Student Projects of Extended Study in Introductory Electromagnetics

Y. Du, X. M. Zhang, S. L. Zheng, X. F. Ye, and K. S. Chen
The Department of Information Science and Electronic Engineering
Zhejiang University, Hangzhou 310027, China

Abstract— It is well recognized that Electromagnetics is one of the most important disciplines yet is also a difficult subject for undergraduate students to grasp. In the literature it has been advocated to incorporate real-world examples of applications to help improve student learning. In this work, we propose an approach that is complementary to the real-world examples one. In our approach, we encourage the students to extend the material from what has been covered in the class through participation in individual project. Positive results are obtained in terms of comprehension of the material, improvement of mathematical skills, as well as buildup of confidence in the participants.

Electromagnetics is one of the most important bases of our modern life, upon which lay the life style enhancing technologies such as communication, RFID, wireless sensor network, antenna, and other electronic systems. Understanding the principles of Electromagnetics is thus required for undergraduate students majoring in Electrical Engineering to prepare them for a smooth and successful career. However, since electromagnetics is a strongly mathematical subject, it is often the case for a student to find it very difficult to apply advanced mathematical techniques while maintaining a physical comprehension [1–5]. In the literature it is observed that incorporating real-world examples of applications serves to improve student learning and to bring a colorful course material presentation. This is undoubtedly an effective way of teaching electromagnetics. However, there might also be some limitations of this approach: The chosen real-world examples may have to be simple and the applicable principles from electromagnetics may be restricted considering the limited knowledge span and mathematical skills of the average student. For instance, the real world examples taken from one study were almost associated with electrostatics or magnetostatics. The very nature of electromagnetics, that is, time varying aspect, is unwantedly de-focused in this approach. In this work, we propose an approach that is complementary to the real-world examples one. In our approach, we encourage the students to extend the material from what has been covered in the class. For instance, after learning the reflection and transmission of a plane wave at the interface of two homogeneous media in the conventional setting, the students may proceed to work out with the help of the instructors the reflection and transmission phenomena when one of the media is anistropic. In this way, the comprehension of the material, the employment or even improvement of mathematical skills can be greatly boosted, which will in turn help build up the confidence and further curiosity of the students.

The proposed extended study is not introduced as a mandatory part of the fundamental EM course; rather, it is based on voluntary participation. To maximize the participation among the students who are taking the EM class, we decide to provide the students with incentives to participate. Specifically, based on historical grades distribution of the EM class, the incentive for participation is set to some additional points within the range of one to six on a 100 scale. To minimize the confusion among the participants, they are instructed that either of three types is legitimate project: theoretical analysis, application oriented, and visualization generation. Yet for the first two categories, the content of the project can not be readily available from either the textbook or some other reference books. Rather, participants who choose these two categories need to work out something of their own: to fill in the details that are omitted in either the analytical material or the connection between EM theory and the specific application at hand. With that in mind, the participants are provided by a limited number of project topics which they can choose, yet the majority of topics is to be identified by the participants. For the current study, each project is treated as an individual one, while interaction with each other and solicitation of assistance from the instructor are still highly encouraged. The project delivery package includes an oral presentation which lasts about 10 minutes plus some question and answer session, a written report, and source code (optional for those whose projects have involved some kind of numerical simulations or computer visualization). The performance is evaluated based on a number of factors including originality, thoroughness of comprehension, scope, and presentation (both oral and written).

Out of 210 undergraduate students who take the EM course (split among four small class sessions), 37 students participate, resulting in a participation ratio of around 15%. The topics covers all three types of permissible projects, with a surprisingly wide range of interests considering

Table 1: Exemplary project topics.

Wireless transmission of electricity
Introduction to FDTD and its simulation of TE101
Electromagnetic wave propagation in plasma
Dispersion of Polarization Mode
RFID technology
RF identification
Study of Electromagnetic cloking
Electromagnetic black holes
Antenna technology in UWB wireless communications
Smart antennas
Reflection and refraction at the interface of left- and right- handed materials
Negative refraction index material
Detection of surface stress using polarization interference
Determination of the dispersion of rectangular dielectric waveguide via EDC method
One dimensional optical crystal transmission line based on characteristic matrix method
Principle of wireless detection of direction of arrival
Analysis of the directional coupler
Synthesis filter design of cascaded couplers
Animation of electromagnetic fields in a rectangular resonator
Static and dynamic analysis of TE modes in a rectangular waveguide
3D visualization of surface currents of circular waveguide
Numerical analysis of scattering from a cylinder with arbitrary cross section
Skin depth effect of metals
Application of genetic algorithm to design of antenna array
Discussion of ways of hole opening in an elevator for unblocked cellular communication

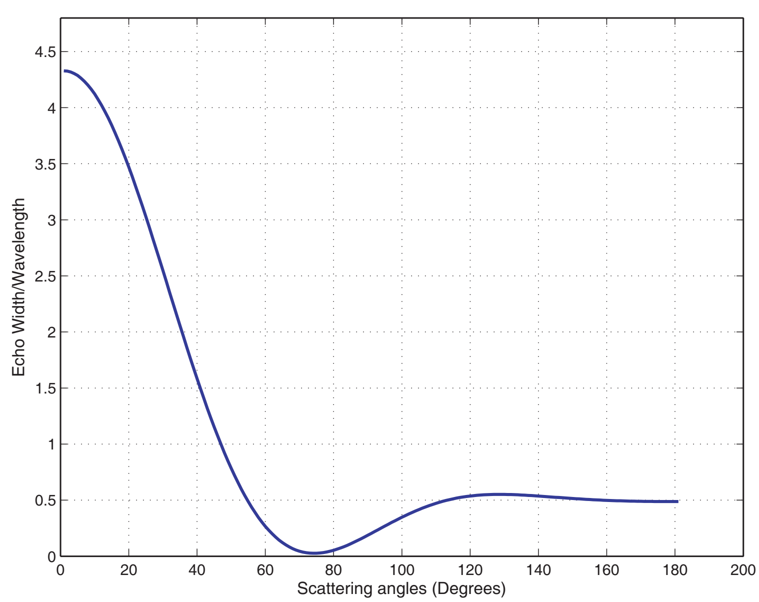

Figure 1: Scattering pattern of a circular dielectric cylindrical shell with plane-wave incident.

their limited *a priori* knowledge of EM theory. The topics are exemplified in Table 1.

Next we highlight some of the projects. The first one concerns numerical analysis of scattering from a cylinder with arbitrary cross section. The participant is expected to learn the concepts such as integral equation, method of moment, boundary conditions, scattering cross section or scattering width. The learning material is taken from one technical paper in IEEE Transactions on Antennas and Propagation [6]. Fig. 1 illustrates scattering pattern of a circular dielectric cylindrical shell with plane-wave incident with parameters chosen identical to that of Fig. 4 in [6]. Very good agreement is obtained, which speaks of good comprehension of the material and implementation of the method of moment. The second project is an analysis of the microstrip directional coupler, where all the details have been dutifully worked out. Numerical illustrations are also provided (See Fig. 2 as one example). The third one is to provide a visualization package of fields distribution of the rectangular waveguide, in accordance with the increasing recognition of the significance of visualization in scientific and engineering learning [7]. Fig. 3 illustrates a 3D visualization of the z

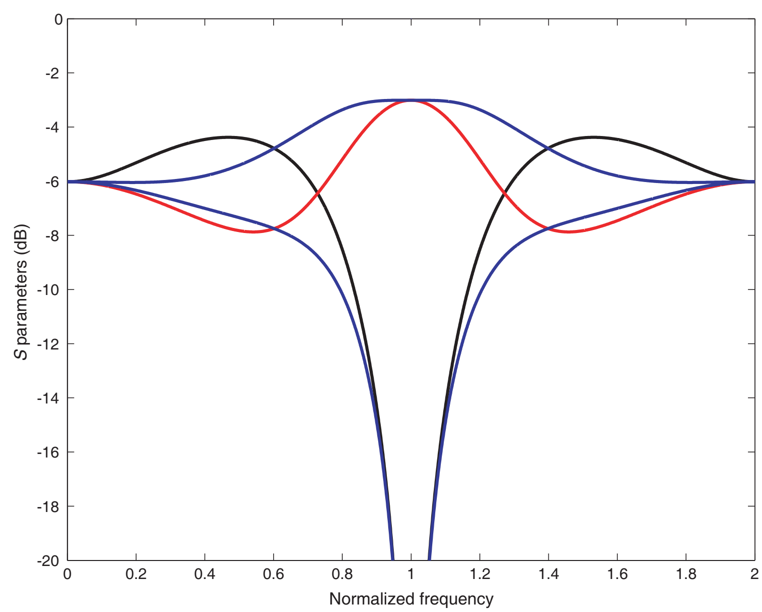

Figure 2: Frequency response of the 3 dB directional coupler.

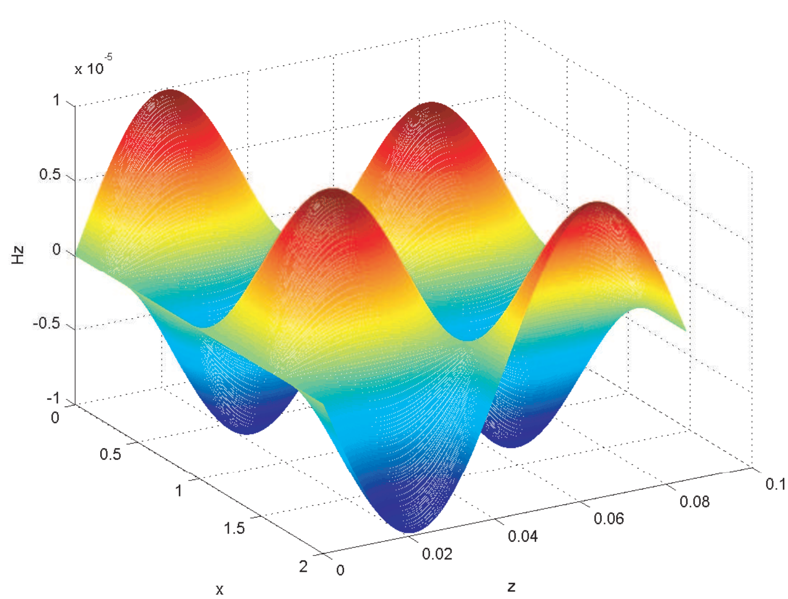

Figure 3: 3D visualization of the z component of the magnetic field in a rectangular waveguide.

component of the magnetic field in a rectangular waveguide.

In summary, in the current study to facilitate the teaching of electromagnetic theory to undergraduate students in their sophomore or junior years, we proposed a student project based approach. In this approach students are given the opportunity to do projects closely related to electromagnetic theory. Their participation is voluntary yet they are told up front that there is reward for those who choose to participate and who has done it well. The form of reward is tentatively set to be some additional points to their final grades (within the range of one to six on a 100 scale). Yet we observe that although most participants are attracted by the additional credits at the beginning, their curiosity and satisfaction with the enhanced understanding of the electromagnetic theory and with the realization of the wide spectrum of fields to which the theory can be readily applied gradually substitute as the true motivations for going along with the project. The wide range of project topics as exemplified in Table 1 also testifies to the breadth and depth of the students, with a encouraging mix of purely theoretical analysis to real-world applications. This very fact also strongly implies the unnecessity of the instructor to attempt to limit the scope of the projects within a preset limited range.

REFERENCES

1. Cheng, K. W. E., X. D. Xue, K. F. Kwok, and T. K. Cheung, "Improvement of classroom teaching of electromagnetics by means of an electronic book," *IEEE Trans. Magn.*, Vol. 39, 1570–1573, 2003.
2. Lowther, D. A. and E. M. Freeman, "A new approach to using simlation software in the electromagnetics curriculum," *IEEE Trans. Education*, Vol. 36, No. 2, 219–222, 1993.
3. Sadiku, M. N. O., "Problems faced by undergraduates studying electromagnetics," *IEEE Trans. Educaton*, Vol. 29, No. 1, 31–32, 1986.
4. Beker, B., D. W. Bailey, and G. J. Cokkimdes, "An application-enhanced approach to introductory electromagnetics," *IEEE Trans. Education*, Vol. 41, No. 4, 31–36, 1998.
5. Iskander, M., "Technology-based electromagnetic education," *IEEE Trans. Microwave Theory Tech.*, Vol. 50, No. 3, 1015–1020, 2002.
6. Richmond, J. H., "Scattering by a dielectric cylinder of arbitrary cross section shape," *IEEE Trans. Antennas. Propag.*, Vol. 13, 334–341, 1965.
7. De Magistris, M., "A MATLAB-based virtual laboratory for teaching introductory quasi-stationary electromagnetics," *IEEE Trans. Educaton*, Vol. 48, No. 1, 81–88, 2005.