EDUCATING TOMORROW'S RF/MICROWAVE ENGINEER: A NEW UNDERGRADUATE LABORATORY UNITING CIRCUIT AND SYSTEM CONCEPTS

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ABSTRACT

This paper describes recent advancements made at the University of South Florida for educating undergraduate electrical engineering students in the fields of wireless circuits and systems. The foundation for the program is an innovative lecture/laboratory course which guides students through wireless component and subsystem analysis and design using a case-study approach. While providing a broad exposure to the wireless arena, students also gain hands-on experience with state-of-the-art instrumentation and computer-aided engineering software.

INTRODUCTION

A clear and growing need exists for skilled electrical engineers in the wireless industry. There has been, by all accounts, a rapid expansion in this field that is expected to continue into the next century. Fierce industry competition, greater consumer demands, and an increasingly crowded frequency spectrum fuel this growth. In order to support the "wireless revolution", well-trained engineers are needed with expertise in system, circuit and antenna design, and the challenge falls squarely upon the shoulders of the academic community. However, the supply is not yet keeping up with demand. For various reasons, a large number of potential electrical engineers have apparently been migrating to other discplines[1], particularly computer science. While enrollments historically ebb and flow, continued growth in the wireless industry requires a near-term correction.

In the University of South Florida's Electrical Engineering Department, a new wireless initiative has begun with the aim of creating an intense, exciting curriculum to attract and educate students. The focal point is the Wireless and Microwave Instructional (WAMI) Laboratory. This lab houses state-of-the-art microwave test instrumentation, industry-standard circuit and system simulation software, a network of Pentium PCs and a circuit prototyping capability. A new undergraduate lecture/laboratory course, called Wireless Circuits and Systems Design, has been developed around the WAMI facility to teach students about the interplay between circuit and system aspects of wireless technology. Following this broad introduction to the field, students are able to choose from several electives which are offered at the undergraduate and graduate levels. In this paper we describe the overall wireless program at USF with regard to organization, content, sponsorship and dissemination.

A WIRELESS EDUCATIONAL FOCUS

The two main hurdles overcome in developing the new wireless program were generating a strong interest among the student population, and finding room in an already crowded curriculum for the relevant courses. A solution to the latter problem came about in part by reducing the existing two-course sequence in electromagnetics to one course, in which the coverage

[1] In the U. S. there were 27,000 BSEEs awarded in 1987-88, compared to only 21,000 in 1996-97 (Source: ASEE).

0-7803-4471-5/98/$10.00 (c) 1998 IEEE

of electro- and magneto-statics is minimal. In parallel, the long-standing undergraduate laboratory on electromagnetic principles was replaced by the two credit hour, lecture/laboratory course called Wireless Circuits and Systems Design. This is a *required* course that is taken by *all* electrical engineering students.

The matter of student interest is being addressed by rapidly evolving the WAMI facility into a high-profile focal point for the microwave and wireless activity at USF. The salient features of this development are as follows:

State-of-the-Art Laboratory - The WAMI Lab is a dedicated facility comprised of six basic work-stations and a Senior Project bench (Figure 1). The software available in the lab includes industry-standard circuit and system modeling software (HP Series IV/PC and Omnisys/CDS), numerical electromagnetic modeling software (Ansoft Strata and HFSS), and an antenna design package.

Along with realizing a laboratory with exceptional resources, an effort has been made to lead students to form an affilitation with the WAMI Lab that exceeds the conventional undergraduate experience. One of the steps taken in this direction is the formation of student-led "E" (Evaluation) Teams, which are assembled each semester to assess the Wireless Circuits and Systems Design course and provide feedback to the faculty.

Diverse Wireless Curriculum - A comprehensive offering of elective courses supports the Wireless Circuits and Systems Design course, many of which are offered at the undergraduate and graduate level. These include courses in passive and active RF/microwave design, MMIC design, microwave measurements, communications systems, mobile and personal communications, signal processing and others. Each electrical engineering student is also required to complete a Senior Design Project, and several students each semester utilize the WAMI Lab to conduct projects on a wide variety of wireless-related topics.

Faculty Involvement - A consistent faculty presence in the lab during class hours not only improves student learning, but also demonstrates our enthusiasm for the Wireless Circuits and Systems Design course. A team-teaching approach has also been adopted, wherein three to four faculty members, with expertise ranging from microwave circuits to communication systems, rotate duties in the lecture and lab.

Industry Presence - One of the precepts of the WAMI Lab is to form a close link with the wireless industry, and in so doing make students fully aware of the varied career opportunities. Activities in this area include inviting guest lecturers from industry, widely publicizing job openings via the web page[2] and in-class announcements, and bringing industry representatives into the lab during class hours. A WAMI Advisory Board, currently consisting of thirteen members from several nationally-based companies, has also been formed to help keep pace with the rapidly changing wireless environment.

WIRELESS DESIGN COURSE

The Wireless Circuits and Systems Design course presents the first opportunity to expose students to the world of wireless engineering. It uses a lecture/laboratory format, in which a 1-hour tutorial is used to present the relevant theoretical background, followed by a 4-hour laboratory session on a subsequent day. It is normally taken in the junior year, following the Introduction to Electromagnetics lecture course.

Along with a technically advanced learning environment, the course incorporates carefully planned teaching methodologies. In order to experience the teaming that is consistent with industry practices, the students work together in pairs and the team members are rotated 3-4 times during a given semester. We believe that it is important to limit the groups to two, so as not to dilute the learning process. The laboratory experiments are built around a model for

[2]The WAMI web page is found at `http://www.eng.usf.edu/WAMI`.

new product development, with assignments targeted toward individual components of the block diagram for a modern receiver/transmitter (Figure 2). Given the inexperience of the students and the relatively complex nature of the topics, the laboratories have been written with great attention to detail. At the same time, students are challenged to develop their critical thinking and problem solving skills.

One of the objectives of the wireless course is to convey the concept of the modern engineering design cycle, as exemplified in the Lumped Element Filter Laboratory. In the lecture which precedes this lab, the importance of filtering in a wireless subsystem is described along with the prototype filter design approach. A prelaboratory assignment requires students to design a lumped element filter to a given cut-off frequency (between 100 and 500 MHz) and simulate the ideal response using Mathcad. During the lab session, students assemble the filters using circuit boards and surface-mount inductors and capacitors, and then measure the S-parameters using a vector network analyzer. The limitations of the ideal model beyond 1 GHz become readily apparent, and a more realistic circuit representation is developed using Series IV/Libra. This refined model includes parasitic elements for the surface mount components, as well as the effects of the interconnect lines. The experiment thus incorporates the *design-simulate-measure-simulate* methodology, and further prompts students to offer a plausible final-design improvement.

The final experiment of the semester focuses on the characterization of a complete wireless-receiver subsystem. Using off-the-shelf coaxial components, students perform swept-signal measurements of the system and investigate issues such as the effects of interference signals. System simulation using Omnisys/CDS is done to compliment the experimental work. This lab helps to reinforce the myriad concepts covered throughout the semester and closely links the circuit and system aspects of wireless sytems.

1 LABORATORY SPONSORS

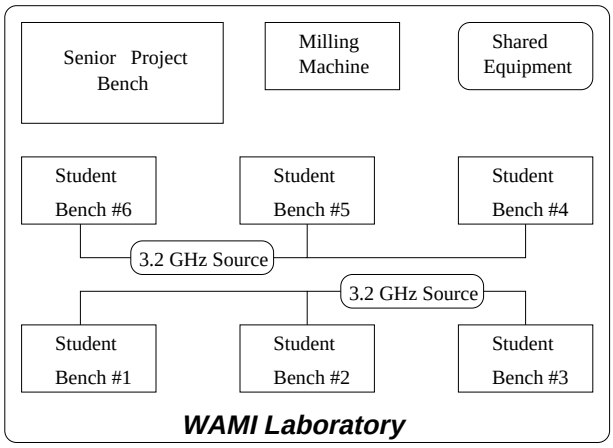
The WAMI Lab was initiated with strong support from industry, government and academia. The first major funding was received from Hewlett Packard's Educational Grants Program. Soon thereafter a grant was obtained from the National Science Foundation's Instrument and Laboratory Improvement (ILI) Program, through the Division of Undergraduate Education (grant DUE-9650529). The NSF award was matched by the University of South Florida. This funding was used toward the purchase of the instrumentation and computers, while several companies continue to participate through the contribution of microwave components and simulation software.

DISSEMINATION

The WAMI Lab and the educational material associated with the wireless design course are being made available to the academic and industrial community through two channels. The first is the WAMI web page (http://www.eng.usf.edu/WAMI), which provides a description of the instrumentation and supplies and a summary of each laboratory experiment, among other items. A complete library of the lecture material and laboratory experiments is available, although at this time access is limited to the students in the course; plans are currently being made regarding the generation of a published laboratory manual. The second means of dissemination is through recent conference papers [1, 2], with a more complete journal paper planned for the near future.

SUMMARY

From their earliest stages of development, the WAMI Lab and the Wireless Circuits and Systems Design course were envisioned as an educational model that could be adopted by other educational institutions. The hands-on laboratory experience, preceded by an abridged lecture



Student Bench:
2.9 GHz Spectrum Analyzer
3.0 GHz Vector Network Analyzer
Digital Scope
Pentium PC
Mobile Cellular Antenna
Power Supplies, Microwave Accessories

Senior Project Bench:
6 GHz Vector ANA
6.5 GHz Spectrum Analyzer
Pentium PC

Shared Equipment:
Printer
Sun Ultrasparc Work-station
Transmit Antenna Towers (2)

Figure 1: The Wireless and Microwave Instructional (WAMI) Laboratory.

on supporting theory, is proving to be a sound approach for arousing student interest. This interest is sustained with strong industry awareness and involvement, a dedicated facility with ample student access, and a curriculum that allows for two or more elective courses to follow the required introductory course. Feedback from students who have recently taken jobs in the microwave/wireless field confirms that the experience with industry-standard tools and practices allows rapid integration into mainstream engineering activities.

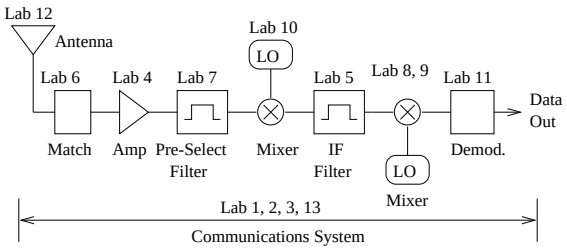


Figure 2: Topics covered in the Wireless Circuits and Systems Design course.

References

[1] P. Flikkema, L. Dunleavy, H. Gordon, R. Henning and T. Weller, "Wireless Circuit and System Design: A New Undergraduate Laboratory," *Proc. Frontiers in Education '97*, Nov. 5-8, Pittsburgh, PA.

[2] L. Dunleavy, P. Flikkema and A. Kuppusamy, "Characterization and Simulation of a 915 MHz Wireless Receiver," *Proceedings of the 50th ARFTG Conference*, Portland, OR, Dec. 1997.