The Montgomery College Parabolic Antenna Project

David Bern, W2LNX
Adjunct Lecturer
Montgomery College, Rockville, MD
DavidBern@Engineer.com

Dr. Muhammad Kehnemouyi
Muhammad.Kehnemouyi@MontgomeryCollege.edu
Chairman, Physics, Engineering & Geosciences
Montgomery College, Rockville, MD

AMSAT-DC Meeting, May 15, 2005

The AMSAT Adopt-a-College Program

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in **partnership with** government, industry, **educational institutions** and fellow amateur radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

We, as radio amateurs and members of AMSAT, have a wonderful opportunity to demonstrate to our young people how much fun, interesting and exciting science and technology can be.

caution: a shameless advertisement

Background

- Montgomery College, Rockville, Maryland, is a two year college with identical engineering courses as the UMCP Clark School of Engineering

- first course in the engineering sequence is ES100: Introduction to Engineering Design
  - freshmen course with no prerequisites
  - learn Pro/ENGINEER, a 3-D solid modeling program
  - learn the application of spreadsheets in engineering
  - assigned a group design and construction project
  - write an engineering report and prepare an oral presentation

- current design and construction projects are mechanical engineering in nature
  - mostly tinkering with little or no math used in the design

- over two years ago, Dr. Kehnemouyi asked me to propose an electrical engineering project for ES100
  - inspired by the presentation A *Disposable* Antenna for Receiving AO-40 on S-Band by Tony Monteiro, AA2TX, at AMSAT-NA Space Symposium, 2002.

Instructional Goals for the Design Project

- experience designing and constructing something
- introduce the design process
- simple design project success criteria
- a sense of of accomplishment and confidence
- understand what formulas mean and how to use them
- experience doing some calculations as part of a design
- work in design teams
- learn some communications skills

Parabolic Antenna Project

- the students had to design and build a parabolic reflector for a 2.4 GHz parabolic antenna
    - interesting mechanical shape
    - calculations are required for the design
    - the formulas are understandable
    - 2.4 GHz is “student-friendly”
    - simple “it works” test
    - inexpensive materials

Provided Resources

- spreadsheet with design formulas
- flip-chart of large graph paper with a one inch by one inch grid
- aluminum window screening
- 2.4 GHz signal source: Hewlett-Packard 8614A signal generator
- patch antenna: circularly polarized 2401 MHz, Robert Suding, W0LMD
- down-converter: modified AIDC 3731AA, Bob Seydler, K5GNA
- communications receiver: Yaesu VR-120D

Parabolic Reflector Design Formulas

- Equation of a parabola

$y = a x^2$ where $a = \frac{1}{4f}$ f is focal length

- Depth of a parabolic reflector

$d = \frac{D^2}{16f}$ or $f = \frac{D^2}{16d}$ D is diameter

- f/D given the beam width of an antenna feed

$\frac{f}{D} = \frac{1}{4\tan(\theta/4)}$ θ is the beam width

Parabolic Reflector Design Formulas

- Length of a parabolic segment

$$L=\frac{\ln(\sqrt{a^2 D^2+1}+aD)}{4a}+\frac{D\sqrt{a^2 D^2+1}}{4}$$

a is defined above

- Surface area of a parabolic reflector

$$S=\pi\frac{(a^2 D^2+1)^{3/2}-1}{6a^2}$$

a is defined above

- Gain of a parabolic reflector

η is efficiency

$$G=10\log_{10}\left(\eta\frac{4\pi A}{\lambda^2}\right)$$ where $$A=\frac{\pi D^2}{4}$$

λ is wave length

Signal Generator

Signal Generator

Patch Antenna and Receiver

The Performance Test

The concrete and cinder block walls of the building provide the right amount of signal attenuation to test the parabolic reflector.

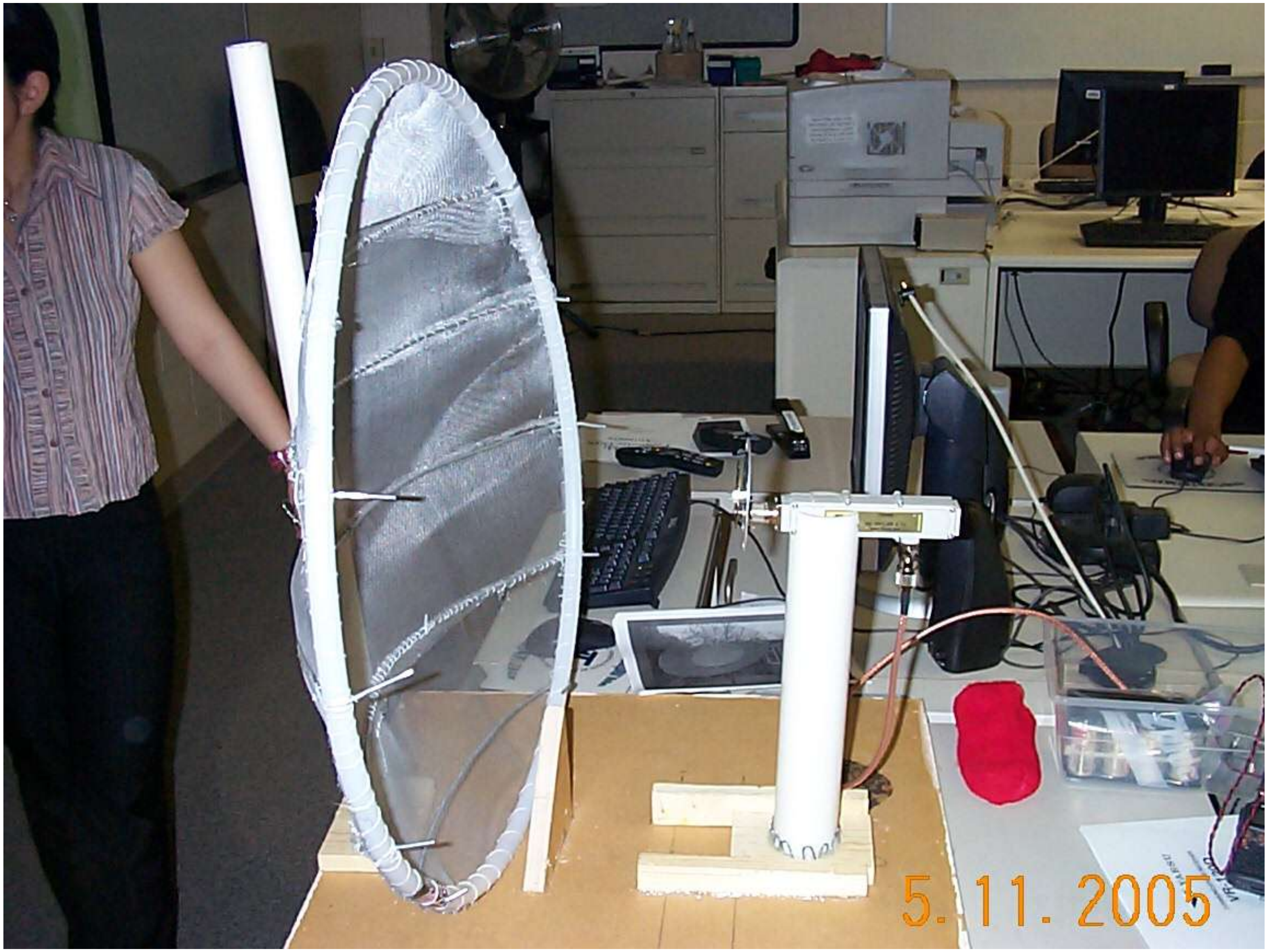
- turn on the VR-120D communications receiver to 146 MHz on wide-band FM in the same room as the H-P 8614A signal generator.

- turn on the H-P signal generator by depressing the LINE, RF, ALC and SQ WAVE buttons. Set the frequency to end of the FREQUENCY dial to 2400 MHz. Adjust the ΔF knob until a tone is heard on the receiver. Adjust the ATTENUATION dial to get the loudest tone. Adjust the ALC CAL OUTPUT until the meter indicates 0 dBm. Peak the signal on the receiver by adjusting its tuning knob to get the loudest signal and maximum indication on the S-meter.

- take the patch antenna and receiver and walk around the hallways until the tone is barely heard. Orient the patch antenna so that the tone disappears. Place the parabolic reflector so that the patch antenna is at the focus. Success when the signal returns.

Team 1: Shila and Mai

Team 1: Shila and Mai



Team 2: Andrew and Chris

Team 2: Andrew and Chris

Student Performance

Team one did well

- asked many questions
- were receptive to suggestions for improvements
- there was a distinct rise in the signal in the performance test

Team two did poorly

- rarely asked questions
- were unable to justify that the round plastic sled is parabolic
- sloppy performance test

Some Lessons Learned

- specify exact dimension of diameter by specifying the gain
- specify tolerances as one-tenth of wavelength
- start the project earlier in the semester
- less lecturing and more class work activities involving the formulas
- specify project milestones with due dates
- evaluate commercial patch antennas and down-converters
- goal of copying an amateur satellite on 2.4 GHz

Conclusions

- we are encouraged that the parabolic antenna project is appropriate for freshmen students
- the parabolic antenna project is challenging but feasible
- students can learn enough math to do this project
- we plan to adopt this project for the Fall 2005 semester at Montgomery College
- personally, I am amazed that all this stuff works so well

References

Kraus, John D., Ronald J. Marhefka, **Antennas for All Applications**, third edition, McGraw-Hill, New York, 2002.

Monteiro, Anthony AA2TX, A *Disposable* Antenna for Receiving AO-40 on S-Band, **Proceeding of the AMSAT-NA 20th Space Symposium**, Fort Worth, Texas,2002.

Seydler, Robert K5GNA, **AIDC 3731AA Down-Converter**, www.k5gna.com

Straw, R. Dean, ed., chap. 19: Antenna Systems for Space Communications, **The ARRL Antenna Book**, 20th edition, ARRL, Newington, Connecticut, 2003.

Suding, Robert W0LMD, **Dish Feed Systems,** www.ultimatecharger.com/Dish_Feed.html

Wade, Paul W1GHZ, **The W1GHZ Online Microwave Antenna Book,** www.w1ghz.org/antbook/contents.htm, 2005.

Questions Answered

Questions?

Suggestions?

Comments?