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Authors
Johnson, WA
Basilio, LI
Kotulski, JD
et al.

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EIGER™: An Open-Source Frequency-Domain Electromagnetics Code

William A. Johnson*(1), Lorena I. Basilio(1), Joseph D. Kotulski(1), Roy E. Jorgenson(1), Larry K. Warne(1), Rebecca S. Coats(1), Donald R. Wilton(2), Nathan J. Champagne(3), Filippo Capolino(4), J. Brian Grant(5), and Michael A. Khayat(6)
(1) Sandia National Laboratories[1], Albuquerque, NM, 871185-1152
(2) University of Houston, Houston, TX, 77204-4005
(3) ERC, Inc., ESCG/JE02, P. O. Box 58477, Houston, TX 77258-8477
4) University of Siena, Siena, Italy, 53100
5) ANT-S, 2011 Research Dr., Livermore, Ca 94550
6) NASA Johnson Space Center, Houston, TX 77058

E-mail: wajohns@sandia.gov

Introduction

EIGER™ is a general-purpose, 3D frequency-domain electromagnetics code suite consisting of a pre-processor (Jungfrau), the physics code (EIGER), and post processor (Moench). In order to better enable collaborative development, EIGER™ version 2.0 has been approved for release as open source software under a GNU Public License. A web site, www.code-eiger.org, has been created for this collaborative development.

EIGER™ is primarily an integral-equation code for both frequency-domain electromagnetics and electrostatics. This version includes the following Green's functions: 2D and 3D free space, symmetry-planes, periodic and layered media. There is a thin-wire algorithm as well as junction basis functions for attachment of a wire to a conducting surface, and also thin-slot models for coupling into cavities. The code is written in Fortran 90 using object-oriented design and has the capability to run both in parallel and serial.

The original development of EIGER™ began in the early 90's as a collaborative effort between University of Houston, Sandia, Lawrence Livermore (LLNL) labs and the U. S. Navy [1]. However, due to different customer bases, eventually two different codes resulted. Applications at Sandia were geared towards EMC and EMI problems for which the thin-slot coupling algorithms were developed. Other Sandia applications that drove the development of this code were the modeling of periodic diffraction gratings for a petawatt laser, photonic band-gap structures, plasmon optics, frequency-selective surfaces, and electro- and magnetostatic problems for pulsed power and micro-machines. The layered media work of Nathan Champagne (developed at the University of Houston and LLNL) has been incorporated into the newest version of the code. This version also uses singularity-cancellation techniques [2] rather than the traditional singularity-subtraction methods. The main computational part of the code has been reduced to numerical evaluation of the inner product $<\mathbf{\Lambda}_m^{test}, \mathbf{O}\mathbf{\Lambda}_i^{source}>$ where $\mathbf{\Lambda}_m^{test}$ and $\mathbf{\Lambda}_i^{source}$ are the Rao, Wilton, Glisson basis functions and $\mathbf{O}$ is a differential-integral operator

[1] Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

involving the appropriate Green's function. These techniques have greatly simplified the implementation of the new EIGER™.

Sample Problems

In the early 1980's the first author had the privilege of working with Richard W. Ziolkowski and Kendall F. Casey, who was our group leader. We made an effort at solving electromagnetic coupling problems using Rieman Hilbert [2] and dual-series techniques. Kendall had shared his notes on quasi-static coupling to a thin spherical shell with a circular hole (Fig. 1) with us and the solution of that problem occupied our free time for the next three years [3]. The EIGER™ solution in Fig. 1 used inner and outer regions with a dielectric interface and thus it has much greater dynamic range than the predecessor code Patch.

The first author was also involved in solving the problem of a wire penetrating the air-water interface (Fig. 2) while working for Kendall (in order to check the NEC code). This work utilized the evaluation of Sommerfeld integrals presented in [5] and required that a large number of unknowns (N_w) on the water side of the interface be used. In Figs. 2a and 2b, N_w is respectively set to 99 and 199. Figure 2c used the previous results to extrapolate N_w to infinity. As illustrated in Fig. 2d, EIGER™ readily solves this problem and agrees with Fig. 2c.

EIGER™'s periodic Green's function capability is illustrated in the next figures. Results for the unit cell of an infinitely periodic diffraction grating are shown in Fig. 3. These results were obtained with a Green's function for a 1D array of line sources in a layered medium and were shown to replicate the results of [7]. In another problem, the Green's function of a doubly-infinite array of point sources was used to model the photonic crystal of Fig. 4.

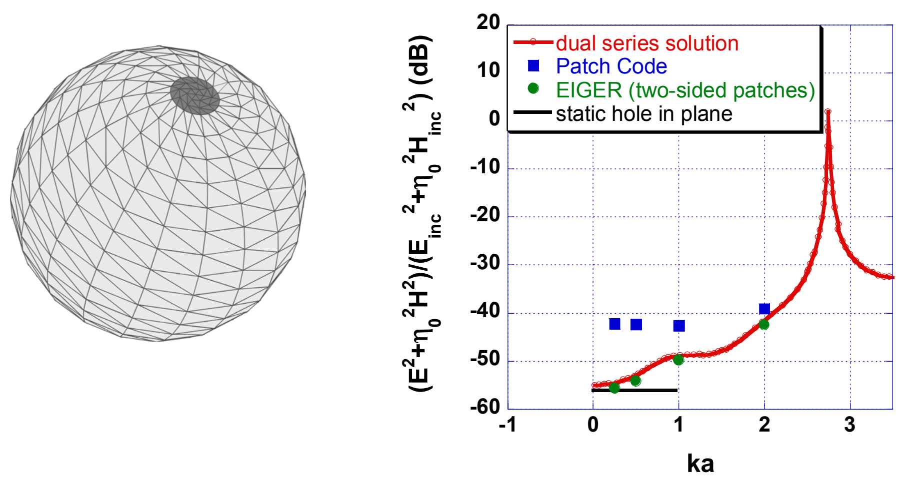


Figure 1. The solution by dual series, Patch, EIGER™, and statics for plane-wave coupling to a thin spherical shell with a circular hole.

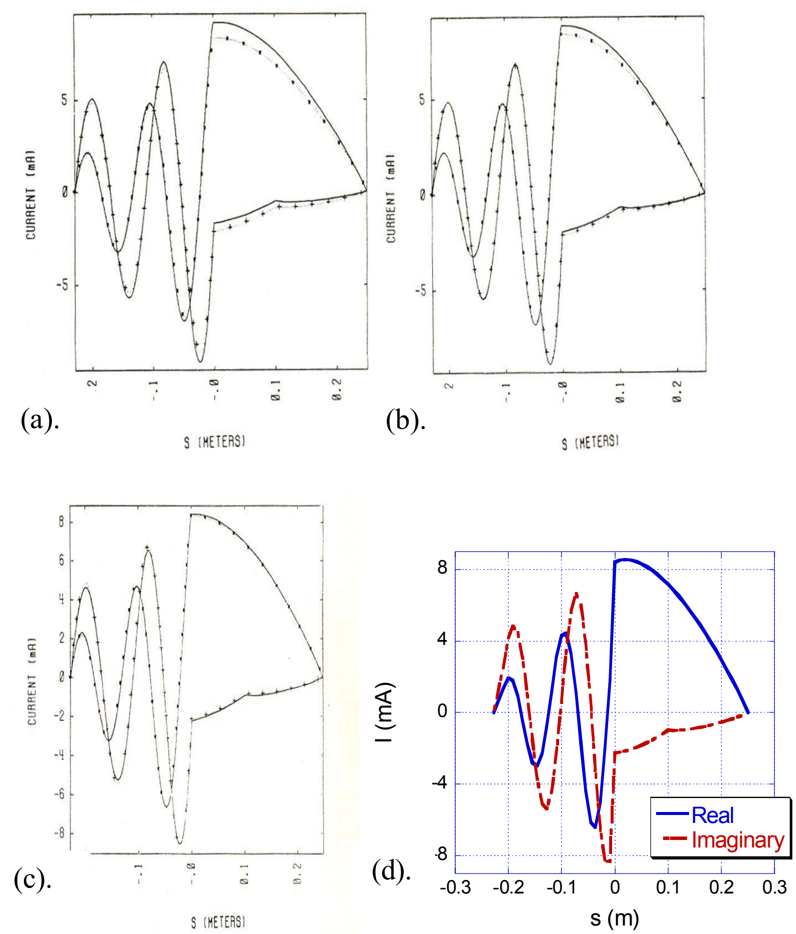


Figure 2. a-b) A comparison of the NEC code with currents on the ground stake [6] c) results from [6] with extrapolation of the number of unknowns in the water side of the interface to infinity d) EIGER^{TM} give the same results as (c).

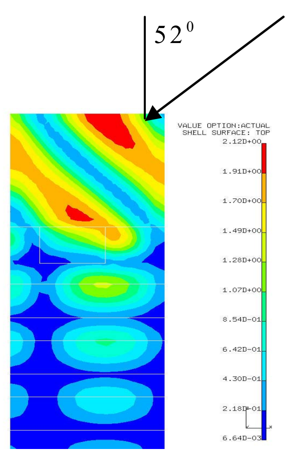
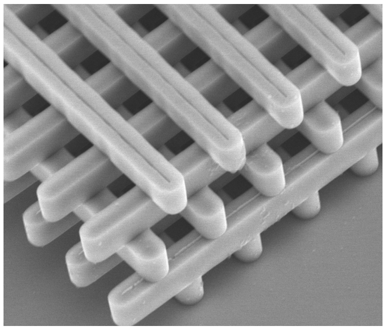


Figure 3. Electric field magnitude in an infinite periodic-diffraction grating. The grating is periodic along the horizontal direction.



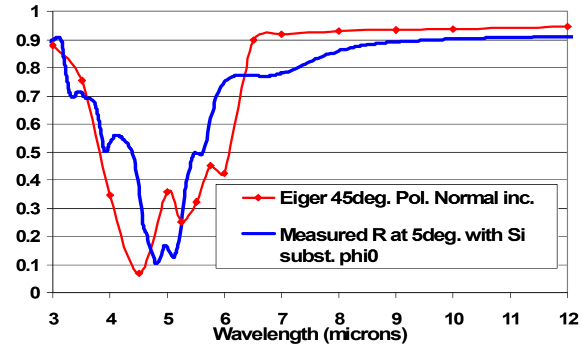


Figure 4. a) Tungsten photonic crystal with 1.2mm wide bars and 4.2mm period b) Numerical simulation of the reflectivity assumes air substrate, measurement conducted on silicon substrate.

Conclusions

We have illustrated a few of the features of the EIGER™ code. Some problems have been chosen to look back at the time when W. A. Johnson was working for Kendall F. Casey and to illustrate some of the impact Kendall had on that author's career. Kendall's standard of technical excellence, as well as his kind and ethical way of treating younger staff has been a model that we should strive to achieve.

Acknowledgement

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