 2003 period and the Advanced Refractive Effects Prediction Systems (AREPS) 2.1 software are used in a case study that analyzed these layers and, in addition, subrefractive and multiple layers. Selected soundings were used in simulations to explain the effects of different types of abnormal layers on the electromagnetic propagation. Although ground systems were not affected by abnormal layers, airborne were. A region with low or no detection is created; even an abnormal layer refracts the electromagnetic energy upwards or downwards. Some combinations of multiple layers may cause even stronger effects. It is concluded that knowledge of the abnormal layers occurrence is important for operations in the Amazon region. Further, airborne radar platforms should measure local refractive conditions, if possible. A comprehensive study in time and space is recommended to provide forecasting.

KEYWORDS: Electronic Warfare, Electromagnetic Propagation, Amazon, Abnormal Refractive Layers, Refractive Conditions, Climatologic Data, AREPS, Radar, ESM, Atmospheric Ducts, Superrefraction, Subrefraction

DISTRIBUTED SUBARRAY ANTENNAS FOR MULTIFUNCTION PHASED-ARRAY RADAR

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As the target radar cross section (RCS) continuously decreases, the need for high-resolution high-gain radar increases. One approach to high resolution is to use distributed subarray antennas (DSAs), because of limited surface available on many radar platforms.

The concept of distributed subarray antennas is examined for both Multifunction Array Radar (MFAR) and Very High Frequency (VHF) applications. By combining distributed subarrays located on the available areas of a constrained platform, the MFAR and VHF DSA can achieve increased resolution and potential reductions in cost and complexity compared to a conventional array. The two-way pattern design of DSA effectively suppresses the undesired grating lobes by using separate transmit and receive antennas. By the pattern multiplication principle, the grating lobes in the subarray receive pattern have been suppressed by proper null placement of subarray in the receive and transmit antenna patterns.

KEYWORDS: Phased Array, Subarray, Multifunction Array Radar, MFAR, Two-way Gain

CLASSIFICATION AND ANALYSIS OF LOW PROBABILITY OF INTERCEPT RADAR SIGNALS USING IMAGE PROCESSING

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The characteristic of low probability of intercept (LPI) radar makes it difficult to intercept with conventional signal intelligence methods, so new interception methods need to be developed. This thesis initially describes a simulation of a polytime phase–coded LPI signal. The thesis then introduces a method for classification of LPI radar signals. The method utilizes a parallel tree structure with three separate "branches" to exploit the image representation formed by three separate detection methods. Each detection method output is pre–processed and features are extracted using image processing. After processing the images, they are each fed into three separate neural networks to be classified. The classification output of each neural network is then combined and fed into a fourth neural network performing the final classification. The outcome of testing shows only 53%, which might be the result of the image representation of the detection methods not being distinct enough, the pre–processing / feature extraction not being able to extract relevant information, or the neural networks not being properly trained. The thesis concludes with a brief discussion about a suitable method for image processing to extract significant parameters from a LPI signal.

KEYWORDS: Signal Processing, Image Processing, LPI, LPI Radar Signals, Classification

WIRELESS CONTENT REPURPOSING ARCHITECTURE FOR DC COMMAND AND CONTROL

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Damage control communications should be improved onboard U.S. Navy ships. Current standard operating procedures are antiquated and should be replaced. Wireless networks are an improvement over the status quo and mobile devices offer new capabilities that greatly improve the situational awareness for team members.

In this thesis, a system architecture is designed for a damage control wireless local area network with Commercial-Off-the-Shelf components. This makes the system affordable and prevents previous miscommunications from occurring.

The ability to view the information on different devices effectively is a unique problem to the mobile user and requires the use of content repurposing at the server.

KEYWORDS: Wireless Local Area Networks, Damage Control

INFORMATION OPERATIONS IN STRATEGIC, OPERATIONAL, AND TACTICAL LEVELS OF WAR: A BALANCED SYSTEMATIC APPROACH

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This thesis explores the idea whether a balanced systematic approach is a better way to integrate Information Operations (IO) at different levels of war compared to uncoordinated efforts at each level. Analysis of the role of information in a conflict in the context of information superiority provides the foundation of the thesis. DoD's IO core, supporting, and related capability based approach was used in the analysis of each level of warfare. Strategic, operational, and tactical level IO were analyzed by matching relevant IO capabilities with the IO effects desired at the respective levels. Sample systems were provided for each capability when appropriate. IO efforts in Operation Desert Storm and Operation Allied Force were analyzed. This thesis concluded that a balanced systematic approach to IO through its integration at all three levels of warfare will produce much better results than the uncoordinated cases in order to exploit the integrative effect of IO on the instruments of national power and the military capabilities at different levels of warfare.

KEYWORDS: Information Operations, Information Superiority, Levels of Warfare, Operation Desert Storm, Operation Allied Force

SMART TRANSPORT-A SURVEY OF TRACKING TECHNOLOGIES FOR CARGO CONTAINERS AND THEIR TRANSPORT PLATFORMS

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As the threat of terrorism rises, nations seek solutions to secure their ports and lanes of commerce upon the world's oceans and skies. The transport industry has taken the lead in developing new technologies to track cargo containers and the transport platforms, for billions of dollars are at stake. This thesis examines the present and future communication and tracking systems used by the transport industry. Furthermore, an investigation into the tracking methods for high-value items such as diamonds will be disclosed. By analyzing the communication and tracking systems used by the transport industry, elements of the Homeland Security organization can mitigate terrorism on the lanes of commerce and ultimately prevent weapons of mass destruction from entering the United States.

KEYWORDS: Cargo Container Tracking, Radio Frequency Identification, E-seals, Satellites, Diamonds

OPNET/STK INTEGRATED ENVIRONMENT FOR MODELING AN UAV NETWORK

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In this thesis, an OPNET/STK integrated model is used as an example to demonstrate the development of an UAV communication network. First, the concept of using an UAV as a mobile node in a network is addressed. Second, both OPNET and STK modeling tools are described in a separate chapter to describe each individual modeling characteristic. Third, an OPNET/STK integrated model is illustrated to show the

characteristics of a combined environment and to analyze the interoperability and performance of this combined model. Finally, some recommendations and conclusions are stated for further study.

KEYWORDS: OPNET, STK, C4I, HALE, UAV, Global Hawk, Wireless Communications, Network Centric Warfare, Network Centric Operation, Military Satellite Communication, Computer Models

RADAR ABSORBING MATERIAL DESIGN

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Low observable platforms have extremely low radar cross section specifications that cannot be achieved by shaping alone. The application of radar absorbing material is necessary, in which case the appropriate constitutive parameters and thickness must be selected. The universal design chart gives combinations of m, e and t that provide zero specular reflection at normal incidence. Three different backing materials were used to generate the charts: (1) perfect electric conductor, (2) free space, and (3) graphite. One can pick the required values from the charts for an ideal zero reflection dielectric/magnetic layer. The extension to other materials is straightforward. Numerical simulations of coated plates were performed to estimate the effectiveness of the absorbing layers in reducing radar cross section. The reduction in monostatic radar cross section value is shown by plotting the radar cross section of the plate with and without radar absorbing material.

KEYWORDS: Radar Cross Section Reduction Techniques, Radar Absorbing Materials, Matched Surface RAM, Universal Design Charts

SOFTWARE DEFINED RADIO DATALINK IMPLEMENTATION USING PC-TYPE COMPUTERS

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The objective of this thesis was to examine the feasibility of implementation and the performance of a Software Defined Radio datalink, using a common PC type host computer and a high level programming language. Dedicated transceivers were used, plugged on the PCI bus of host PCs running Windows 2000. Most of the functionality was programmed using the Microsoft Visual C++ language. The tasks to be performed included the channels configuration (number of active channels, center frequencies, sampling and data rates, choice of the appropriate up and down conversion filters), the management of the data transfer between the host computer and the transceiver, the baseband data modulation and demodulation, and the data organization into packets with appropriate headers in order to achieve phase and time synchronization solely by software. A part of the transceivers' configuration was achieved using a configuration utility running in Excel, provided by the manufacturer. Several combinations of M-PSK modulation schemes, channel numbers and datarates were tested in order to measure the performance limits of the system and its ability to perform the required tasks in real-time. The received data streams were further analyzed with the use of Matlab in order to verify the proper functionality of the communication scheme.

KEYWORDS: Software Defined Radio, Communications, Datalink, WaveRunner