The VT/UMR Wireless Communications Curriculum

W. H. Tranter
Department of Electrical Engineering
University of Missouri - Rolla
Rolla, Missouri 65401

J. H. Reed, B. D. Woerner and T. S. Rappaport
Wireless and Mobile Radio Research Group
Bradley Department of Electrical Engineering
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Abstract

Faculty from Virginia Tech and the University of Missouri - Rolla (UMR), with the support of the NSF CRCD program, are developing a three-course sequence in wireless communications. This course development activity is in response to the large demand for wireless engineers resulting from the unprecedented growth of wireless communication services. The three-course sequence covers basic wireless and cellular systems, the DSP implementation of wireless systems, and computer-aided design and analysis of wireless systems. The course sequence makes extensive use of MATLAB for demonstrations, problem solving, projects and simulation and features a DSP laboratory for introducing students to the hardware aspects of wireless communications.

1. Overview of Goals and Objectives

The field of wireless communications is experiencing tremendous growth throughout the world. Cellular telephone and paging services not only provide a significant portion of the communications infrastructure in the US but wireless services also provide necessary services in developing countries where traditional wired services are unavailable or are unreliable. Because of this unprecedented growth, the communications industry is experiencing a large demand for engineers who can design, analyze and deploy wireless systems. As a step in meeting this demand the faculty of the Mobile and Portable Radio Research Group (MPRG) at Virginia Tech joined with the communications faculty at the University of Missouri - Rolla (UMR) to develop a three course sequence in wireless communications that could easily be exported to other schools. The first of the three courses (Course 1) treats the fundamentals of wireless communications. The second course (Course 2) introduces the student to the hardware aspects of wireless systems and focuses on the design of a wireless modem based on digital signal processing (DSP) technology. The third course (Course 3) treats the simulation of communication systems with an emphasis on wireless systems. Simulation is a useful, and often necessary, step in the design and analysis of wireless systems because of the complexity of these systems and because of the harsh environment in which they operate.

The goal of our project is to develop these three courses to a point that establishes a standard of excellence for courses in the wireless area and then to make these courses and related course materials available to other schools in a form that will allow others to offer educational programs in the wireless area with a minimum of development effort. Course materials supplied to

these programs will take the form of textbooks, lab manuals, project notebooks, MATLAB files for systems demonstrations, simulations and analysis and video tapes of guest lectures.

2. Current Status and Accomplishments

At the present time (3/30/97) the initial development of all three courses has been completed and all three courses have been offered for credit at least once. Course 1 (Fundamentals of Wireless Communications) has been taught at both Virginia Tech and at UMR. The course was initially developed at Virginia Tech and was taught at UMR for the first time in the fall semester of the 1996-97 academic year. A number of MATLAB-based modules have been developed that support this course. These modules illustrate sampling, quantization, pulse shaping, multipath and equalization, modulation and Monte Carlo simulation. A number of handouts have been developed that explore major topics in wireless communications. The important topic of standards in wireless communications is also presented. In addition a project notebook of suggested student design projects has been developed.

Course 2 was taught for the first time at Virginia Tech as an independent study course in the fall semester of the 1996-97 academic year and was first taught as a regular credit course during the spring semester of the 1996-97 academic year. Because of equipment constraints, enrollment was limited to 22 students, which was less than half of those who expressed interest in taking the course. It should be mentioned that Texas Instruments made significant donations of both hardware and software in support of Course 2. Without this support it would not have been possible to develop and offer this course in year two of the NSF/CRCD project. This course takes the form of a sequence of laboratories that cover the following topics: An Introduction to the DSP System, Direct Digital Synthesis, Carrier Acquisition, Code Synchronization, Symbol Synchronization, Coding and Vocoders.

Course 3 was developed at UMR and has been taught twice at Virginia Tech. Course 3 was also offered at Canterbury University in Christchurch, New Zealand, during Professor Tranter's sabbatical at Canterbury in early 1996. Thus, Course 3 has enjoyed an international audience. When the simulation course was initially offered it used the textbook by Jeruchim, Balaban and Shanmugan (*Simulation of Communication Systems*, Plenum Press, 1992). It is now taught using notes prepared as a part of the NSF/CRCD effort. A number of MATLAB modules have been developed in support of this course. These include noise generators, signal-to-noise ratio estimators, bit error rate estimators, and examples of performance evaluation of digital communication systems using Monte Carlo simulation, quasi-analytic simulation and importance sampling techniques, to name only a few. In addition to a major textbook (under contract to Prentice-Hall) several small books are under development to support the simulation course. These books, called EDAPS (Examples, Demonstrations and Application Packages for Simulation) treat in detail topics that are fundamental to either the design of communication systems or to the simulation of these systems. All of the EDAPS are MATLAB based and present the topics of interest through simulation-based examples and demonstrations. The EDAPS provide the student with a simulated laboratory in which the student can run experiments and explore design alternatives. One EDAPS book, *Phase-Locked Loops and Synchronization Systems*, has been completed. Other topics, either under active development or consideration, include Channel Modeling for Wireless Systems, Channel Equalization, and Noise Generators.

3. Plans for Remainder of Project

Now that all three courses have successfully past the development stage, attention will turn to refinement of the courses and to the preparation of materials that can successfully be exported to other programs. In Course 1, the development of MATLAB programs to demonstrate the most important concepts in wireless communications and to support the analysis of wireless systems will continue. In Course 2 the laboratory experiments will be further refined and a laboratory manual, suitable for distribution to other schools, will be developed. The major activity related to Course 3 over the next year will be the completion of the simulation textbook and the EDAPS packages that support this course.

4. Materials That Have Been Developed

The materials developed to date consist of detailed handouts and MATLAB programs for Course 1, a preliminary set of student-tested laboratory experiments for Course 2, and the Phase-Lock EDAPS, and MATLAB simulations for the support of Course 3. The current status of the NSF/CRCD problem will be updated on our web site. (See the next section for the URL.)

5. Dissemination Activities

Dissemination of the course materials developed as a part of the NSF/CRCD effort is taking place on a number of levels. A home page on the World Wide Web was established at the initiation of the program and is frequently updated. The URL is

http://www.ee.vt.edu/mprg/education/nsf/nsf.html

Posted on this web page are complete course outlines, descriptions of laboratory experiments and MATLAB code for demonstrations and system simulations. Within the past year a contract has been signed with Prentice-Hall Publishing Company for publication of a textbook based on the simulation course (Course 3). The draft manuscript for this book will be submitted by the end of 1997. Several publishers have shown interest in the EDAPS sequence discussed in Section 4 and the first EDAPS (Phase-Locked Devices and Synchronization) is currently under review by Prentice-Hall. It therefore appears that several textbooks will result from the NSF/CRCD effort and that these will be available on the open market. In addition laboratory manuals are being developed for the DSP course. These can, and will, be distributed to other schools.

6. Evaluation Activities

At the present time, the bulk of our evaluation activities include the interest shown in our web page, student evaluation of our courses, feedback from corporate visitors and employers of our students as they become familiar with our efforts, and peer review of our materials submitted for publication. The ultimate evaluation of our efforts will come from those who base their courses on our products and from the success of the students who take the courses developed under this program.

7. Benefits Seen and Expected

The most immediate benefit of the NSF/CRCD program to develop a wireless communications curriculum was an obvious strengthening of the educational program at Virginia

Tech and at UMR in the communications area. Prior to the development of this program UMR had no course offerings stressing wireless communications. The initial offering of Course 1 (Wireless Communications) not only drew the attention of students but also drew the attention of wireless companies that visit the campus to recruit students. Positive reaction was immediate. Several companies expressed a strong desire to employ students who had taken these courses and to support the program through small grants and donations of equipment. In addition, many of the MATLAB modules developed in the NSF/CRCD effort have found their way into other courses in the Electrical Engineering curricula. This is especially true of the courses in digital communications and digital signal processing.

Virginia Tech, which offered a successful course in wireless communications prior to the initiation of our CRCD effort, has seen a significant strengthening of their wireless curriculum from a single course to a three course sequence. This has generated widespread support from students, faculty and from the industries and agencies that support the program. Virginia Tech has supported a strong program in wireless communications for a number of years and has obtained strong support from industries and from government agencies. The three-course sequence in wireless communications provides students with a background that allows them to be even more productive in their research efforts.

It is clear from responses to our web page and from discussions with faculty from other programs that a number of schools have interest in initiating at least one of the courses developed as a part of our NSF/CRCD effort. The dissemination efforts mentioned in Section 5 will insure that sufficient materials are available to allow other schools to develop similar courses with a significant reduction in effort.

References

The following papers have been published on the VT/UMR Wireless Communications Curriculum:

T. S. Rappaport, W. H. Tranter, J. H. Reed, B. D. Woerner and D. M. Krizman, "Curriculum Innovation for Simulation and Design of Wireless Communication Systems", *Proceedings of the 1996 Annual Conference*, Session 1626.

W. H. Tranter, T. S. Rappaport, B. D. Woerner, J. H. Reed and D. M. Krizman, "The Role of Simulation in the Teaching of Communications", *Proceedings of the 1996 Frontiers in Education Conference*, Paper7a1.1.