

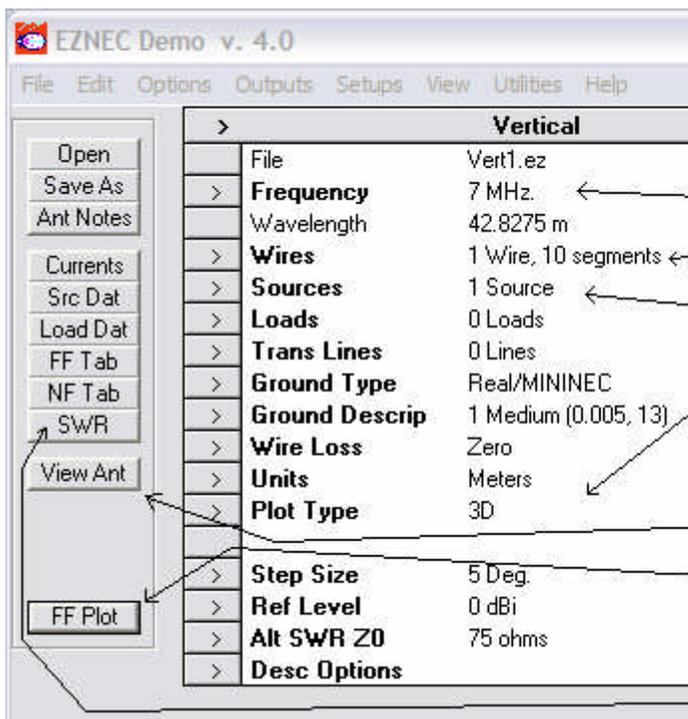
This antenna pattern might be the pattern resulting from a monopole antenna on the top of a spacecraft.

It has good omnidirectional coverage except for the hole directly overhead and all directions below the spacecraft.

On the ground it might make a good omni for most passes.

**Introduction:** One aspect of communications that will have the biggest impact on your physical spacecraft design will be the antennas. Either the antennas are big and cumbersome and impact the structure simply due to their size and pointing requirements or are small or simple but then all surfaces of the spacecraft become part of the near field of the antenna and have significant impact on the antenna radiation patterns. Further, all spacecraft have to have at least one omni-directional antenna for command and control, and these will usually fall into the later category with significant pattern effects.

To model the radiation pattern of your antenna and the impact of surrounding surfaces, we have licenses for the antenna analysis program called EZNEC installed on the workstations in R-122..



**First you will:**

- Select the frequency and scale
- Build your wire-grid antenna model
- Set the location of your transmission line
- Select the plot type (3D)

**Then you will:**

- View your antenna model
- Plot the radiation patterns
- Plot the Standing Wave Ratio

EZNEC uses the method of moments to sum up all the contributions of all the RF currents flowing in all surfaces of an object to calculate the resulting far-field radiation pattern. You will use this program to

explore the basic fundamentals of antenna patterns and gain and then will develop a project using it. Below is the EZNEC main control panel:

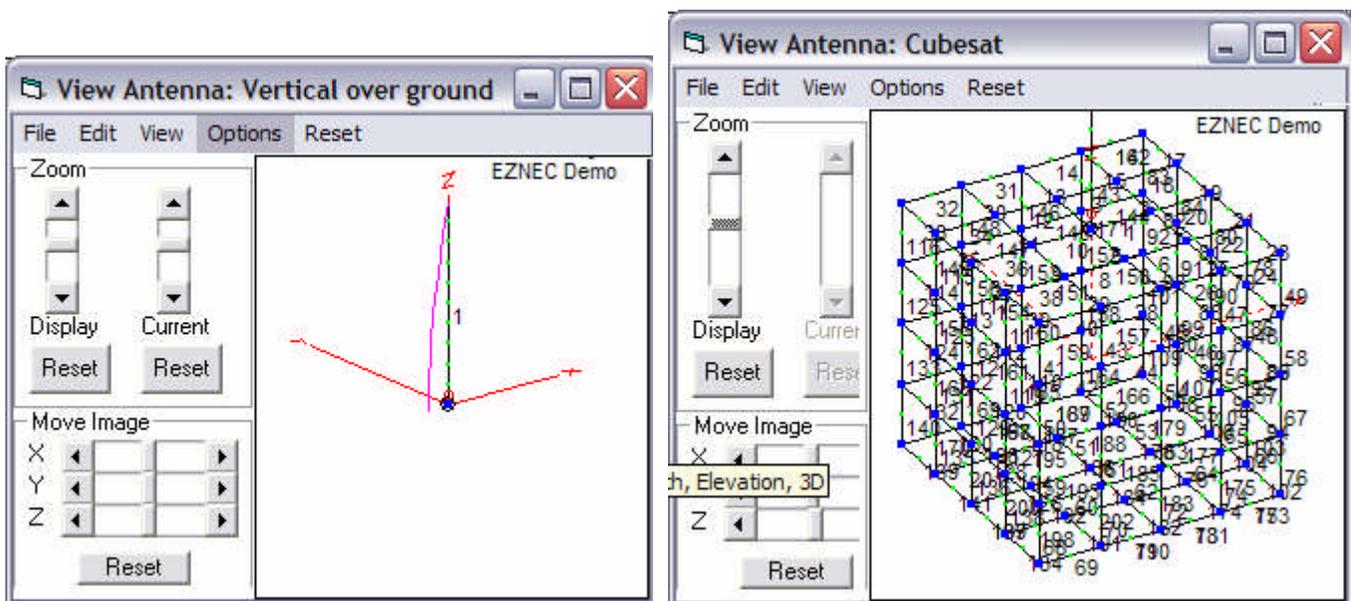
**CAUTIONS:** *In this lab, you will be opening certain model files to manipulate them. PLEASE make sure that you do not SAVE a modified file over the top of our standard files. Either change the name of the file or save it on the desktop.*

**TEAMS:** We only have 9 licensed workstations with EZNEC installed, so form teams of two students per workstation. Many of these exercises will take two people, since one will operate the program and the other can best assist with a pencil and some engineering paper to make sketches and help compute X, Y, Z coordinates for the wire models.

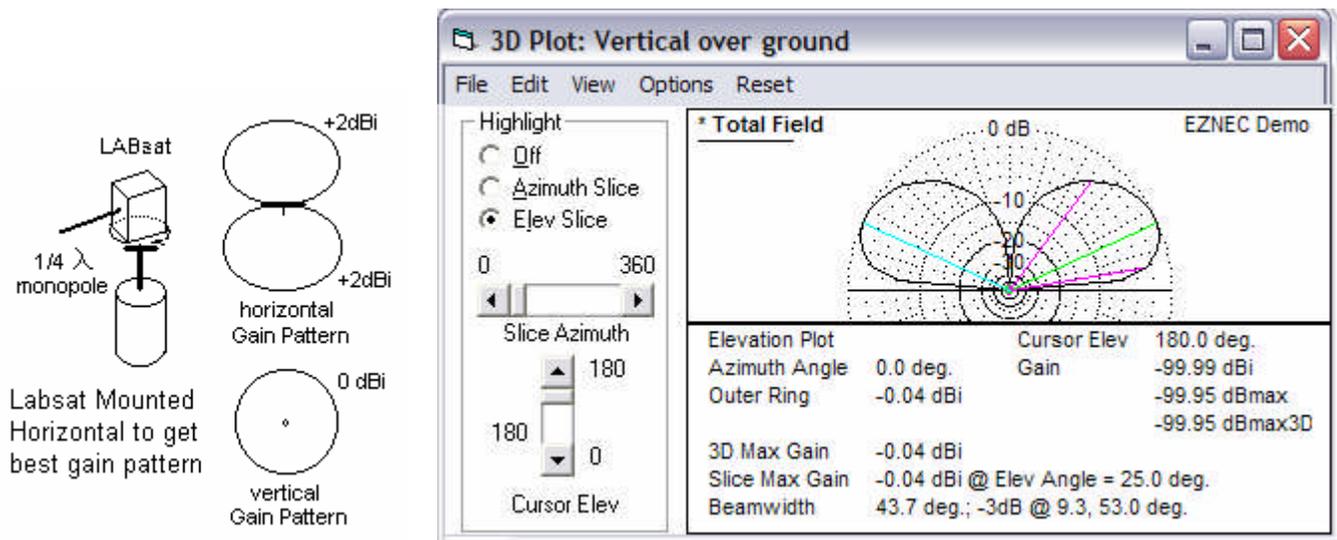
**CAPTURING IMAGES:** To save EZNEC images for your report. Hit the Print-Scrn key, then open the Windows PAINT program, and hit *paste*. Then save the file and email it to yourself.

**Antenna Models:** The model is made up of small lengths of wire with the sum of all their contributions integrated over space. This is called a *wire grid model*. To limit processing demands, the general rule is that segments no larger than about 0.1 wavelength are sufficient to give a reasonably close approximation to reality. Unfortunately the software is limited to 500 segments and it is surprisingly easy to run out. You will use the WIRES tab to build your antenna model, and SOURCES to set the location of your transmission line feed point. The location of segments in the model are simply points in the X,Y,Z planes. Below left is a simple model of a monopole over a plane, and a more complex model of the 10 inch cube PCsat is shown on the right with a monopole whip antenna on the top.

**HINT:** *Be sure to have a few pages of engineering paper handy to help you sketch your wire model and help you decide on the coordinate system and point values.*



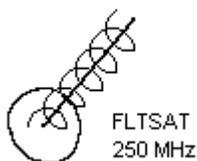
**3D Pattern Plots:** The result of the EZNEC calculations is a 3D plot of the antenna pattern that can be viewed and rotated in any angle as shown on the next page, or a 2D plot that contains a number of numeric results such as the maximum gain of the main lobe, and the 3 dB beamwidth as shown below:



**Part A: Labsat Monopole Pattern:** The first element of this lab is to build a model of a LABsat with a 530 MHz monopole antenna and take off-air measurements of its antenna pattern to compare its theoretical pattern from with your measurements. The monopole should be 1/4 wavelength long at that frequency.

- 1) Open the LABsat530.ez model and modify the “wire” that represents the monopole to the correct length. Raise the model about 5 feet above ground. Use at least 10 segments in the monopole wire. Enter your source at the base of the wire where it attaches to the LABsat. Set plot type to azimuth. Leave the antenna as a free space model (do not use any ground for this part).
- 2) Produce a far-field 2D elevation plot and save the image for your report. Do NOT save your antenna model unless you give it a unique name, so that we do not destroy the original LABsat530.ez model.
- 3) Now add a real ground and see the effect of ground reflections on the antenna pattern.

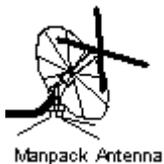
**Post Lab:** You will compare this antenna pattern to the pattern you will measure in the antenna lab.



**Part B: Helix Antennas:** To complete this part you will construct an EZNEC model of the Fleetsat helix we used in the EA-204 lab and compare the predictions with the measurements you will make in the

EA467 Antenna lab. Start by loading the Dipole1.ez and change UNITS to inches so you can make measurements with a simple ruler.

- 1) Under the WIRES tab, create a helix of the dimensions of our Fleetsat antenna. Set End-1 on the ground plane pointing in the +Z direction Use 8 segments per turn and make the wire diameter about 0.4"
- 2) Add a perfect ground plane and then delete the original wire #1 which was the original dipole. Now set a source at the beginning of wire #1 where it is connected to the ground plane.
- 3) Do an SWR plot of the antenna over the frequency from 220 to 320 MHz.
- 4) Call up the various displays of the antenna, pattern plots and SWR and hit the Print-Screen key and paste the images into PAINT and save for your report.



**Part C. Manpack Antenna:** The manpack antenna is a cross polarized pair of dipoles to optimize satellite reception when the polarization is not known. For this lab, you will build your EZNEC antenna model for only one of the dipoles since the two polarizations are independent of each other.

- 1) Take measurements of the manpack antenna with a ruler so that you have the dimensions of both the dipole, its height above its ground plane and the dimensions of the ground plane. Open the Dipole1.ez as a starting point. Change the model by scaling it to 300 MHz and entering a wire grid model of one of the dipoles and the ground plane. Make the dipole as two rectangles with a small 2" short segment in between and place your source at the center of that short segment.
- 2) Make the radials of the ground plane by making just one, and then use the RADIAL tool to generate the rest. Remember to give them a meaningful thickness. Look at the wires table, and now add in the additional circumference wire part of the ground plane.
- 3) Produce both 2D and 3D plots and data for your report.

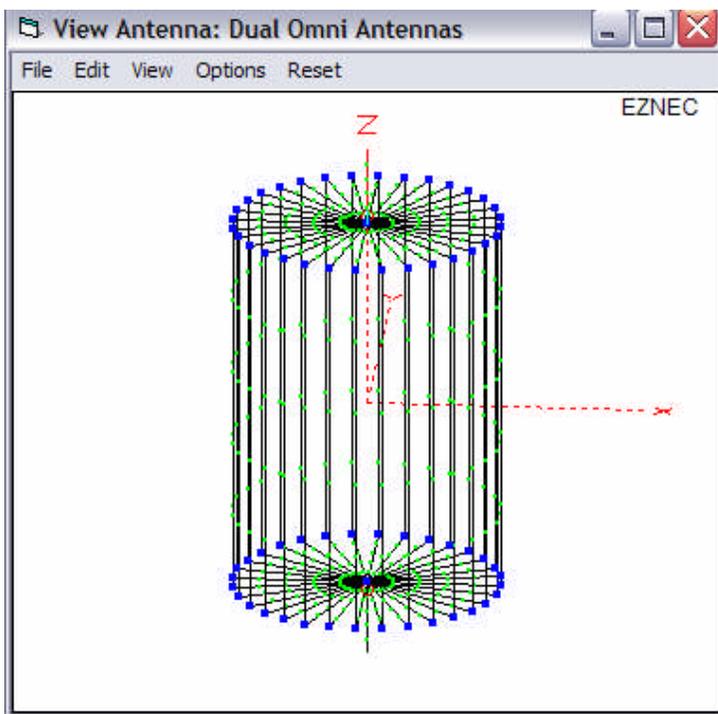


**Part D: Parabolic Dish Antennas:** One of the most common antenna types used for space applications is the parabola because it can be used over a variety of frequencies by only changing the feed system. The feed then is usually only a dipole in front of a small reflector to focus the energy into the dish. But since the largest structure of the dish acts as nothing more than a reflector to focus energy on the feed usually only the pattern of the feed is modeled in programs like EZNEC, and then the gain calculated purely from the geometry. But for the purposes of this lab, we generated a wire grid model of the dish itself. To keep

the number of segments below the 500 maximum, we only use a linear feed in one polarization, and therefore we only need to model the dish in that one polarization. The holes in the dish are less than 0.1 wavelength to keep within the rule of thumb.

- 1) Open the file named “dish.ez”. View the antenna model and you will see that it is a very deep dish with the feed dipole deep inside. Normally dishes are flatter and have the dimensions where the focal point is .4 from the center of the dish compared to the diameter. As loaded, the feed point is 3 inches from the dish. Look at the Far Field and 3D plot and then 2D plot and antenna gain.
- 2) Using the WIRES tab, adjust the height of the feed dipole and see the effect on the gain and radiation pattern. See if you can find the location of the highest gain.
- 3) Adjust the length and thickness of the feed dipole to get the lowest SWR at 2400 MHz and comment for your report.

**Part E. Omni Antennas, Spacecraft and Multipath:** All spacecraft need omni antennas, but large spacecraft usually need one on opposite ends of the spacecraft to assure spherical coverage. But whenever you have two antennas connected to the same system, if they have overlapping coverage, there will be multiple lobes in the antenna pattern due to the mutual constructive and destructive interference of the waves in the overlapping areas. This lobing effect is called “multipath” which causes these phase differences. This effect occurs in all RF systems when there are multiple reflections and different path lengths from one antenna to any point. Follow the instructions below:



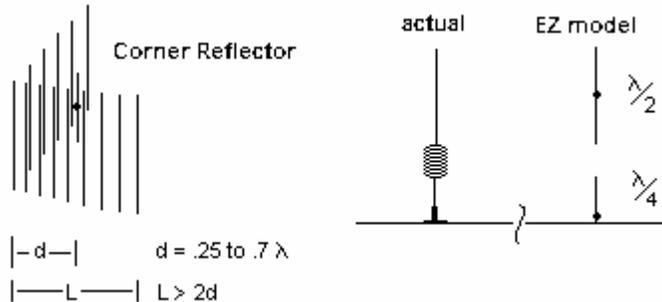
**Open:** the file named dual-omni.ez

**Demo 1:** See how the pattern improves if only one OMNI is used. (go to sources and delete the second source (wire 2)).

**Demo 2:** See how the pattern gets worse if the frequency is higher. (change the frequency on the frequency tab).

**Demo 3:** See how the pattern gets worse if the antennas are moved to opposite corners where their coverage overlaps increase. (Change wire 1 end to X=10.5 and Wire 2 end to X=-10.5)

**Part F. Personal Antenna Design:** For this portion of this lab, you will design an antenna reflector system and model it on your own. You will build the wire model, and obtain your best gain, and also preferably a low SWR at your operating frequency. You only need to do one of the following suggested projects:



- A corner reflector of at least 20 rods to place behind your personal 802.11 Wireless Access Point dipole antenna (2400 MHz) to attempt to give gain in one direction and give you some security in other directions. See how much gain you can achieve. Make your corner reflector at 90 degrees with rods spaced closer than 0.1 wavelength. Iteratively find the optimum location for the feed along the centerline to get the best gain.
- A pocket corner reflector for your cell phone (as in (a)), but designed for the 800 MHz cell phone band or your PCA phone at 1800 MHz.
- Model the typical Cell phone gain antenna you see on cars, which is a 1/4 wave monopole on a ground plane, but then over the top of it is a full size dipole fed in phase. In real antennas, this is accomplished with a coil to give a phase delay, but your model will simply use a source at the base of the monopole and another source in the middle of the raised dipole. What is the optimum spacing for the Dipole above the monopole?

**Post Lab:** You will be using many of the elements of this lab for comparison with the values obtained in the Antenna Lab next period. You will write a combined formal lab report to cover all the material in both labs.. Compare actual results to theoretical or those results from the antenna modeling program to show how theory meets practice. The lessons learned here will be very important to you in your satellite design.