REAL: The Remote Educational Antenna Laboratory

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Introduction

Electrical Engineering students taking engineering electrodynamics at the undergraduate level often come away with the impression that the topic is abstract, mathematical, and will be of little practical use to them. Even after taking two semesters of the subject, students are often not able to see how what they have learned will help them design interesting products or systems. In contrast, after taking one or two semesters of subjects such as analog circuits, digital circuits, or control systems, a student can design and build a wide variety of interesting circuits and systems using widely available components.

One type of electromagnetic component that is practical for students to design and build is an antenna. Antennas can be simulated and analyzed using relatively inexpensive design software, and can be made using techniques such as elements printed on circuit boards, and metal and dielectric parts that can be cut and assembled with hand tools. One of the first courses to make use of extensive fabrication of printed circuits and antennas was developed by Rutledge and colleagues at CalTech [1].

Many Electrical Engineering programs already offer courses on antennas, and these courses are increasing in importance because of the growth in the wireless industry. These courses predominantly use software for antenna design and analysis, with few offering project courses to actually build and test antennas. A primary reason for not building antennas as part of a course is that some type of antenna range is needed to measure the radiation pattern of an antenna. Only a relatively small number of universities have such a facility, and fewer still have a facility that is available for undergraduate education. In some instances, creative faculty have set up simple systems consisting of a turntable, microwave sources, and detectors in a regular laboratory to illustrate the basic concepts of antenna patterns, but these are not available in all programs and are not very precise.

We have constructed an indoor antenna range within an anechoic chamber that is large enough to characterize the types of antennas that are suitable for personal electronic devices in the frequency bands between 1 and 18 GHz. Using the internet and suitable planning and scheduling arrangements, this facility will be made available for use in antenna project courses throughout the country, and ultimately throughout the world. We refer to this facility as the Remote

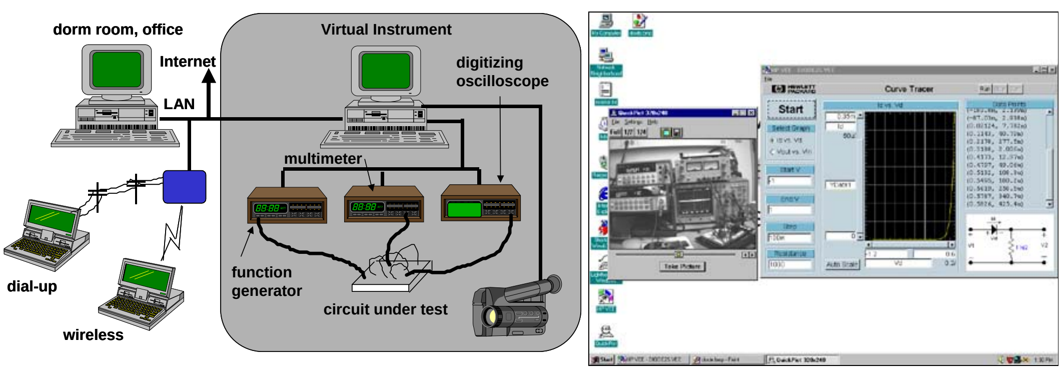
Educational Antenna Laboratory, or REAL. We believe this facility can play an important role in educating engineers with the knowledge needed by the wireless industry, and help to invigorate undergraduate courses in engineering electrodynamics by providing timely, hands-on applications through antenna design.

Remote Laboratories in Engineering Education

Carnegie Mellon was one of the first universities to incorporate remote access of real instruments into an undergraduate course. A complete operational remote laboratory was demonstrated for an ABET visiting team in the fall of 1994, and was subsequently used in an experimental course in the Fall semesters of 1995 and 1996 (see Figure 1) [2]. The course and concept were recognized in 1996 as one of five Finalists in the Education and Academia category of the Smithsonian Computerworld Awards. The laboratory was also used for lecture demonstrations in the freshman Introduction to Electrical and Computer Engineering course in the summer of 1999, and the Spring of 2000 (Figure 2).

A number of educators and researchers around the world are now active in the area of remote experimentation, or web-based laboratories. Two systems of particular note are the *Resource Center for Engineering Laboratories on the Web* at the University of Tennessee at Chattanooga (http://chem.engr.utc.edu/) [3], and the *MicroObservatory of On-line Telescopes*,
(http://mo-www.harvard.edu/MicroObservatory/) [4].

To the best of our knowledge, no other remote antenna laboratory similar to that described here and generally available for educational activities is in operation anywhere in the world.



(a) **(b)**

Figure 1. (a) Virtual lab used in an experimental course at CMU in 1995. (b) Screen capture from remote laboratory used for a classroom demonstration of the I-V characteristics of a diode at CMU in 1999.

Description of the Facility

The chamber dimensions without absorber are 10’x16’x10’. The “receive” end wall (i.e., the wall behind the test antenna) as well as specular regions on the ceiling, sides, and floor, are covered with 18” pyramidal RF absorber, while the “transmit” end wall (i.e., the wall behind the fixed chamber antenna) is covered in 12” pyramidal absorber. The remainder of the surface is covered in 8” wedge absorber oriented along the propagation direction. The chamber design was provided by Cuming Microwave Corp., and should provide quite zone VSWR performance of better than -40 dB at 2 GHz and above.

A door on the side near the receive wall provides access to the positioner, while access to the “transmit” antenna is achieved via a window on a custom hinge assembly (Figure 2(a)). The mounting bracket for the transmit antenna also provides support for the web camera and chamber lighting.

The positioner in this first-generation facility has a single axis of rotation, so orthogonal pattern measurements require the antenna to be manually remounted. Measurements are made using a vector network analyzer, with present capability up to 9 GHz. The measurements are controlled by a computer that also hosts a web server, so that the measurements can be taken by remote users. A screen capture of the web interface showing the inside of the chamber is shown in Figure 2(b), and a pattern taken with the facility is shown in Figure 3.

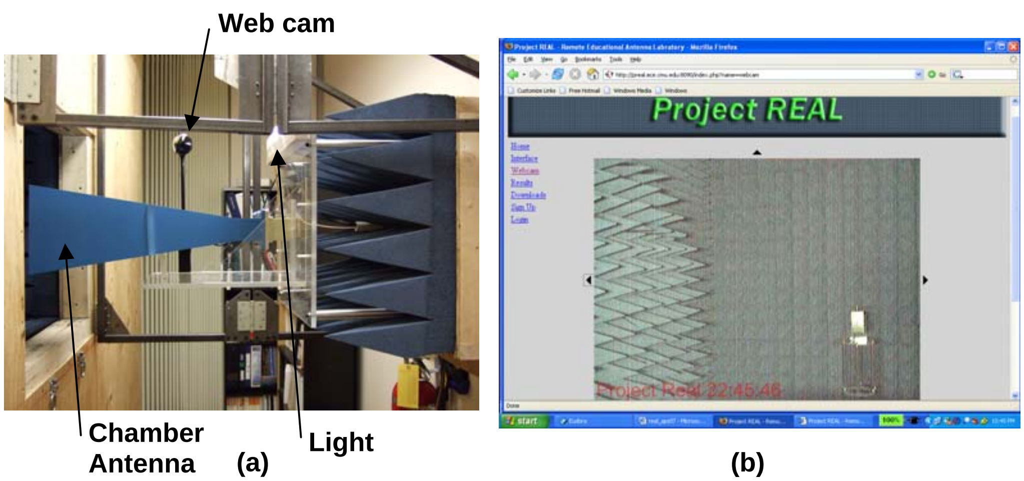


Figure 2. (a) The fixed chamber antenna along with lighting and a web camera are mounted on a window that slides open on a custom hinge. (b) Screen capture showing the web interface and inside of the chamber. An antenna mounted on the rotation stage is visible at the lower right.

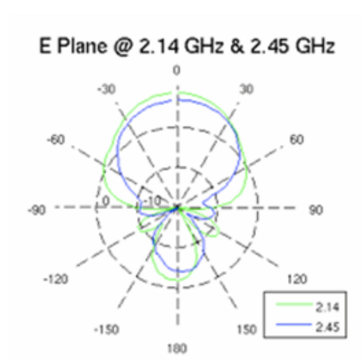


Figure 3. E-plane pattern of a printed 3-element Yagi taken with the REAL facility [5].

Procedure for Use

The REAL facility is presently in the beta testing stage and is not yet publicly available. Consequently, the policies and procedures for scheduling and remote use of the REAL facility are still under development. However, the general procedure is anticipated to be as follows.

Students at participating universities will design and build antennas at their university using local facilities and resources, and time will be scheduled on the REAL facility for testing the antennas.

Prior to the scheduled time, the antennas to be tested will be shipped to REAL. The antennas will be mounted in the chamber by the REAL technician, who will then turn control of the measurements over to the remote users and stand by in case assistance is needed. The users will have full control of the microwave measurement equipment as well as the antenna position and rotation. Live audio and video connections will assist the remote users. Measurements available to the users will include antenna return loss as a function of frequency, azimuth and elevation radiation patterns, and antenna gain by comparison with standard antennas.

Summary and Conclusion

The Remote Educational Antenna Laboratory is a new facility for the purpose of providing calibrated characterization of student constructed antennas. When completely operational, it will be available for use by students and instructors around the world, providing measurement experience to enhance and deepen the practical understanding of antennas.

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