MASTER OF SCIENCE
IN
ENGINEERING SCIENCE

COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF SHOCK PROPAGATION AND REFLECTION IN A PULSE DETONATION ENGINE COMBUSTOR

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The ability to enhance detonation wave transmission at a diffraction plane through various shock reflection/focusing conditions was evaluated numerically. The geometry dimensions were generally representative of the condition existing in a valve-less pulse detonation engine developed by the Naval Postgraduate School, and consisted of a small cylindrical "initiator" combustor, which transmitted a shock wave to a larger diameter combustor. The wall cross section of the larger combustor was varied to evaluate the increase in reflected shock temperature and pressure conditions, ultimately revealing the dramatic increase in local temperature for a "scalloped" outer wall condition over the cylindrical cross section cases. The initiator diameter was held constant and the larger combustor diameters varied in order to evaluate the effects of diameter ratio on the shock reflection conditions for both cylindrical and scalloped geometries. A computational fluid dynamics (CFD) solver known as OVERFLOW was used to model the fluid dynamic processes, but was limited in capability to shock wave Mach numbers less than about 4.2.

KEYWORDS: Pulse Detonation Engine, PDE, Combustion, Detonation, Computational Fluid Dynamic, CDF, Overflow, Shock Reflection, Shock Focusing

NUMERICAL ANALYSIS OF THE PERFORMANCE OF STAGGERED PIN-FIN MICRO HEAT EXCHANGERS

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The heat transfer and pressure drop characteristics of a staggered micro pin-fin heat exchanger were analyzed using a three dimensional finite element based numerical model. Simulations were conducted based on low Reynolds number, fully developed laminar airflow through an array of circular pin-fins. A range of results was obtained from different configurations with varying pin spacing, axial pitch, and pin height. The results from this study would be useful in ongoing work on the design of a laminar flow micro heat exchanger for high heat flux dissipation systems.

KEYWORDS: Numerical Analysis Heat Transfer, Micro Pin-Fin Heat Exchanger, Turbine Blade Cooling, Electronic Component Cooling

NUMERICAL STUDY OF THE EFFECT OF THE FUEL FILM ON HEAT TRANSFER IN A ROCKET ENGINE COMBUSTION CHAMBER

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The combustion chamber of a liquid-fueled rocket engine with an injected fuel film on the wall has been numerically simulated. The engine has been modeled to operate on a RP-1/gaseous oxygen mixture at a chamber pressure of 35 atmospheres. The fuel is a hydrocarbon blend and is used for both engine operation and the fuel-film layer. The fuel layer acts as a flowing thermal insulating shield, reducing the amount of convective and radiative heat flux from the hot combustion gases to the chamber wall. This effort evaluates the effectiveness of the fuel layer in achieving a reduced heat flux to the chamber wall under varying emission/absorption conditions. The tendency of hydrocarbon fuels to produce soot precipitates at near 550K directly affects the optical properties of the fuel layer, and the resulting heat transfer to the wall has been modeled and discussed.

KEYWORDS: Heat Transfer, Rocket Engine, Combustion Chamber, Film Cooling, RP-1, Absorption Coefficient, RADCAL, TEP, CFDACE

COLD FLOW DRAG MEASUREMENT AND NUMERICAL PERFORMANCE PREDICTION OF A MINIATURE RAMJET AT MACH 4

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Experimentation was carried out in a supersonic wind tunnel to investigate the drag force on a miniature ramjet when subjected to Mach 4 flow. CFDRC-FASTRAN, a numerical flow solver developed for the analysis of high-speed flows, was used to model the performance of the miniature ramjet. To reduce computational time, a 2D axisymmetric model of the ramjet was developed to investigate the shock angles over the intake and the results were compared with the experiment. A 3D axisymmetric flow model was developed to investigate the fuel mixing which was injected into the ramjet from the nose cone and from the struts, which held the centerbody in place. Finally, a 2D model was developed to investigate the combustion of the propane fuel, which was injected from the struts. For all of the simulations, a two-equation, $k-\omega$, turbulence model was used. Further investigation is needed at supersonic freestream conditions in the simulation of the combustion process.

KEYWORDS: Ramjet, Drag Measurement, Mach 4, Turbulence Modeling, Simulation

BROADBAND COUNTERWOUND SPIRAL ANTENNA FOR SUBSURFACE RADAR APPLICATIONS

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Subsurface radar, also known as ground penetrating radar, is increasingly being used to detect and locate buried objects such as mines and structures that are found within the upper regions of the earth's surface. This thesis reviews the work done to date in this area, laying emphasis on possible antenna designs to match the range of intended applications. An overall design strategy is outlined, together with a more detailed treatment of the ground penetrating radar subsystems and topics that are relevant to effective

subsurface radar operation. These include the dielectric properties of earth materials, the choice of frequency of operation, as well as the design and construction of suitable antennas.

Finally, a new antenna structure called the counter-wound spiral antenna, which is suitable for subsurface radar applications, is examined. The counter-wound spiral antenna has a broad bandwidth and a linear polarization with a controllable plane of polarization from a planar geometry. It has an electronically steerable plane of polarization. This unique property offers a reduction in antenna polarization loss and allows the extraction of maximum information from the target scattered echo.

KEYWORDS: Subsurface Radar, Ground Penetrating Radar System, Frequency Independence Antenna, Spiral Antennas, Ground Dielectric Properties

VULNERABILITY OF WIRELESS POINT-TO-POINT SYSTEMS TO INTERCEPTION

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Wireless systems have always been susceptible to interception in both urban and indoor environments. In point-to-point communication links, the placement of base station antennas is usually determined by an experimental or analytical assessment of the propagation path. Since point-to-point links are typically used to network widely separated areas, antennas used in such situations are likely to be directional, but may still be susceptible to interception by covert entities.

In this thesis research, issues pertaining to vulnerability will be identified and preventive measures will be suggested. The generation of received signal contours as a function of location and frequency for different propagation models will also be investigated. This thesis thus examines the vulnerabilities of wireless point-to-point communication to interception by propagation simulations using computational electromagnetic codes available in the Naval Postgraduate ECE Department's Microwave and Antenna Laboratory. The software developed was used to examine the vulnerability of these wireless systems and identify simple measures that can be taken to increase the system's security.

KEYWORDS: Wireless Point-to-Point Systems, Urbana Wireless Toolset, Cifer, Xcell, Signal Contours, Antenna Rotation, Wireless Vulnerability, Interception

MODELING OF THE RING-HYBRID DIPOLE ANTENNA AND MUTUAL COUPLING IN A SMALL ANTENNA ARRAY

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This thesis project modeled a microstrip ring-hybrid dipole that is capable of simultaneously producing a sum pattern and difference pattern using the method of moments (MoM) based on the Rao-Wilton-Glisson (RWG) edge elements. The ring-hybrid dipole is simply a ring-hybrid coupler driving a dipole antenna. A two-feed point dipole model was developed and its antenna parameters were found to be a good representation of the ring-hybrid dipole actual values. In the feed network modeling, the matrix solution combined the MoM equations on the antenna surfaces and a magic-tee scattering matrix by applying Kirchhoff's voltage and current laws at the terminals of the antenna. Once the excitation is specified, the complete system of equations was solved to yield the MoM current expansion coefficients and the signals in the feed network.

The effect of mutual coupling in an array of three ring-hybrid dipoles was examined by extending the model. In the receive mode, the direction and polarization of the incidence plane wave were varied. The phases for both the sum port and difference port outputs were observed to change smoothly, except during

situations of cross-polarization and zero phase difference. The array model will form the foundation for the design and analysis of a mutual coupling compensation network.

KEYWORDS: Method of Moments, RWG Basis Function, Scattering and Radiation, MATLAB, Dipole Antenna, Antenna Feed Network, Scattering Parameters, Transmission Line, Magic-Tee, Ring Hybrid, Phased Array Antenna, Mutual Coupling

DIGITAL ANTENNA ARCHITECTURES USING COMMERCIAL-OFF-THE-SHELF HARDWARE

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Changes in warfighting tactics and advancement of technology shape ways to implement and design multifunction phased array radars. This thesis investigated whether the commercial modulation boards used in the 3-D 2.4-GHz phased array transmit antenna are capable of wideband performance. The phase of the transmitted signal out of the modulator board was adjusted to provide a phase shift from 0 to 2π, and the insertion phases at these phase settings were measured using a Vector Network Analyzer, sweeping the frequency from 0.8 to 2.5 GHz. The measured insertion phases are used to simulate the radiation pattern of a linear phased array, and the results show that modulator does not have instantaneous wideband characteristics.

This thesis also looked at the design of the complementary phased array receiver architecture using commercially available demodulator boards. The demodulator board was successfully configured to operate as a phase shifter. Phase shifted transmit signals were injected into the demodulator, and corresponding phase shifts were measured via the *In-Phase* and *Quadrature* voltages.

KEYWORDS: Phased Array, Array Bandwidth, Beamforming, Radar, Antenna, Transmitter, Receiver, Direction Finding, Modulation, Demodulation, COTS

BISTATIC RADAR SYSTEM ANALYSIS AND SOFTWARE DEVELOPMENT

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Bistatic radar has some properties that are distinctly different from monostatic radar. Recently, bistatic radar has received attention for its potential to detect stealth targets due to enhanced target forward scatter. Furthermore, the feasibility of hitchhiker radar has been demonstrated, which allows passive radar receivers to detect and track targets. This thesis developed a software simulation package in MATLAB that provides a convenient tool to examine the bistatic radar design parameters and predict system performance. The software model is suitable for instructional purposes due to its user-friendly graphical user interface. Several bistatic radar applications were used to illustrate the software features, and their results were analyzed and discussed.

KEYWORDS: Bistatic Radar, Multistatic Radar, Oval of Cassini, Performance Prediction, Computer Simulation, Graphical User Interface