MASTER OF SCIENCE
IN
SYSTEMS ENGINEERING

SPECIAL ABSTRACT MODELING AND SIMULATION OF A SEARCH RADAR RECEIVER

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Evaluation of radar performance using an actual radar is extremely costly. Such a process usually provides only samples of data under limited and difficult-to-control scenarios. In contrast, computer simulation using a validated model of the radar system provides flexible and cost-effective means of testing various aspects of the system. This research represents an initial attempt on this goal: construct function-by-function validated models of radar systems for performance assessment on the computer and produce simulation software which can accept environment data and threat scenarios and drive the radar models. Several desirable aspects of radar operations have not been included in this work. Among them the multiple PRF capability and range-Doppler ambiguity resolution; ECCM features such as carrier frequency agility and sidelobe cancellation; clutter map for enhanced zero velocity target detection are the ones to be considered for implementation in the immediate future.

INTERMODULATION IN CHANNELIZED DIGITAL ESM RECEIVER

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This thesis investigates intermodulation distortion generated by analog-to-digital converters (ADCs) in a channelized digital ESM receiver when processing multiple signals simultaneously. Spurious free dynamic range (SFDR) associated with this distortion is discussed. Two methods for increasing spurious free dynamic range are evaluated. First, by adding a small amount of Gaussian noise to the input of the receiver, the intermodulation distortion is found to be reduced significantly. Second, by using a narrow bandwidth sub-Nyquist sampling rate with high dynamic range ADCs it is possible to increase the spurious free dynamic range of the digital receiver. The first method is a simple approach but the ability to increase the SFDR is limited. The second method is more effective but requires greater computation and complex receiver design.

A SYNOPTIC PREDICTION OF EXTREME SUBREFRACTION

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Microwave communications and data links are a proven terrestrial technology around the globe. Their introduction to United States naval assets as part of the Cooperative Engagement Capability places them in an unfamiliar setting. The atmosphere over water imposes certain limitations upon electromagnetic transmissions that should be appreciated and understood by those employing these systems at sea. This thesis is a case study of the “Blizzard of ’96" snowstorm that hit the Mid-Atlantic United States on January 7, 1996, and its effects upon the Wallops Island, Virginia Microwave Test Range operated by The Johns Hopkins Applied Physics Laboratory. An analysis of microwave events (specifically sustained deep fades) on the basis of predictable synoptic weather systems is presented along with conclusions and recommendations for the operators of microwave communications systems by naval units.

ELECTRONIC ATTACK VULNERABILITIES OF AN ANALOG CELLULAR COMMUNICATION STANDARD
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Telecommunications is one of the fastest growing industries worldwide and cellular communications is one of the fastest growing sectors within telecommunications. Cellular mobile radio systems are now present in over 150 countries worldwide. These communications systems will be used to varying degrees in every future conflict in which the United States becomes involved. In many less affluent countries throughout the world cellular communications will become a defacto portion of those countries' civilian and military Command and Control (C2) infrastructure. Information Warfare (IW) planners must, therefore, determine vulnerabilities of cellular mobile radio systems that may be used by hostile forces. This thesis presents an examination, as well as experimental verification and modeling, of electronic attack techniques that could be used against an existing analog cellular communication standard.

COMINT ANALYSIS IN A LITTORAL ENVIRONMENT
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This study consists of a performance evaluation of ship-mounted COMINT systems collecting against VHF/UHF data/voice signals in a littoral environment. The detection range for each combination of collector and emitter was determined with the aid of the AFIWC software program "Passive Detection (PD)". The atmosphere propagation effects and phenomena such as trapping and ducting were taken into account using the NCCOSC software program "Engineer's Refractive Effects Prediction System (EREPS)". The performance of COMINT systems against representative RF receiver and transmitter systems, including cellular and SATCOM systems in the UHF band, was evaluated and summarized in a matrix, as the end product of this work. The unclassified study was limited to the capability of the modeling programs, including the availability of the environmental data concerning the area as well as the characteristics of the equipment evaluated. Geolocation was not included.

INTEGRATION OF INTELLIGENCE RESOURCES INTO THE AN/SRS-1 SIGNAL DETECTION AND DIRECTION FINDING SET,
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As the United States faces the next century of warfare in the information age, the importance of Signals Intelligence (SIGINT) will increase. For the United States Navy to maintain pace with the evolution of global technologies and its impact on intelligence operations, the afloat cryptologist must play a larger role in the detection and exploitation of potential Signals of Interest (SOI).

This thesis examines the AN/SRS-1 Combat Direction Finding System (Combat DF) and how intelligence assets can be coupled to efficiently meet future operational demands of the joint warfighter. In addition, direction is given for future improvements in the Special Intelligence communications networks. Although potentially unobtainable in the foreseeable future, these ideas are intended to explore possibilities regarding our information interchange methods and associated hardware.

Through a review of the signal analysis capabilities of Combat DF, this thesis highlights specific signal analysis improvements immediately available through the use of existing signal processing tools such as MARTES. Using a signal analysis example, the immediate beneficial impact of including a Signal Analysis Workstation (SAW) to complement Combat DF will be clear to the reader. As a minimum, the obvious benefit of additional signal analysis capabilities should be clearly visible.

COUNTERBATTERY DETECTION AND LOCATION FROM THE SEA USING THE AN/SPY-1 RADAR SYSTEM

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With a reawakening in littoral operations, there has been an increasing emphasis in revitalizing the U. S. Navy's Naval Surface Fire Support (NSFS) capability. This has primarily centered around improvements to weapon systems, but it must also include the other elements of a fire support system including target acquisition. One of the most successful systems in the ground battlefield environment, as evidenced by actions during Operation Desert Storm, has been the U. S. Army and Marine Corps Firefinder radars which can detect and locate firing positions of enemy indirect fire weapons so that enemy batteries can be quickly engaged. NSFS must substitute for the full spectrum of the ground fire support system until it can emplace ashore and then should augment it once it is ashore. Operations and contingencies of the last 15 years have demonstrated the need for a seamless capability of fire support, including target acquisition and especially counterbattery detection and location, across the complex sea-land interface. The AEGIS AN/SPY-1 radar, on cruisers and destroyers, has a similar phased array radar as the Firefinder system, which is the key to its success. This thesis looks at how the various models of this radar could be modified to perform the counterbattery mission with special emphasis on the problem of land clutter. The radar's integration into the entire amphibious force's fire support command and control network and the requirements for any future radar system are also addressed.

AN/SRS-1 (COMBAT DF) AND THE JOINT MARITIME COMMAND INFORMATION SYSTEM (JMCIS): A CASE FOR LINKING

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U.S. Navy's AN/SRS-1 (COMBAT DF) is being introduced into the fleet aboard the LHD-1 and DDG-5 1 classes of ships. This shipboard cryptological system provides the capability to conduct signals exploitation over a wide range of frequencies. This system represents a significant improvement in capability over the OUTBOARD system installed aboard DD-963 class ships. When first conceived, COMBAT DF was designed as a stand alone system with limited off-ship connectivity through which to transmit or receive tactical locating and targeting information on Signals of Interest (SOI). JMCIS is the latest effort of the U.S. Navy to produce an all encompassing Command, Control, Communications, Computers and Intelligence (C^4I) system with global connectivity. This paper attempts to present the problems with COMBAT DF connectivity and how by linking COMBAT DF with JMCIS, the ability of the warfighter

to conduct warfare will be enhanced. This is accomplished through the real-time transmission of tactical information via a computer-to-computer network.

MODELING AND EXPERIMENTAL TESTING FOR FUTURE DEVELOPMENT OF NIGHT VISION ELECTRO-OPTIC (NVEO) FLIR92 MODEL
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Recent advances in thermal imaging technology have resulted in the fielding of two-dimensional array detector based imaging systems. These designs have been labeled second-generation, and are rapidly replacing first generation systems having linear detector arrays with a parallel scan type architecture. It has been postulated that first generation prediction models are not applicable to second generation systems. In particular, the minimum resolvable temperature difference (MRTD) modeling needs refinement in the areas of sampling, quantization noise, and array non-uniformities in order for it to be applied to second generation systems. The present industry standard for MRTD is the Night Vision FLIR92 Model. Results from the FLIR92 Model and the two well known first generation models will be presented and compared with experimental measurements made on two thermal imaging systems available at the Naval Postgraduate School.

INTERCEPTING A COVERT NAVAL RADAR
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Radars with low probability of intercept (LPI) characteristics present a considerable threat to current electronic support measures (ESM) receivers. A radar with LPI characteristics could conceivably track a target without ever being detected. The Pilot class of marine radars has just such a claim. Developed in 1986, the Pilot class of covert radars are being sold on the world market by Celsiustech as the *Pilot Mk 2* and by Signaal as the *Scout.* The Pilot class of radar uses a frequency modulated continuous wave (FMCW) carrier and very low power to remain virtually undetectable while painting targets as far as 25 miles away. This thesis assesses the LPI threat and describes how the Pilot radar is rapidly emerging as a new class of LPI radars. It tests the Pilot's claim of "indetectability" by evaluating the Pilot waveform against the ALR-81(V)3, one of the U.S. Navy's most sensitive and versatile Electronic Intelligence (ELINT) receivers. Designed and built by Condor Systems, the ALR-8 l(V)3 scanning superheterodyne receiver is part of the electronic warfare (EW) suite aboard the ES-3A Sea Shadow reconnaissance plane. A test conducted in cooperation with Condor Systems demonstrated the performance of the actual ALR-8 1 (V)3 receiver hardware verses a simulated Pilot radar waveform.

ACTIVE PHASED ARRAY RADAR ANALYSIS
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A phased array antenna can electronically steer the direction of the antenna beam almost instantaneously. In an Active Phased Array Radar (APAR), this capability is used to allow the system to multiplex its time between many different

functions; the primary functions are search and target tracking. Potentially, the APAR can be designed based on the task it is performing, such that any savings in radar time in meeting the requirement of one task allow that time to be devoted beneficially to other tasks. The primary goal of this research is to investigate the performance assessment and improve the techniques for control of an Active Phased Array Radar performing the tracking function. In order to reliably and efficiently track targets, a MS. Excel 5.0 Spread Sheet program is implemented so that tracking range must be rapidly changed. With this program we can explore the many degrees of freedom that future APAR's will bring, such as adaptable update rate, antenna beamwidth, transmitted power, frequency, etc.

INTERPOLATION TECHNIQUES IN HIGH-RESOLUTION RESIDUE ANTENNA ARCHITECTURES

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A direction finding antenna based on residue number systems (RNSs) is presented. Special spacing requirements for the array elements are derived and processing of the array output for high speed direction of arrival (DOA) estimates is discussed.

The RNS antenna processor encodes the interferometer phase response, which is a sawtooth folding waveform. By design, the phase response of each element pair folds with folding period equal to the chosen modulus.

If DOA samples are generated by stepping the emitter direction between -90 and 90 degree in small increments, some samples will fall about the code transition points and result in encoding errors. The resulting DOA estimates from such a realizable system could contain large spikes or "glitches" at these points. These encoding errors in the resolved DOA can be reduced by interpolation. Three primary methods will be discussed to compare the capability of removing the glitches: LSB-Shift Method, Random-LSB Method, and Shift Last Good-Sample Method. A comparison of the performance of the three methods is made on the basis of simulation data.

A STUDY OF UHF FLTSATCOM VULNERABILITIES AND ITS APPLICATION TO CLASSIC CRYSTAL

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Determine the minimum satellite transponder uplink frequency separation for satellites having overlapping field-of-views for the world-wide UHF FLTSATCOM system (LEASAT/GAPFILLER/FLTSAT/UFO) for the current satellite orbit configuration/ transponder frequency plan. Examine the vulnerability of the SSIXS users given the current UHF satellite system configuration/frequency plan and see if a more intelligent choice of channel/frequency plan could reduce the vulnerability of SSIXS DAMA users.

TIMELY AND RELEVANT IW/C²W MODELING

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Today's environment is characterized by rapid technological change in communication systems and networks. These rapid changes make the task of developing timely and useful C²W and C²W support systems difficult at best. This thesis provides discussion on whether commercial-off-the-shelf programs, combined with government-off-the-shelf models, can create solutions to the IW/C²W challenge. We worked with a modeling and simulation program, GLEEM, developed by the AFIWC to analyze GPS links in an hostile jamming environment. Here, GLEEM is considered a starting point for a generic modeling program to be used for detailed analysis of C²W related network links. We chose GLEEM because it includes features not completely included in other projects, thus providing a greater capability to model real world IW scenarios and questions posed by commanders. Two means of providing insight on GLEEM are used. First, we use GLEEM to simulate a modern mobile communication link and the ability of a space-based receiver to detect the signal. Second, we use the information we've learned about GLEEM to discuss how it might be used to simulate current research at NPS. We conclude that programs like GLEEM are in their infancy but there is significant potential and development work should continue.

BISTATIC RADAR CROSS SECTION SYNTHESIS FOR RECTANGULAR RESISTIVE SHEETS

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A method of moments solution for the bistatic scattering from planar resistive sheets is presented. The matrix scattering equations are inverted to obtain a rigorous inverse solution that can be applied to the synthesis of radar cross section. Computer calculations for several sheets demonstrate that the synthesized resistivity is in good agreement with the original resistivity.

EFFECTIVENESS OF OFF-BOARD ACTIVE DECOYS AGAINST ANTI-SHIPPING MISSILES

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Radar guided anti-shipping missiles are the primary threat for most modern Navies. The inherent nature of the monopulse radar employed by most anti-shipping missiles makes it highly resistant to active ECM techniques. Decoys are attractive because they provide a source of radiation that can capture the radar seeker and direct the missile away from the ship. However the time and direction of launch are critical parameters which determine the operational success of the decoy.

This thesis evaluates the protection provided by active off-board decoys which are deployed by ships during an engagement against a radar guided anti-shipping missile. The research emphasizes launching active decoys. Many of the operational characteristics of the launching decoy are investigated, including direction of launch, timing of launch and the RF characteristics of the decoy.

A COMPARISON OF DDS AND DRFM TECHNIQUES IN THE GENERATION OF "SMART NOISE" JAMMING WAVEFORMS

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This thesis presents a comparison of the effectiveness of "smart noise" jamming waveforms against advanced threat radars, which are generated using either Direct Digital Synthesis (DDS) or Digital RF Memory (DRFM) based support jamming. The challenge lies in the fact the modern radar employs advanced waveforms, ultra-low sidelobe antennas, coherent sidelobe cancelers, and sidelobe blankers to inhibit signals entering through its sidelobes. This thesis compares the effectiveness of using DDS versus DRFM techniques to meet this challenge. In particular, the effect of mismatched frequency on the DDS jamming waveform is described, as is the effect of quantization and multi-signal storage in the DRFM. A quantitative comparison of these jamming techniques against the AN/TPS-70 surveillance radar is made.