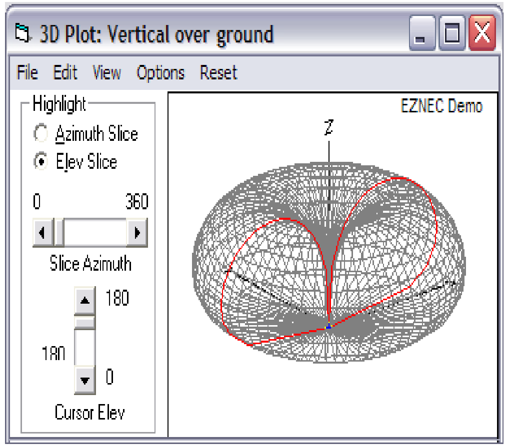
EA467 Antenna Design using EZNEC (revA) Fall 2008

Introduction: A significant aspect of your spacecraft physical design will be the antennas. Either the antennas are big and cumbersome and impact the structure, and pointing requirements or are small and 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. 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.



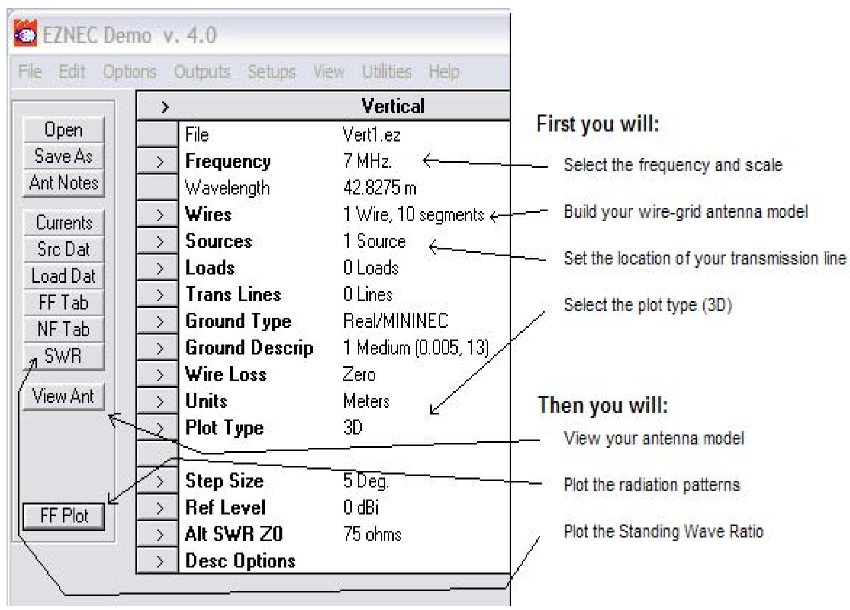
This antenna pattern might be the pattern resulting from a monopole antenna on the top of a spacecraft.

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.

To model the radiation pattern of your antenna and the impact of surrounding surfaces, we use the antenna analysis program called EZNEC installed on the workstations in R-122. NEC stands for Numeric Electromagnetic Code and gives us a computer method for predicting the performance of antennas.

EZNEC sums up 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. Above is the EZNEC main control panel.

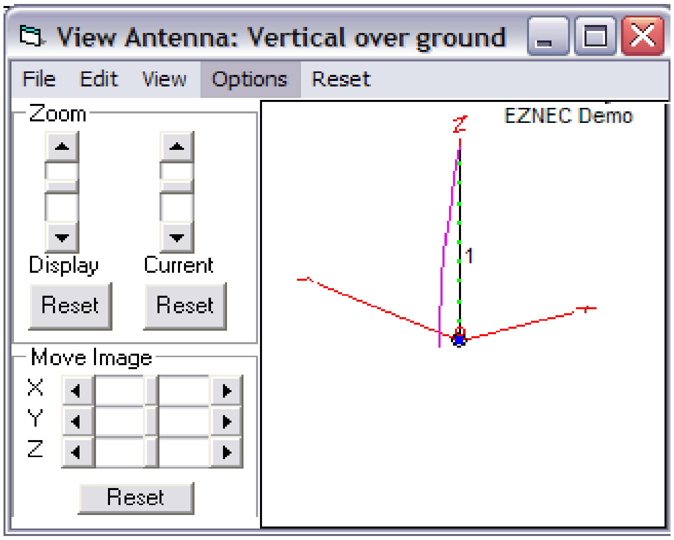


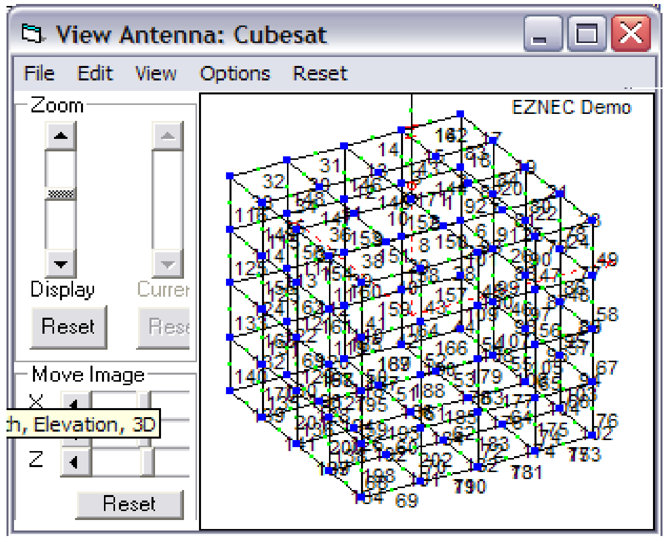
CAUTIONS: *In this lab, you will be opening certain model files to manipulate them. PLEASE make sure that you do not SAVE a modified file over the top of our standard files. Please change the name of the file to your file name and save it on the desktop.*

***TEAMS*:** All R-122 workstations have EZNEC, so form teams of 2, one can operate the program and the other can assist with pencil and scratchpad to help compute X, Y, Z coordinates for the wire models.

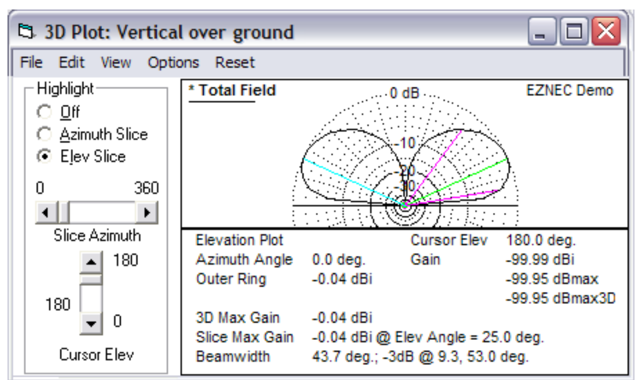
CAPTURING IMAGES: To save EZNEC images for your report use COPY under the VIEW menu. Paste these plots into a WORD document for your report. Then save the file and email it to yourself.

Antenna Models: The spacecraft solid model is made up of small wire segments called a *wire-grid* model. To limit processing load, wire segments no larger than about 0.1 wavelength are sufficient to give a reasonably close approximation to reality. EZNEC is limited to 500 segments which is surprisingly easy to use up. You will use the WIRES tab to build your antenna model, and SOURCES to set the location of your antenna feed point. The location of each wire in the model is specified by the XYZ coordinates of the end points. Below left is a simple model of a ¼ wave monopole over an infinite ground plane, and on the right, that same monopole mounted on the top of a cubesatellite in free space.



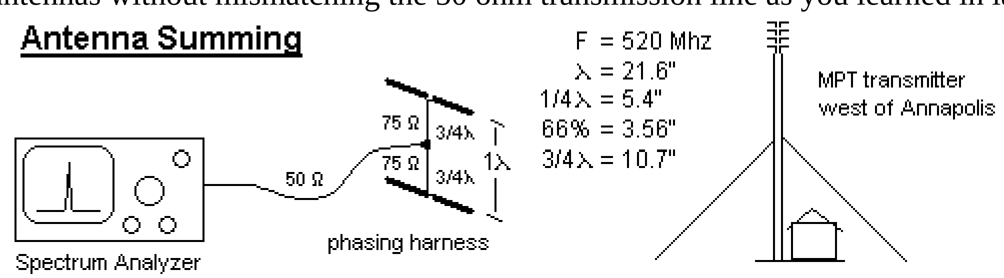


3D Pattern Plots: The result of the EZNEC calculations is a 3D plot of the antenna pattern that can be viewed and rotated in any angle, or a 2D plot that contains a number of numeric results such as the maximum gain of the main lobe, and the 3 dB beamwidth as shown to the right.



Part A: Simple Dipole Antennas

The simplest antenna is a ½ wave dipole fed at the center. It can be built with a characteristic impedance near 70 or 50 ohms depending on its exact diameter and length. In this experiment you will build an EZNEC model of one and then two dipoles fed in phase as shown below (as you will use in next week's antenna lab). Notice how this dual antenna uses two ¼ wave transmission lines to combine the two antennas without mismatching the 50 ohm transmission line as you learned in last weeks lab.



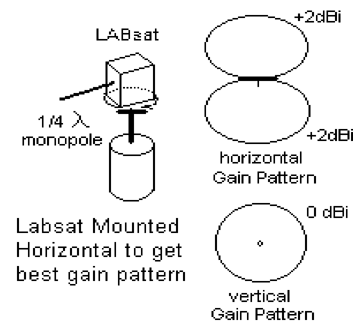
1) OPEN lab-dipole-dual.ez. Then immediately use SAVE-AS tab under your own file name.
2) View the antenna and then set PLOT TYPE to 3D. Next view the FarField plot and rotate as needed to visualize the donut pattern.

3) Then click "show-2D plot" to see the max gain and 3dB bandwidth (copy and save it).
4) Click WIRES and see the dimensions of this wire model
5) Click SOURCES to see that this dipole is fed in the center of the wire
6) Click SWR and RUN to generate an SWR plot between 480 to 560 MHz Click on the center frequency to see the actual SWR and impedance (about 1.4 with impedance about 70-j6 Ohms)

Now build a second dipole 21.6" above the first as shown in the above diagram using the following steps:

7) use WIRES tab to WIRE-COPY #1 with a +21.6 Z offset
8) use SOURCES tab to confirm that it also copied a source with wire 2 also
9) Repeat steps 2 and 3 to see how dual antennas add to create gain lobes and interfere to create nulls.
10) **Post-Lab**, you will use this data and plots to compare your actual antenna measurements next week.

Ground Reflections: The nearness to ground can significantly affect antenna patterns. Continue with the above model by using the GROUND-TYPE to change from free-space to perfect ground. Repeat step 2 to see how this affects the pattern with even more lobes and nulls. Fortunately, our spacecraft are usually in space eliminating ground reflections and making antenna predictions easier.



Part B: Labsat Monopole Pattern: This experiment will build a model of a LABsat with a 520 MHz ¼ wave monopole antenna and compare its theoretical pattern from EZNEC with actual off-air measurements.

1) Open LABsat900-H.ez and then SAVE-AS your ***new filename***.

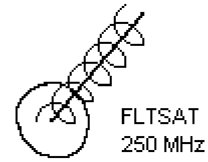
2) View the model to see the antenna (wire #56). Set the plot type to 3D and do a Far Field (FF) Plot and then View-Ant to see the 3D antenna pattern. Notice how the field pattern of this short 2.6" antenna is asymmetrical between the antenna end and the body end because the antenna is small relative to the size of the spacecraft. Do an SWR plot from 880 to 940 MHz and see how the SWR is a very good 1.1 at 910 MHz.

3) Now, change this antenna wire model for our desired 520 MHz antenna. Use the WIRES tab to change this antenna length (wire #56) to a quarter wave at 520 MHz. Now do an SWR plot from 480 to 560 MHz to find the lowest SWR. If it is above 520 MHz, your antenna is too short. If below, your antenna is too long. Change the wire length and re-do the SWR until you get the best SWR at 520 MHz. This will be about 2.0 SWR or better. Now, continue to improve the SWR by playing with the diameter of the antenna (#56) and also the short stub under it, #55.

4) Do a 3D elevation plot and select Azimuth plot with an elevation angle of zero. Notice how the pattern is "rounder" than the original 900 MHz antenna because the length of the antenna is now larger relative to the spacecraft. This demonstrates how the physical dimensions of a spacecraft can affect antenna patterns. Click on the SHOW-2D button and move the cursor around to find the maximum gain of this antenna. Save the pattern and SWR plots for your report.

Post Lab: You will compare this EZNEC antenna pattern to the real pattern you will measure in the next lab out on the plaza.

Part C: 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.



1) Start by using the WIRES tab, and then WIRE-DELETE all wires. Now ***save a NEW filename for this experiment*** for your group.

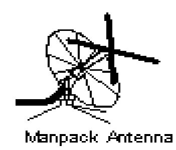
2) Under the WIRES tab use the CREATE menuto make a helix of the dimensions of our Fleetsat antenna. Set End-1 on the ground plane pointing in the +Z direction Use 8 segments per turn and make the wire diameter about 0.4”

3) Change the frequency to 250 MHz. Add a perfect ground plane and then delete the original wire #1 which was an artifact from before. Now set a source in the middle of wire #1 (where it is connected to the ground plane). At this point, the 3D plot should look like a nice main lobe. On the 2D plot move the cursor and measure the gain of the main lobe.

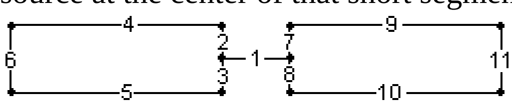
4) Do an SWR plot of the antenna over the frequency from 220 to 320 MHz which covers both the uplink and downlink to the FLEETSATS and UFO’s. Notice it is quite high. Next, change the Alt-SWR-Zo to 140 ohms which is the common impedance of a Helix. On the SWR plot screen, select VIEW-Controls and select ALT (140) ohms. This should improve the SWR because of the better match. Notice how flat the performance of the Helix is across this rather wide bandwidth.

5) For **post-lab**, Call up the various displays of the antenna, pattern plots and SWR and copy the plots to your PAINT or WORD files for preparing your reports later.

Part D. 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 UHF dipoles since the two polarizations are independent of each other.



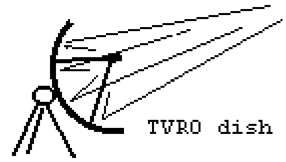
1) Take measurements of the manpack antenna with a ruler so that you have the dimensions of both the dipole, its height above its ground plane and the dimensions of the ground plane. Open the Dipole1.ez as a starting point. ***Do a SAVE-AS to a new filename.*** Change the model by scaling it to 300 MHz and entering a wire grid model of one of the dipoles and the ground plane. Make the dipole wire grid as two rectangles with a small 2” short segment in between (#1 below) and place your source at the center of that short segment. This will take 11 segments as shown here:



2) To make the radials of the ground plane reflector, add just one as a new wire at the correct –Z distance, and then use the CREATE-RADIAL tool to generate the rest. Remember to give them a correct thickness. Look at the wires table to see the endpoints of the radials, and manually add in the additional circumference wires of the ground plane.

3) Produce both 2D and 3D plots and data for your report. Check the SWR across the frequency of 220 to 320 MHz and report the gain of the antenna.

Part E: Parabolic Dish Antennas: One of the most common space antenna types is the parabola because it can be used over a variety of frequencies by only changing the feed system. The feed is usually a simple dipole in front of a small reflector to focus the energy into the dish. But since the large structure of the dish is simply 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 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.

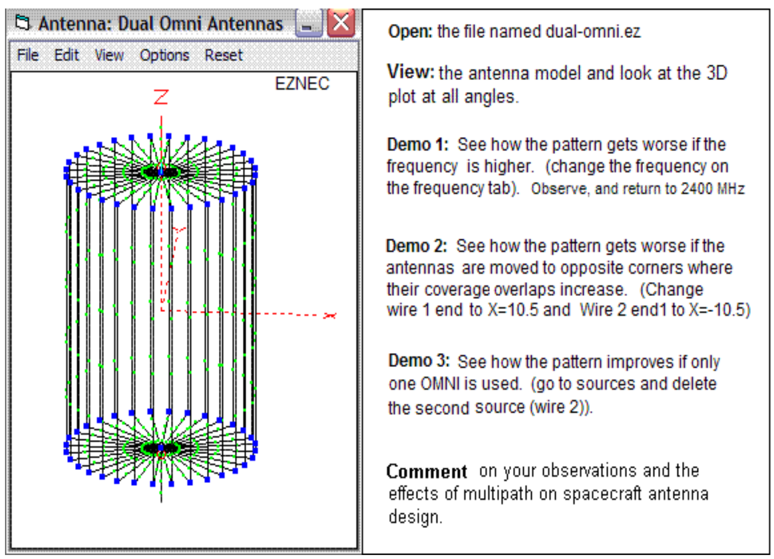


1) Open the file “dish.ez”. ***Do a SAVE-AS to your filename.*** The model is a deep dish with the feed dipole deep inside. Normally dishes are flatter and have the dimensions where the focal point is .4 from the center of the dish compared to the diameter. As loaded, the feed point (wire #425) is 3 inches from the dish. Look at the Far Field and 3D plot and then 2D plot and antenna gain.

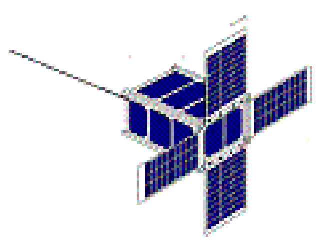
2) Using the WIRES tab, adjust the height of the feed dipole (#425) and see the effect on the gain and radiation pattern. See if you can find the location of the feed to give the highest gain.

3) Adjust the length and thickness of the feed dipole to get the lowest SWR at 2400 MHz and comment for your report. Take copies of the images for your report.

Part F. Omni Antennas, and Multipath: All spacecraft need omni antennas, but large spacecraft might need one on opposite ends to assure spherical coverage. But when you have 2 antennas paralleled, with overlapping coverage, there will be multiple lobes in the antenna pattern due to mutual constructive and destructive interference of the waves in the overlapping areas. This lobing is called “multipath” due to 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 in the image to the right.

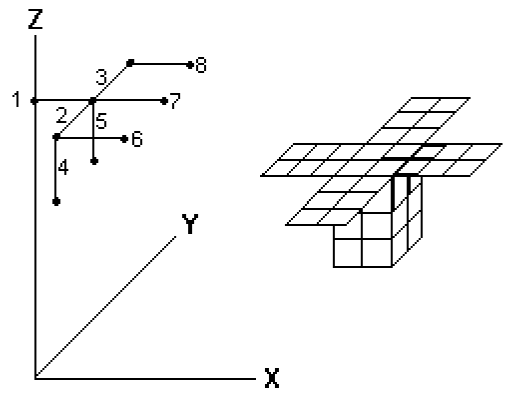


Part G. ParkinsonSAT Antenna Design: For this part, you will design an antenna system for our next USNA satellite. The space craft is a 4” x 4” x 6.6” rectangle with four deployed 4” by 6” solar panels from one end. The antenna needs to be a quarterwave monopole for 145.825 MHz. We need to determine which end is the best, and what length of the antenna will give the lowest SWR. You will build the wire model, and different groups will place the antenna in one of four possible locations.



Possible Antenna locations: Center top, center bottom, corner top, corner bottom

To keep the number of elements in the wire grid model reasonable, you will use a 2 inch grid. This is going to take over 120 elements. At first this seems very challenging since you have to enter the XYZ coordinates of each wire end point. But EZNEC has some powerful tools for copying wires. To simplify your effort, we have prepared the fundamental 8 wires for one edge of the top of the model as shown at right. The actual wires are highlighted on the model sketch. The entire spacecraft can be built up by copying, shifting and rotating these elements. Use the VIEW Antenna tab frequently to see your model grow and keep track of each block of elements you produce because some will need to be copied and re-used.



Spacecraft:

1) Take the 4 wires that make up a row of squares along the side (#2 to 5) and WIRES-COPY them twice in the Z axis, first with Z offset of -2.2 and then again with a -4.4 inch offset to make most of a complete side.
2) Next copy wires 1, 2 & 3 to the bottom (Z offset -6.6) to fill out the side and bottom.
3) Now make one of the solar panels by copying wires 6,7 and 8 first with X offset of 2 and then again with X offset of 4.
4) Finish the solar panel by similarly copying wires 2 and 3 with X offsets of 2, 4 and 6 to finish a complete side of the spacecraft. Next you will copy and rotate that side and panel by increments of 90 degrees to complete the spacecraft.
5) Copy the complete side (wires 1-31) with zero offset (ignore error warning). Next, WIRE-ROTATE them (32-62) through 90 degrees. Repeat the COPY of 1-31 then ROTATE the resulting new side 63-93 through 180, then copy 1-31 again and rotate 94-124 through 270 degrees about the Z axis to make the other 3 sides and finish the spacecraft.

Monopole ¼ wave Antenna

1) Find the coordinates of your antenna location
2) Add a short 0.4 inch wire segment at the base to use as a feed point
3) Add a SOURCE in the middle of this wire
4) Extend a much longer wire beyond it to the estimated quarter wave length

Now vary the length of the quarter wave wire a few percent to minimize the SWR at 146 MHz. Next, vary the diameter of this wire to minimize the SWR value. These two adjustments are interactive and both have to be adjusted to find the right length.

Do a 3D plot of the field pattern and an SWR plot so we can compare antenna designs between groups.

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 EZnec results to show how theory meets practice. The lessons learned here will be very important to you in your future satellite designs.