

ELECTROMAGNETICS EDUCATION IN NORTH AMERICA

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ABSTRACT

This paper starts with a description of the activities of the education committees of the IEEE Antennas and Propagation, Microwave Theory and Techniques, and Electromagnetic Compatibility societies and the United States National Committee of the International Union of Radio Science (USNC/URSI). We then present the initial results of a survey of electromagnetics (EM) education in North America with a discussion of typical EM curricula at the undergraduate and graduate levels. Current research and initiatives in EM education in North America as reported in the periodicals and international conferences is also surveyed.

ACTIVITIES OF THE EDUCATION COMMITTEES OF THE IEEE SOCIETIES

In the late eighties and early nineties the IEEE Antennas and Propagation Society (APS) and the National Science Foundation in the USA sponsored the Computer Aided Electromagnetics Education (CAEME) initiative that funded a number of computer software and animation projects to help visualize and understand electromagnetics concepts. That initiative eventually resulted in publication of two books in 1991 and 1995. The IEEE APS education committee was involved in soliciting and publishing a number of tutorial papers and several video productions of basic antenna and electromagnetics concepts. Presently the APS Education Committee oversees IEEE AP activities for undergraduate and graduate education. Four major activities are underway.

First, the IEEE AP society provides ten \$1000 undergraduate scholarships and five \$2500 graduate fellowships each year. These are open to students all over the world.

Second, the committee instigated a survey of EM curricula around the world. The purposes of this study are: (1) compare global trends, (2) understand “typical” EM curricula, (3) locate novel EM teaching strategies to share with the community, and (4) assess possible projects for IEEE support that would benefit the EM education community. The initial results of this survey are included in this paper. We plan to make it an ongoing survey.

Third, the committee maintains a website of EM courses (which includes EM, EMC, Wireless Communications, Numerical Methods, etc.) and course materials at www.ece.utah.edu/~cfurse/APS . This provides access to online notes, examples, videos, labs, tutorials, teaching resources, etc.

Finally, the chair of the IEEE AP Education committee writes a bimonthly column on education in the IEEE AP Magazine. The column includes an electromagnetic tutorial that may be of use in an EM class, announcements (such as the scholarships), and a teaching skills article.

The Microwave Theory and Techniques Society of IEEE (MTT) also has been very active in promoting excellence in electromagnetics education by providing up to ten undergraduate/pre-graduate scholarships of \$1500 each and six graduate fellowships of \$6000 each. MTT scholarship winners are provided additional travel support and are encouraged to attend an international Microwave symposium in US or Europe.

The Electromagnetic compatibility (EMC) society's education committee is very helpful in introducing EMC curriculum in the universities and colleges. They have an annual competitive university grant of \$10,000 for starting a new EMC curriculum. In addition, the EMC Society conducts an annual student design competition which typically rewards the team that provides the best EMI mitigation to some specified electronic circuit. They have set up an ongoing survey of university faculty to monitor the progress of their education activities.

The IEEE APS and USNC/URSI summer meetings in North America have student paper competitions and provide some student travel support. USNC's annual winter meetings in Boulder provide significant travel support to all US university students who are principal and presenting authors.

INITIAL RESULTS OF THE SURVEY

Many of the undergraduate students in the United States are required to take only one electromagnetics course whereas in Canada typically the electrical engineering students are required to take two courses while the computer engineering students need only one. We found that there are different approaches to teaching the concepts. The traditional model starts with a review of vector analysis, followed by static fields and some basic time varying fields. Transmission lines and detailed analysis of plane waves and other concepts are taught later. Some people prefer to start with transmission line theory as a distributed circuit model. Both time domain and frequency domain analysis of transmission lines are discussed. It is then followed by a review of vectors, static fields and time varying fields. Another model starts with the general time varying fields and Maxwell's equations and then static fields are presented as a special case.

The survey respondents stated that generally students find EM courses very challenging and demanding, even though students have a fair amount of preparation in the required Math and Physics courses. A variety of simulation and visualization tools, including some popular commercial Computer Aided EM software and those produced in house by various university faculty have been employed. Discussion of practical applications along with abstract theory has been found to be helpful. The greatest challenge facing the educators is to motivate undergraduate students to enjoy the learning experience such that many of them may pursue graduate education in the EM related fields. The graduate students who choose to study EM are generally well-motivated. We believe that the IEEE Societies should support projects that develop innovative and interesting teaching tools.

TRENDS REPORTED IN THE LITERATURE

We reviewed the literature over the last five years for reports of new initiatives in electromagnetics education. We concentrated on the following conference proceedings and journals:

- ASEE/IEEE Frontiers in Education Conference

- IEEE Antennas and Propagation Society International Symposium
- IEEE Microwave Theory and Techniques Society International Symposium
- IEEE International Symposium on Electromagnetic Compatibility
- IEEE Transactions on Education

Most of the initiatives reported in the literature fit into one of the following categories:

- Use of modeling, simulation, and visualization software to improve comprehension
- Alternatives to vector calculus for analysis of EM fields
- Development of virtual laboratory environments
- Incorporation of active (experiential) learning in the classroom
- Incorporation of problem-based learning activities, sometimes integrated with other courses
- Incorporation of electromagnetic compatibility (EMC) issues into the EE curriculum
- Development of assessment tools such as concept inventories
- Web-based instruction

It was almost universally recognized in the literature that the traditional approach to teaching electromagnetics to undergraduates is abstract and mathematically intensive and that because of this students in the past have tended to avoid taking courses with significant electromagnetic content. The largest number of papers addressed this issue and proposed the use of software tools to help students visualize the structure and evolution of electromagnetic fields associated with transmission lines, waveguides, antennas, and other devices. Some educators are also employing analysis approaches that avoid the use of vector calculus to help students grasp in a more straightforward manner the connections between physical phenomena and the mathematical models that describe and predict them. Vector calculus is then introduced later in the course when the students can more easily appreciate its value. In addition, many students are being given the opportunity to study real-world problems using modern software in environments that mimic the design process in industry. The IEEE Electromagnetic Compatibility Society has been strongly encouraging educators to expose their students to EMC-related issues as the basis for application examples and course projects in an effort to raise awareness of this increasingly important field.

The influence of the ABET 2000 criteria for evaluating and accrediting EE and ECE department curricula is also evident. Educators are developing concept inventories and other means to assess the effectiveness of their courses. Active learning and problem-based learning experiences are being introduced in an effort to enhance retention of course material and to reduce the tendency to “compartmentalize” knowledge so that students can better understand the relevancy of electromagnetics to other disciplines both within and outside electrical engineering.

Computational technology and the Internet are being exploited more than ever. Many universities are beginning to offer distance-learning opportunities to answer the needs of working engineers who wish to continue their education. Web-based instruction and virtual laboratories have been developed in the hope that students in remote locations might be able to experience educational activities that differ little from those enjoyed by residential students. These technology-based initiatives also supplement and reinforce in-class activities and in some cases help to compensate for the limited availability of hardware resources such as network analyzers.

CONCLUSION

We find that the universities and the professional societies in North America have been active in motivating and supporting students in the study of electromagnetics and related courses. However, it continues to be a challenging task, especially at the undergraduate level. We hope that concerted efforts of several universities in collaboration with Education committees of IEEE’s MTT, AP, and EMC Societies and URSI to create new initiatives to continually improve the teaching tools and innovate and develop interesting techniques of presentation without sacrificing the rigor would help.