ELECTRICAL ENGINEER

A METHOD OF INCREASING THE KINEMATIC BOUNDARY OF AIR-TO-AIR MISSILES USING AN OPTIMAL CONTROL APPROACH

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Current missile guidance laws are generally based on one of several forms of proportional navigation (PN). While PN laws are robust, analytically tractable, and computationally simple, they are only optimal in a narrow operating regime. Consequently, they may not optimize engagement range, time to intercept, or endgame kinetic energy. The advent of miniaturized high-speed computers has made it possible to compute optimal trajectories for missiles using command mid-course guidance as well as autonomous onboard guidance. This thesis employs a simplified six degree of freedom (6DOF) flight model and a full aerodynamic 6DOF flight model to analyze the performance of both PN and optimal guidance laws in a realistic simulation environment which accounts for the effects of drag and control system time constants on the missile's performance. Analysis of the missile's kinematic boundary is used as the basis of comparison. This analysis is immediately recognizable to the warfighter as an engagement envelope. The guidance laws are tested against non-maneuvering and maneuvering aircraft targets and against a simulation of a cruise missile threat. An application of the 6DOF model for a theater ballistic missile interceptor is presented.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Missile Guidance Laws, Proportional Navigation, Optimal Control, Kinematic Boundary

AN EXTENDED KALMAN FILTER FOR QUATERNION-BASED ATTITUDE ESTIMATION

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This thesis develops an extended Kalman filter for real-time estimation of rigid body motion attitude. The filter represents rotations using quaternions rather than Euler angles, which eliminates the long-standing problem of singularities associated with those angles. The process model converts angular rates into quaternion rates, which are in turn integrated to obtain quaternions. Gauss-Newton iteration is utilized to find the quaternion that best relates the values of linear accelerations and earth magnetic field in the body coordinate frame and the earth coordinate frame. The quaternion obtained from the optimization algorithm is used as part of the observations for the Kalman filter. As a result, measurement equations become linear. The computational requirements related to the extended Kalman filter developed using this approach are significantly reduced, making it possible to estimate attitude in real-time. Extensive static and dynamic simulation of the filter using Matlab proved it to be robust. Test cases included the presence of large initial errors as well as high noise levels. In all cases the filter was able to converge and accurately track attitude.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Sensors, Modeling and Simulation

KEYWORDS: Inertial Navigation, Extended Kalman Filter, Quaternion

DESIGN OF AN ULTRA-WIDEBAND DIRECTIONAL ANTENNA FOR A GIVEN SET OF DIMENSION CONSTRAINTS

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This research encompasses the preliminary and detailed design phases of a directional high-power UHF antenna that fits within a restrictive cylinder. The antenna design was limited to a free-space situation.

In the preliminary design phase, various antenna configurations were evaluated through simulation using the Numerical Electromagnetics Code (GNEC) to determine the optimum design. The optimization process was divided into consecutive steps. The best antenna from one step was further developed in the next step, and so on, until the final preliminary design, the RATTLE-1 antenna, was obtained. The Antenna Comparison Technique (ACT), a procedure that compares normalized grades evaluated for each antenna, was used to choose the optimum antenna configuration.

The detailed design phase concentrated on solving the impedance matching problem between the antenna and the transmission line. The final solution entailed the use of a tapered coaxial line balun. The performance of the RATTLE-1 integrated balun was evaluated through simulations using the High-Frequency Structure Simulator (HFSS) and prototype measurements.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Antenna Simulation, Antenna Optimization, Conical Spiral Antenna, Broadband UHF Antennas, Tapered Coaxial Line Balun