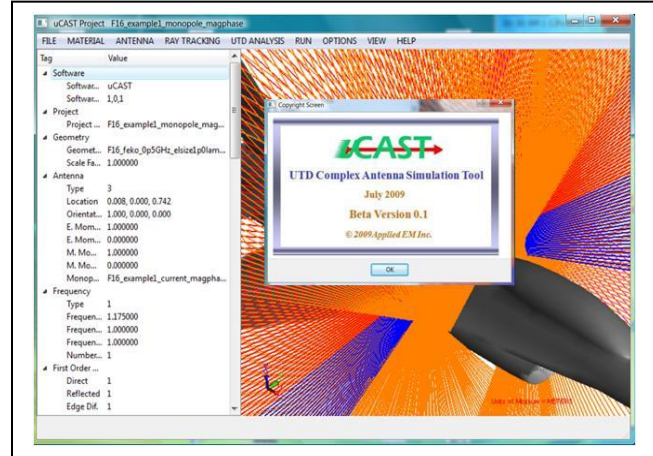


Advanced Antenna Pattern and Mutual Coupling Prediction Software -

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PROBLEM STATEMENT

With the ongoing explosive growth in civilian and military communications, new antenna designs are required for increasingly more complex environments in general and on airborne platforms (fighter planes, UAVs, passenger jets, etc.) in particular. Thus, antenna design and placement on aircraft bodies is becoming a critical issue. Moreover, the antenna device must now be designed to account for its innate operational environment. Failure to meet the system requirements can result in degradation of the overall system performance and hence compromise mission goals. The integration of complex multifunction antennas under a single platform also introduces serious coupling and performance concerns. For the latter case, the single aperture implies possible loss of coverage and thus proper installation in the presence of platform interactions is crucial to the design. Of particular importance is the fact that current and future aircraft platforms will contain multilayer dielectric/magnetic coated surfaces and treatments to control their radar cross section (RCS), and to increase the isolation between neighboring antennas on the same platform. Therefore, any future code for airborne antenna pattern and coupling prediction needs to be able to deal with electrically large and realistic airborne platform shapes, and to include effects of absorber material coating.

The main objective of this project is to develop an electromagnetic (EM) computational tool that can be used to predict RF sensor performance in electrically large, complex environments resulting in the ability to accurately design and place the system. The capability to compute the influence of one antenna on others is a must while the ability to compute near-field quantities is desirable.

WHO CAN BENEFIT?

Presently, typical military vehicles (such as the U.S. Army Blackhawk helicopter, C-150, F-15 aircraft) can have more than 22 antenna elements for VHF/UHF, Global Positioning System (GPS), Personal Communication Services (PCS), Commercial Satellite Broadcast Radio and Industrial-Scientific-Medical (ISM) communications. For commercial applications, there is a need to design antennas for various large and small-scale platforms essential in cellular telephony, as sensors for inventory and anti-collision avoidance, for intelligent vehicle highway systems, etc. As can be realized, the multitude of these antennas and the fast design cycle makes the development of math-based tools for EM systems a necessity. Given that use of antennas and sensors is expected to continue to grow, the need for math-based tools will also continue to grow. Therefore, the proposed tool is expected to play a major role in the design and improvement of antennas for a multitude of military and commercial communication systems. Use of such math-based tools will substantially shorten the design cycle and can lead to many dB in improved performance for antenna systems and circuit matching networks.

Potential users for the developed software will include airframe manufacturers such as Boeing, Northrop Grumman, Lockheed Martin etc, and automobile manufacturers such as General Motors, Ford, Chrysler etc and surface ship top-side design houses. Apart from these anyone involved with communications, Electronic Warfare (EW) system design will need a tool like UCAST being developed under this project.

BASELINE TECHNOLOGY

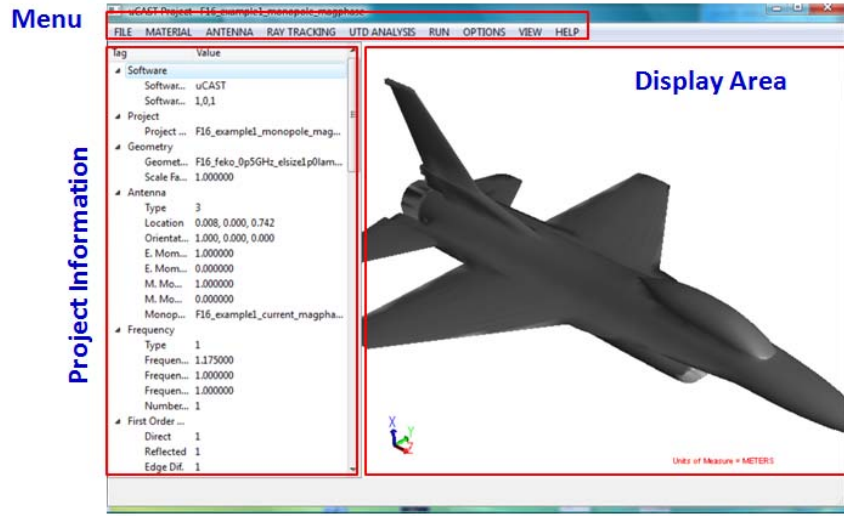
The challenges outlined above cannot be addressed with traditional electromagnetic (EM) simulation methods including the most recently developed fast numerical methods and various finite approximation techniques, especially at X-band frequencies and above. Numerical methods have proved to be very successful in low and mid frequency (VHF/UHF) regimes. Although these methods are based on rigorous integral or partial differential equation formulations, they cannot presently solve electrically large problems of EM radiation pattern and coupling prediction associated with antennas on aircraft at higher frequencies (S/X/Ku/Ka bands).

The difficulty with conventional numerical methods stems from the fact that the number of unknowns to be solved via these methods increases rapidly with frequency, so they do not scale with frequency. Furthermore, some asymptotic high frequency (HF) methods, whose accuracy increases with frequency, such as the physical optics (PO) method and its modifications based on the physical theory of diffraction (PTD), require an integration of the surface currents over the lit portion of the platform, so they also do not scale with frequency. More importantly, the PO/PTD is highly inadequate in the shadow region around all smooth parts of complex airborne antenna platforms where it predicts incorrect field values. PO/PTD is also not valid at edges shadowed by curved surfaces in which they occur. On the other hand, the uniform geometrical theory of diffraction (UTD), which is a ray based asymptotic HF method (being implemented in UCAST) is versatile and provides a physical picture for the antenna radiation mechanisms and its interactions

with the complex platform. There are readily available codes such as the NEWAIR and the NEC-BSC codes, respectively from Ohio State University (OSU) that employ the UTD to model large structures in the presence of simple transmitting or receiving antennas such as electric and magnetic dipoles or small slots and are widely used by the airframe manufacturers. *However, simulation of the platform in NEWAIR and NEC-BSC codes is accomplished using a combination of perfectly conducting multiple canonical shapes such as flat plates, finite elliptic cylinders, composite cone frustums, finite composite ellipsoid, and thin wires.* This choice of simpler canonical bodies is employed in these UTD codes so that ray-tracing can be accomplished more conveniently. Furthermore, diffraction effects in radiation problems are primarily governed by shadowing phenomena so that wings and stabilizers can be adequately modeled by flat plates, etc. It is noted that the UTD rays obey the generalized Fermat's principle. Although HF codes such as XPATCH of SAIC and CADSCAT of Boeing overcome the geometry restrictions inherent in the simpler canonical shape based modeling by using CAD files, those codes are primarily based on PO implementations. Thus, they become more expensive as the operating frequency increases. Moreover, they are still limited in material treatments and accuracy, since they do not typically include the proper diffraction terms and shadow contributions, especially for antenna problems.

TECHNOLOGY DESCRIPTION

Existing UTD tools are based on a simple model in terms of canonical perfectly electric conducting (PEC) shapes such as elliptic cylinders, flat plates, cone frustums and spheroids rather than a CAD model of an arbitrarily shaped geometry. They also have only limited capabilities to analyze radiation pattern of antennas mounted on surfaces with material treatments. The new generation EM simulation tool based on UTD, UCAST being developed under this project will be able to deal with electrically large and realistic CAD models of airborne platforms and to include effects of material treatments. The major objective of this project is to develop a UTD-based computational tool applicable to arbitrarily shaped faceted geometries with or without multilayer coatings. A ray tracking algorithm is implemented in UCAST to launch and track the ray paths associated with the radiation and coupling of airborne antennas. The tool will apply the relevant UTD mechanisms along the paths identified by the ray tracking algorithm. An associated Graphical User Interface (GUI) is being developed to provide the capability to import aircraft CAD models in various formats. It will also offer pre-processing capabilities such as the evaluation of the suitability of an imported CAD model for the application of available UTD mechanisms and placement of various types of antennas in the presence of the aircraft platform.



UCAST Graphical Interface

Table 1. Features, Advantages and Benefits

Features	Advantages	Benefits
UTD based code	Frequency independent	Analysis of electrically large structures (1000s of wavelength) is possible
Use of CAD Geometries	No need to approximate the geometry with canonical shapes	Accurate solutions
Pattern Prediction on the platform	Can account for the effects of the platform on antenna radiation pattern	Very critical for design of systems on platforms
Mutual coupling predictions	Can account for effects of the platform on coupling between various antennas	Essential for systems design on platforms
Graphical User Interface	Allows for ease of use	Quick learning curve for the user.
Interface with commercial EM simulations tools	Ease of use with existing capabilities of commercial tools for pre and post processing.	Faster integration in to the production process.

CURRENT STATE OF DEVELOPMENT

Implementation of most of ray tracking algorithms has been completed along with UTD algorithms for conducting bodies. Preliminary Graphical interface is completed and will be ready for beta testing soon. Interface with a leading commercial EM tool is in progress. At the end of this project, UCAST will be at a TRL level of 4.

Milestone	Date	TRL Level
Beta Testing of UCAST	Dec 2010	5
Validation of UCAST with Aircraft Measured Data	June 2011	7
Qualification Tests by PMA	Dec 2011	8

Support from primes and the acquisition community is desired to bring the project to completion.

REFERENCES

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ABOUT THE COMPANY



Applied EM is a research and development company specializing in antenna design and development. Applied EM located in Hampton, Virginia, was founded in 2000 as a client of Hampton Roads Technology Incubator (<http://www.hr-incubator.org/>). Applied EM recently graduated from the Incubator. Applied EM's customers include NAVSEA,



NAVAIR, Army Research Lab, Army Aviation and Missile Command, Hanscom AFB, Warner Robins AFB, National Security Agency, NASA etc. Applied EM has collaborations with ATK Systems, Lockheed Martin, L-3 Communications and other DoD contractors. Our University partners include the Ohio State University, University of Colorado, University of Delaware and Virginia Tech. Applied EM is currently focusing its efforts to commercialize various innovative antenna technologies developed under DoD SBIR program.

Dr. C. J. Reddy, President of Applied EM has 20 years of experience in the area of antennas and computational electromagnetics. He worked at NASA Langley Research Center for 8 years where various FEM codes for electromagnetics. He also worked on design and simulation of antennas for automobiles and aircraft structures. Dr Reddy's development of hybrid Finite Element Method/Method of Moments/Geometrical Theory of Diffraction code for cavity backed aperture antenna analysis received a Certificate of Recognition from NASA. At Applied EM, Dr. Reddy successfully led many Small Business Innovative Research (SBIR) projects from the US Department of Defense (DoD). Dr. Reddy also serves as the President of EM Software & Systems (USA) Inc. At EMSS (USA), he is leading the marketing and support of commercial 3D electromagnetic software, FEKO in the US, Canada, Mexico and Central America.

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