

Antennas for Everyone

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Abstract

For several years the Electrical Engineering Technology program's senior level communications course has run an antenna contest where students must design and build their own antenna for reception of a specified UHF television channel. With modifications, the same contest has recently been used for an engineering freshmen orientation program and for Master's students in Electrical Engineering. The contest has become a great success with both the seniors and graduate students who design their own antennas and with the freshmen that follow directions to construct and test the antenna. Low-cost building materials are provided for the freshmen. In addition, they are able to complete the contest in a few hours. In contrast, upper-class students purchase their own supplies and take a few weeks to complete the building, although testing for a class of ten to twenty can be completed in one hour. The contest is extremely versatile in terms of student level and equipment needed. For testing, the minimum equipment needed is a modified TV and voltmeter. For advanced testing, the equipment needed would be an expensive RF vector network analyzer and a spectrum analyzer. Freshmen students learn about the basic antenna parameters such as polarization and frequency of operation. The advanced students learn about efficiency, directivity and gain, and have time to study the practical concepts of creating a low loss match. Graduate students find the building and creative aspect of the contest quite different from many of their computationally intensive antenna assignments. Over the years, someone in the senior class has tried nearly every antenna type. Most students walk away with at least a working antenna they can use in their home.

Introduction

Hands-on and laboratory experiences are highly emphasized in the SIUC Department of Electrical and Computer Engineering as well as in the Department of Technology. Both of these departments teach senior-level and/or graduate-level courses on antennas or on communications where antennas are a significant part of the course. Many antenna types are introduced in these courses, which use standard textbooks^{1,2}. Many of the antenna types introduced can be fairly inexpensive to build at certain frequencies, requiring copper tubing or wires and connectors. There was a need for the students to have experience designing, building and testing their own antennas. Yet, because of the expense of antenna laboratory equipment, the College of Engineering at SIUC had Vector Network Analyzers for measuring antenna impedance for years before it had a near-field or far-field antenna pattern measurement system. As lack of equipment can bring inspiration³, it was during that time that an antenna contest was developed for seniors.

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Later, the contest was modified for incoming College of Engineering freshmen participating in Success Week.⁴

Senior or Graduate student project

For this contest, students build a UHF TV antenna for a specified local channel. They tune their antenna's impedance in the laboratory using a vector network analyzer before the contest day. Then, they compete with other students on the day of the contest to see which gets the strongest signal.

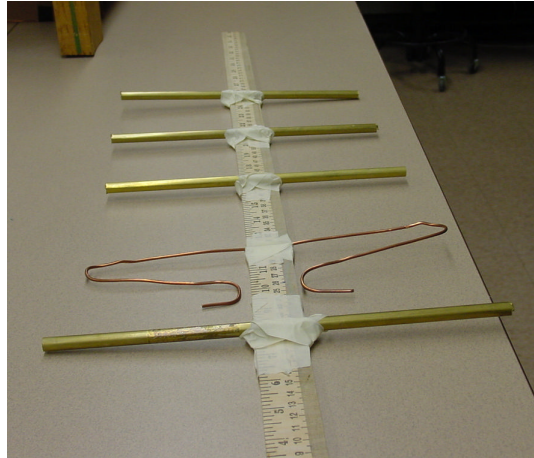
Students must first consult their textbook or other source to determine the frequency of operation of the specified channel. For example, we have usually used WCTC Channel 27 in Marion, Illinois that operates in a 6 MHz band about 551 MHz. At this frequency, a wavelength in free space or air is about 0.54 m. This allows for reasonably sized antennas even if the driving element is resonant.

Students are given access to the lab for construction and testing before the contest date. They are supplied with the connector needed to hook to a cable that goes to the television set on the contest date. Any other connectors, baluns, transformers, and the antenna material itself are supplied by the students. It is up to the student to decide on the type of antenna to try and how to proceed with the design.

Students are graded by the VSWR they measure in the laboratory and received signal strength relative to their classmates and to a demonstration dipole antenna. Signal strength is measured from an outdoor 4th floor balcony. Students are allowed five minutes to find the orientation for their best reading. The signal strength can be the voltage reading on the AGC of the television set or the dBm reading on a spectrum analyzer. Both methods have been used, but not for the same semester since the television has a 75-Ohm connection and the spectrum analyzer has a 50-Ohm connection.

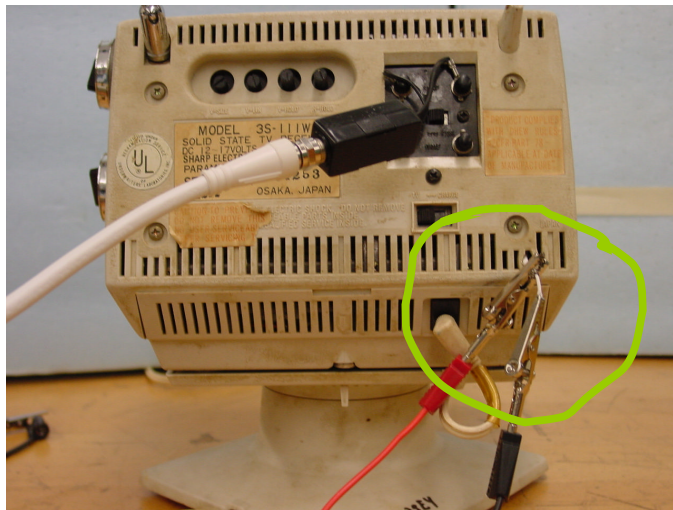
Freshmen project

The freshmen project needs to be completed in a few hours. That includes time for learning a bit of theory, construction and testing. The staff provides the freshmen with the center frequency of operation of the channel, the formula to calculate wavelength from frequency, and inexpensive materials to build a folded-dipole driven Yagi-Uda antenna as well as lengths and spacings specified in terms of wavelengths. Shown here is one antenna under construction. A yardstick serves as a boom and a way to measure lengths and spacings. The driver is made of copper wire. The reflector and directors are made of tubing the students must cut to size. All elements are connected quickly to the boom with tape. Students use a 4:1 balun to connect to the 75-Ohm TV cable. Only a few students have time to adjust their antenna while looking at a VSWR measurement. Most go right to the outside test site.

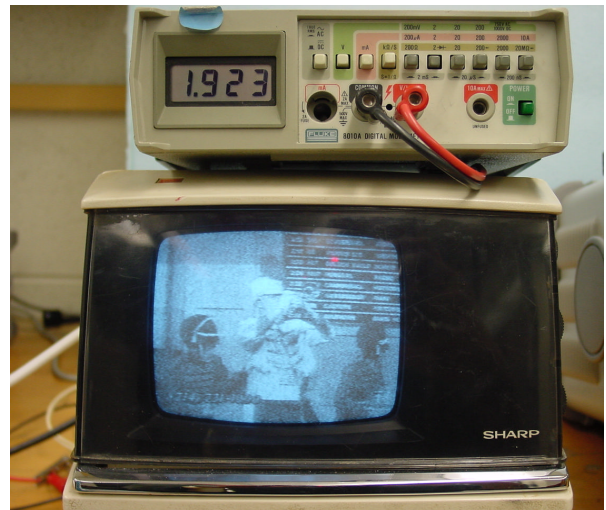


Freshman Yagi-Uda under construction

Television set



Back of television set showing connection to AGC



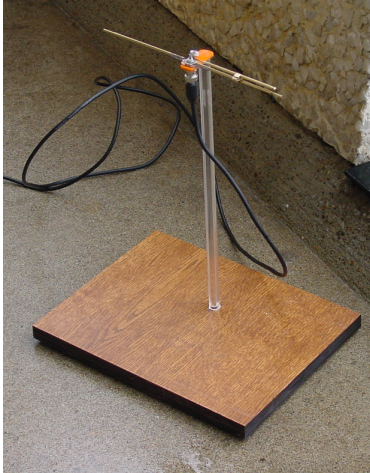
Front of television set in lab showing picture and voltage reading

A small, shielded coax is connected to the AGC voltage, which was labeled on the printed circuit board of the TV. This dc voltage varies from approximately 1.8 volts at the noise level up to 3.8 volts for the maximum signal for the signal from Channel 27 for the antennas tested.

Polarization and Pattern

Shown here is a demonstration dipole that was constructed by the professor. This is used as the first entry in the contest. Normally, all the other contestants will use an antenna with more gain than a dipole unless they have a loose connection. By rotating the dipole and watching the signal strength, students see that the television station is broadcasting horizontal polarization, and that the dipole has nulls in its pattern along the axis of the dipole. Seniors know this and enjoy watching the experiment prove true their knowledge. Freshmen were briefly taught about polarization and pattern before building their Yagi-Udas, and now see this demonstration.

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Demonstration Dipole



Spectrum analyzer reading power received in band by dipole.

Directivity and Gain

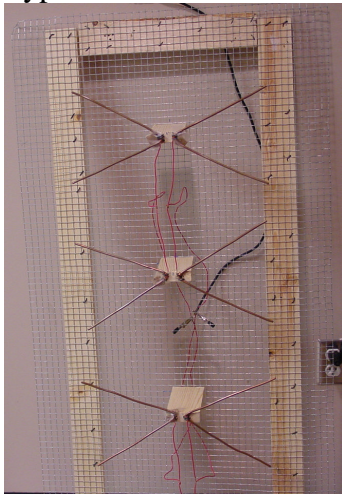
For the seniors, one of the most important lessons of the experiment is that some antennas of very large size and thus expected large directivity do not perform well on the outside test if they did not test well on the VSWR measurement in the lab. The fact that Gain is efficiency times Directivity is usually made very clear during testing.



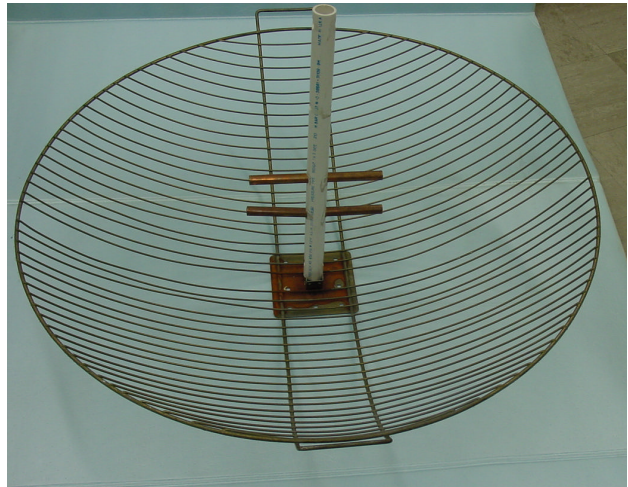
Impedance Measurement on VNA of freshman Yagi-Uda

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Types of antennas



Three element bow-tie array



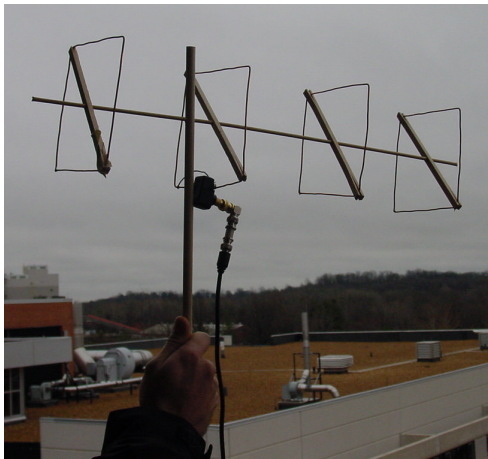
Parabolic dish



Qugi (quad and yagi)



Corner reflector



4-element Quad array



Henna

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Antenna winners have included a 3-foot diameter parabolic dish, a 6-element Yagi Uda, a 13-element Yagi Uda, 4 10-element Yagi Uda's in a broadside phased array, V antenna, rhombic, horn, 14-element Yagi Uda and a corner reflector with a Yagi. Some of the graduates have gone to work at Channel Master, Antenna Specialist and other antenna companies. Pictured above are some of the entries from the Fall 2001 contest.

Bibliography

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2. Warren L. Stutzman and Gary A. Thiele, *Antenna Theory and Design*, 2nd ed., John Wiley & Sons, New York, 1998.
3. Randall Musselman, "A Fun Hidden Transmitter Hunt Offers an Inexpensive Hands-On Antenna Experiment Rich with Insight", Session 1332, *ASEE 2001 Annual Conference and Exposition*, June 25, 2001.
4. Chevalier, L.R., Chrisman, B., and Kelsey, M., 2001. "Success Week: A Freshman Orientation Program at Southern Illinois University Carbondale College of Engineering." *International Conference on Engineering Education*, Aug. 6-10, 2001, Oslo/Bergen Norway.

Biographies

DR. FRANCES J. HARACKIEWICZ received her B.S.E.E., M.S.E.E. and Ph.D. from the University of Massachusetts at Amherst in 1984, 1986 and 1990 respectively. In 1989, she joined the faculty at Southern Illinois University Carbondale, and is now an Associate Professor in the Department of Electrical and Computer Engineering. Her research is in microstrip antennas, anisotropic materials, and pre-college engineering outreach.

DR. JEFFERSON F. LINDSEY III is a professor of electrical engineering technology at Southern Illinois University Carbondale and owner of Lindsey Associates an engineering design firm. He has a BSEE, MSEE and DEng from the University of Texas, University of Houston and Lamar University respectively. He has published over 60 technical articles, and is the designer of the antennas used on the Apollo astronaut backpack and on the lunar rover.

DR. LIZETTE R. CHEVALIER received her B.S. degree in Civil Engineering from Wayne State University, and her M.S. and Ph.D. from Michigan State University. She joined the faculty at Southern Illinois University – Carbondale in 1995. Her main interest is environmental engineering with an emphasis on soil remediation involving nonaqueous phase liquids. In addition she is active in engineering education using modern technology.