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Computational Electromagnetics and Integration of Research in the Classroom

This issue's column focuses on teaching computational electromagnetics, one of the classical courses in many university EM programs.

The IEEE Antennas and Propagation Society Education Web site contains many links to computational EM classes: http://www.ece.utah.edu/~cfurse/APS/. Here, you can find several complete courses, with lecture notes, projects and assignments, software, etc., covering topics such as FDTD, Method of Moments, Finite Elements, Physical Optics and Ray Tracing, etc. If you have a course with online notes that you would like to add to this list, please e-mail it to cfurse@ece.utah.edu.

Two tutorials in this issue's column describe Physical Optics and ray-tracing software and give links available for education. Both of these tutorials have arisen from the authors' research interests, and have been integrated directly into the classroom. The software is available online, and can be found through the EM software sharing page that can also be found from the above Web site.

Computational EM lends itself to easy integration of research in a teaching environment, and many example projects found in the computational EM Web page do just that. Some examples of ways this can be done are as follows:

Use Interesting Research Results as a Motivational Tool

Allen Taflove has provided a collection of color results obtained from FDTD, covering a wide array of applications that is almost certain to tickle the interest of nearly every student in an introductory EM course, or in a computational EM course.

Choose Class Examples and Problems that can be Related to Research

Collect "Show and Tell" pictures, pieces of hardware, or interesting stories about EM research. Show how these concepts can be related to what students are learning in class. And don't forget to tell about the research experience, itself. When I explain to my students that "My projects are *never* working. When they finally work, we are on to the next part of the project, and it isn't working," they seem to feel very comforted that their experience is not all that different from mine. How many months does it take to debug an EM code? Sometimes, many!

Use Your Research Project as the Lab

Most professors are really excited about their research, and it shows. Students need to see and feel this excitement in order to (hopefully!) catch the research bug. Modify your research project and use it as a lab project for the class. This may require sizeable abbreviation, simplification, and modification for general class use, but be sure not to make it so simple that the research experience is entirely removed. You will hear more about my own experiment with this in future *Magazine* sections. At the University of Utah, we have integrated the first "Signal Processing" class with the first EM class. In the labs, they build and test a rudimentary telemetry system for a cardiac pacemaker that originated from antenna work from my lab, and transceiver design from the lab of a colleague (www.ece.utah.edu/~ece3300; click Labs).

Use Class Assignments to Gather Preliminary Data for Publication

Never underestimate the power of several freshly-trained students (undergrad or grad) who are allowed to contribute directly to research results! In my last teaching experience with computational EM, I asked the students to solve two problems that have been incorporated directly into submitted technical publications. Computational EM lends itself to this particularly nicely. Since much of my research is in the location of faults on aircraft wiring, we used the FDFD method to determine the impedance of very small faults on wires, and demonstrated that location of these small faults is next to impossible (a significant conclusion, since much time and effort is spent trying to locate them). The students were clearly more interested in this effort, and were more diligent about checking their own results, knowing that they were headed for potential publication, than they ever were with essentially the same assignment unrelated to any research results.

Talk to Students About Research Opportunities

Most students don't even consider graduate school until someone mentions the option to them. Personal attention is great, but it is not always possible. Discussion with a class or other large group is good for getting students who are potentially interested to seek out advice to make the choice to attend graduate school.

Involve Students in Research Opportunities as Early as Feasible

Students like to get directly involved in a good project. When is too early? The results may surprise you. Many high school students can contribute in very meaningful ways to a research group (I have worked with three in the past year, one of which won accolades at the national science fair, another with which we are preparing a technical publication, and a third that received the highest honors at entrance the university has to offer.) Undergraduate research almost always inevitably leads to graduate research. It is not uncommon for professors to have their graduate students effectively supervise the undergraduate students, and, done well (with enough professorial mentoring), this can be a very positive experience for both.

A *MATLAB* Physical-Optics RCS Prediction Code

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Abstract

POFACETS is an implementation of the Physical Optics approximation for predicting the radar cross section (RCS) of complex objects [1]. It utilizes the scientific computational features of *MATLAB* and its graphical-user-interface (GUI) functions to provide an error-free encoding of input parameters and efficient calculation of RCS. *POFACETS*,provides a convenient tool for a "first cut" at the RCS of complex shapes by representing its constituent parts by triangular facets.

The software calculates the monostatic or bistatic RCS of the object for the parameters specified by the user, and displays plots for the model's geometry and its RCS. The latest version (*POFACETS 3.0*) features new options and tools for complex target design, and provides new computational capabilities, including the approximate effects of the ground, the exploitation of symmetry planes in targets, and the effects of materials and coatings [2]. The software is ideal for use by students on projects and for instruction. It has been used in the past by students in the Naval Postgraduate School's Aeronautical Engineering Department and Total Ship Systems Engineering Program to compute the RCS of their platform entries for student design competitions.

Keywords: Radar cross section; radar scattering; physical optics; complex objects

1. Introduction

The Physical Optics (PO) approximation is one of the most convenient RCS prediction methods for an arbitrary three-dimensional target [3]. The Geometrical Optics current is used over the illuminated portions of the target surface, while zero current is assumed over the shadowed portions. The current is then used in the radiation integrals to compute the scattered field far from the target. Physical Optics is a high-frequency approximation method that gives best results for electrically large bodies, and is most accurate in the specular directions.

One approach to high-frequency scattering calculations is to approximate a complex model with an array of simple shapes, such as triangular flat plates. The RCS is obtained by computing the scattered field of the collection of these simple shapes to obtain the total RCS of the target. *POFACETS* computes the scattering from each triangle as if it is isolated in free space. Multiple reflections, diffraction, and surface waves are not included. There is a limited capability to include shadowing, which involves defining which side of a particular triangle is internal to a closed body and, hence, not allowed to be illuminated.

A summary of the software capabilities follows:

- *MATLAB* graphical user interface (GUI)
- Library of common geometrical shapes readily available
- Manual model design capability (the model triangle nodes are entered manually)
- Graphical model design capability (the model is generated from basic geometrical components from the library)
- Scaling, rotation, and translation of a model or its subparts
- Merging of several multiple models
- Model import capability from *AUTOCAD* (stereolithographic format), *ACADS* (Lockheed-Martin) and *CIFER* (SAIC/Demaco)

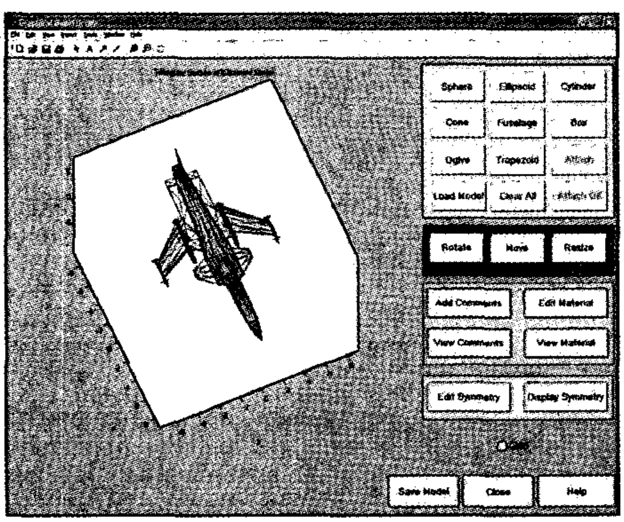

Figure 1. A model of an armed X-29.

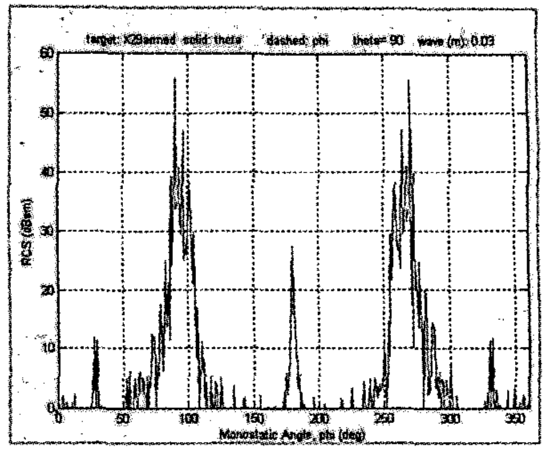

Figure 2a. RCS display options: a linear plot.

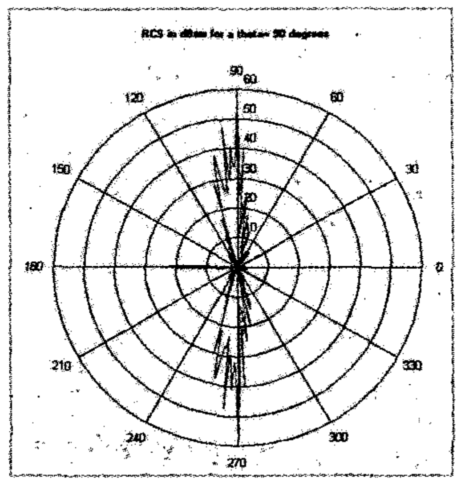

Figure 2b. RCS display options: a polar plot.

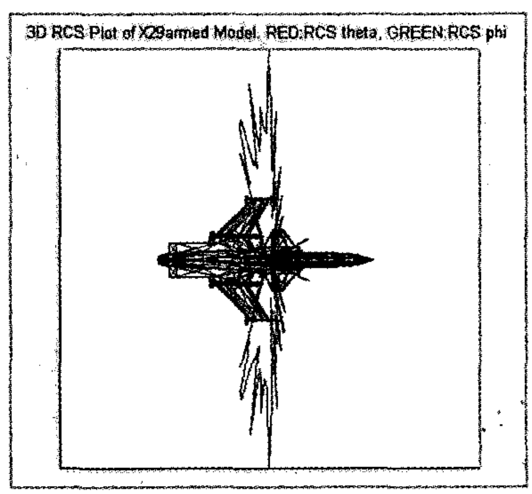

Figure 2c. RCS display options: a combination of an RCS plot and the model geometry.

- Bistatic or monostatic RCS calculation versus angle or frequency
- One-dimensional RCS cuts or surface contours in direction-cosine space
- Polar plots and RCS plots superimposed on model geometry
- θ (TM_z) or ϕ (TE_z) incident polarizations
- Co- and cross-polarized RCS components are computed
- Approximate diffuse RCS component can be computed for rough surfaces
- Approximate effects of an infinite ground can be included
- A user-updateable library of materials is included
- Material layers can be applied
- Symmetry planes in a model can be defined and exploited to reduce run-time
- Open code architecture allows the user to tailor the code to specific needs
- Help functions and error checking are included for all windows
- Several sample model files are included

2. The *POFACETS* Graphical User Interface

Figure 1 shows a complex model that was derived by combining six different models: a model of the X-29 aircraft (imported from *CIFER*), two copies of an AIM-9 Sidewinder missile, and two models of a AGM-84 Harpoon missile. The model's surface material is defined as a perfect electric conductor. Figure 2 depicts the various monostatic RCS display options for a model. The RCS was calculated for a $\theta = 90°$ cut, TM-polarized incident wave at a frequency of 10 GHz.

3. Availability

POFACETS 3.0 is available free of charge, and can be downloaded from the author's Web site at http://www.nps.navy.mil/faculty/jenn. Although the software runs under *MATLAB* version 6.5, it is not entirely platform independent. The GUI version available on the Web site has been tailored for *Windows*. A version without the GUI and fewer computational capabilities is provided for use on *UNIX* and Macintosh platforms.

4. References

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3. C. A. Balanis, *Advanced Engineering Electromagnetics*, New York, Wiley, 1989.