"Jiffy"
Visualization Software
for
NEC-based Antenna Design
by

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1 Introduction

It is never been easier to design antennas! Most hams enjoy "fiddling" with antennas, but comparatively few of us are really interested in doing one-handed chin-ups at fifty feet above the cold frozen earth on a snowy and windy night in January. ("Been there, done that, and have the T-shirt!")

2 Modeling Software

In recent years there has become available a large variety of software intended for hobby class computers which is capable of modeling antenna configurations. Some of these programs are extremely capable and sophisticated. Their wide availability has wrought a revolution in antenna design, and has turned serious design from a "black art" to a "cottage industry". In particular, the programs from W7EL (see [1]) have been used to great effect on machines with operating systems such as MSDOS, Windows 3.1, or Windows 95. Those programs will almost certainly work well with the next class of operating systems for the hobbyist market, such as Windows NT or the promised Windows 98.

For those amateurs who desire to work with other operating systems there is a great deal of software "out there" for modeling, but comparatively little software for visualizing the results of that modeling.

Hams who are involved with such operating systems as Unix, or its many derivatives, are unlikely to be satisfied with hobbyist operating systems. This statement is not meant to "draw fire". People who are satisfied, for whatever reason, with what they are using are unlikely to be pleased if they have to change to something they do not want to use, no matter what the reason. For those who have not used Unix, FreeSCO Unix, or some form of Linux, my personal opinion is that you are missing something.

The "grand-daddy" of modeling programs appears to be "NEC", a program which resulted from government research, and which still seems to be regarded today as an extremely capable program. NEC is widely available in source code form on the Internet (See [2]). In its original form, NEC consists of about 9000 or so lines of FORTRAN. There are equivalent conversions to the C language which are no smaller.

NEC compiles cleanly under the popular g77 compilers (See [3]), which are widely available for most versions of Linux and Unix. Implementations of g77 are available for SCO Unix 3.2v5.0.X from several sources including [4]. The net result is that unix-based professional modeling programs are available for free over the Internet, and those programs are suitable for use by the average amateur with a modest computer.

The output from NEC, however, consists mostly of long columns of numbers, and using that output for design may be tedious at best. Thus, the purpose of this article.

3 Various Visualization Aids

The huge number of Unix-like systems on the Internet has spawned an enormous collection of software for those systems. The interest in Linux, especially, seems to have caused a lot of creativity to have been expended. Plotting is an activity that has received a lot of attention, and there are a number of plotting systems available on the net which an average amateur easily can manage to compile and install.

It is no wonder that several amateurs, notably KD6PAG [5] and I2KFX have devoted considerable effort to making the output of NEC more "friendly". For instance, KD6PAG has developed a plotting package that reads the output of NEC and generates a GIF image which can be manipulated by any of a huge number of tools. I2KFX has recently published on the Internet ([6]) a program based on the "yorick"([7]) package and which generates screens (including a Smith chart) under X-windows which are extremely helpful in designing antennas.

The purpose of this article is to introduce yet another visualization package (the "GFE" system – "Jiffy" for short) which may be useful to amateurs. It is based on the popular TCL/TK language which is available in the public domain, and which compiles "out of the box" on Linux and SCO Unix systems, and most other Unix systems. Compiled versions are available for the various flavors of Windows operating systems for PC's as well.

The W5GFE software system is based on an extension of TCL/TK called "BLT" (See [8]). This extension is easy to compile and install cleanly on SCO Unix, and should prove to be no problem under Linux. Binary versions are available from various FTP sites.

4 The GFE "Jiffy" Software

The software consists of a suite of five short programs, each of which is intended to serve a specific purpose. Two of these programs are trivial in nature and serve merely as tools of convenience. The effect of these two programs is so miniscule that the programs are really unnecessary, but if you are working with a large number of antennas you may find them handy.

wires.tcl is intended to assist in visualizing the physical arrangement of the wires which make up an antenna. While this tool is a simple one, it is especially helpful and I find that I use it a great deal.

preelev.tcl is intended to "preprocess" NEC input data to ensure that NEC will deliver output data that is useful for other programs in the suite if one wishes to view "elevation graphs". This is one of the "tools of convenience".

preazimuth.tcl serves much the same function, but helps NEC produce output data for "azimuth graphs". This is the other "tool of convenience".

elevpattern.tcl takes the output from a NEC run and provides an "elevation graph" which depicts the vertical plane pattern of the antenna. The output consists of three graphs, one with Cartesian coordinates, and two with polar coordinate renditions.

azpattern.tcl takes the output from a NEC run and provides an "azimuth graph", or horizontal plane pattern of the antenna. Like "elevpattern.tcl" this program produces three graphs.

5 An Example of Use

So let's try it! Rather than design an ideal antenna and assume we have the real estate to accommodate it, let us instead try to design an antenna that must fit in a real situation.

Our rural Oklahoma home sits on about 37 acres of dense oak forest. The house is situated on the highest portion of the land, and the only open portion consists of a meadow running from the house to our southern fence. The meadow is long and comparatively narrow, so it is natural for a ham to consider planting a rhombic in that area.

There are physical constraints of course. The meadow would accommodate a rhombic that was no more than 120 feet wide at its widest point, and perhaps 240 feet long. By using four telephone poles at the corners of the antenna I expect to be able to place the antenna about 50 feet above the ground. The "folklore" would suggest that this is too low, but the real question is, would such an antenna be worth building for 20 meters ?

We start by drawing a diamond (rhombus) with a center at the origin, a "long diagonal" of 240 feet, and a "short diagonal" of 120 feet. This is actually quite a bit different from contriving a theoretical antenna by first determining the length of each leg. Here I am trying to "fit" an antenna into a given space. Since I am just "exploring" I will assume that the wire I will use has a radius of 0.01 feet, which should be close enough. The resulting data cards for NEC are:

```
CM NEC Input File for Rhombic
CE
GW  1 10   -120.0     0.0     50.0        0.0    60.0    50.0   0.01
GW  2 10   -120.0     0.0     50.0        0.0   -60.0    50.0   0.01
GW  3 10     0.0     60.0     50.0      120.0     0.0    50.0   0.01
```

```
GW  4 10     0.0      -60.0      50.0       120.0      0.0     50.0   0.01
GS  0  0     0.3048
GE  1
GN  1  0       0     0      0.0       0.0  0.0  0.0       0.0      0.0
FR  0  1       0     0     14.0       0.0  0.0  0.0       0.0      0.0
EX  0  1       1     0      1.0       0.0  0.0  0.0       0.0      0.0
EX  0  2       1     0     -1.0       0.0  0.0  0.0       0.0      0.0
RP  0  180     1  1001    -90.0       0.0  1.0  0.0   10000.0      0.0
EN
```

There are a number of resources, particularly on the Internet ([9]) which will be of great help in learning to describe a given antenna to NEC. The art is somewhat arcane, but not difficult to master, at least for antennas built from "straight wires".

We describe each of these "cards" briefly. The cards which begin with "CM" are "comment cards". These cards are collected at the front of the card deck, and the entire collection of comment cards is terminated with a "CE" card. Some versions of NEC will allow these cards to be interspersed throughout the card deck, while others will require the comment cards to occur only on the front of the data deck.

The next card, a "GW" card, provides coordinates for the endpoints of a single wire. There may be many such cards in a deck, with each "GW" card describing a wire, and the collection of "GW" cards describe the shape of an antenna. Since NEC expects its input to utilize measurements in meters, and I have input the coordinates of the antenna in feet, the "GS" card is used to scale the entire antenna to metric measure. (Multiplying "feet" by 0.3048 yields "meters".)

The "GE" card marks the end of the description of the physical antenna itself.

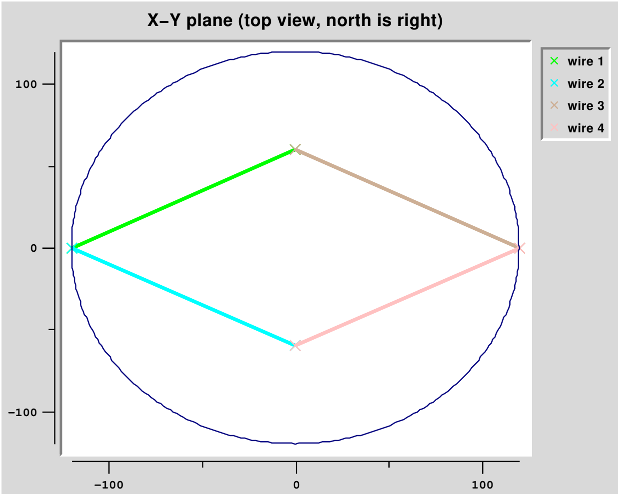
The "GN" card specifies the characteristics of the ground, and the "FR" card indicates a frequency (14.0 mhz in this case) for the applied excitation, which is further described by the "EX" card.

For our purposes, the "RP" card, which requests calculation of a "Radiation Pattern" is the most important. More in a moment about that one.

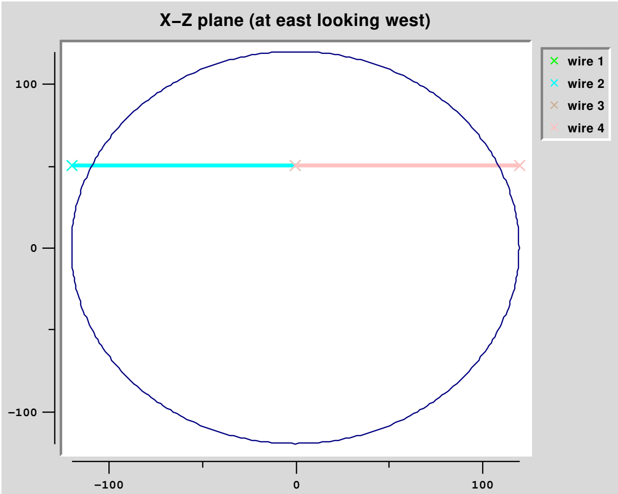
The "EN" card signals the end of the data deck.

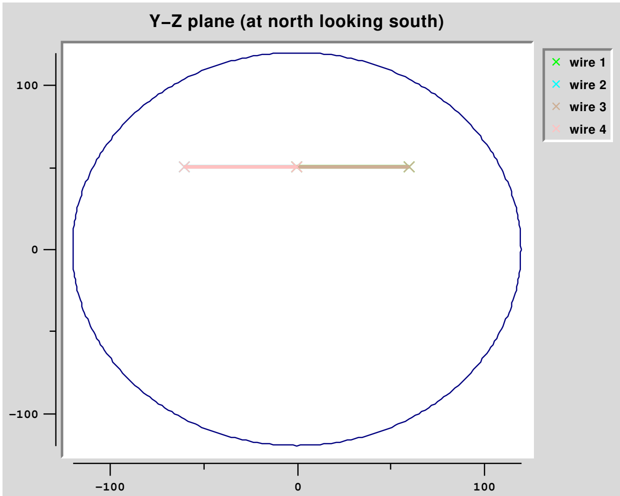
I have not yet bothered with trying to "terminate" the rhombic at this stage since I am still just "exploring" anyway.

Storing the data in a file and using "wires.tcl filename" I see these three windows. (There is no need to run NEC yet. We are just trying to see what the sky wire will look like.)



X–Y plane (top view, north is right)
wire 1
wire 2
wire 3
wire 4
100
0
−100
−100
0
100


X–Z plane (at east looking west)
wire 1
wire 2
wire 3
wire 4
100
0
−100
−100
0
100



The windows represent three "views" of the antenna. One view has the observer "looking down" on the antenna, a second view represents what an observer would see if the observer was directly north of the antenna, and the third window represents a view from the east. These three "views" should help visualize the antenna. The "wires" are colored the same way in each of the windows so that if you are modeling a more complicated antenna you can tell which wire you are looking at in each of the windows.

The antenna we are proposing "looks" like a rhombic, sure enough, but we have to wonder if it will really offer any performance. To find out, we need to understand the "RP" card.

6 The "RP" Card

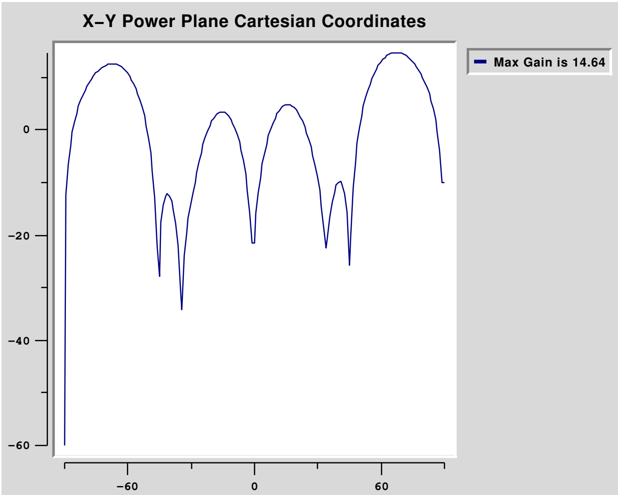
The "RP" card requests calculation of "Radiation Patterns". It can specify a wide variety of parameters including elevation and azimuth angles. An expert using NEC would probably use a much more complicated arrangement than I am proposing, but bear with me a bit, please.

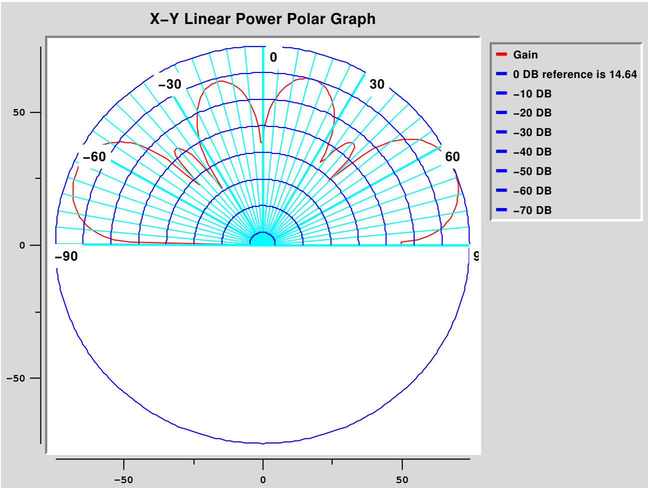
Following the excellent advice of W4RNL and others (see [10] or [12]) I will first compute an "elevation plot" for the antenna. In order to prepare the data file with an appropriate card without disturbing whatever "RP" card is actually in the file, we use the command "preelev.tcl datafile > hold" to substitute our own "RP" card for the one in the data file and place the modified data in a file called "hold". (The original data file is not disturbed.) We use "hold" for input to NEC. When NEC executes you will have to select, via some mechanism the name of the output file. My NEC provide a default name of "fort.2" for this output file.

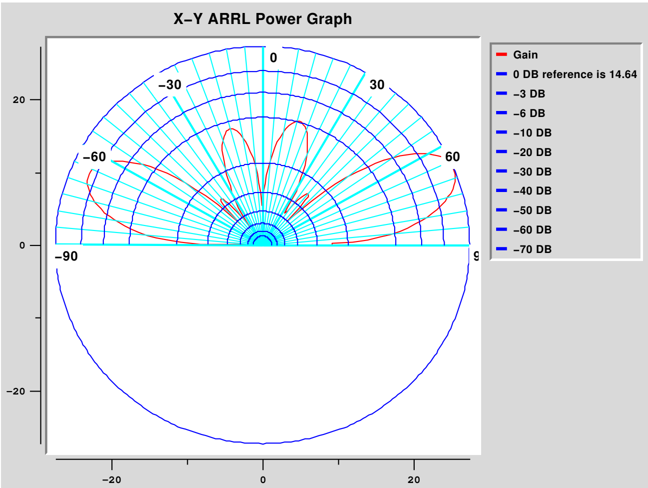
6.1 Determining an Elevation Pattern

When NEC has run to completion, use "elevpatterns.tcl fort.2" to examine the output. This will again generate three "windows", this time with three equivalent graphs using different scales. Each of the three graphs represents a plot of the "elevation" radiation pattern for the antenna.

Here are the three plots.







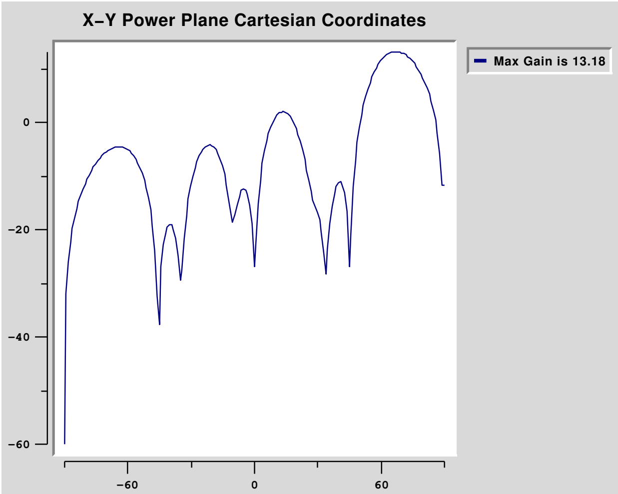
The three plots all contain the same information. The "Cartesian" plot is probably easier to use to determine front-to-back ratios and “gain”, while the two plots in polar form are probably more useful for visualization of the field generated by the antenna. The “ARRL” plot is especially helpful for determining the “-3 DB” beam width.

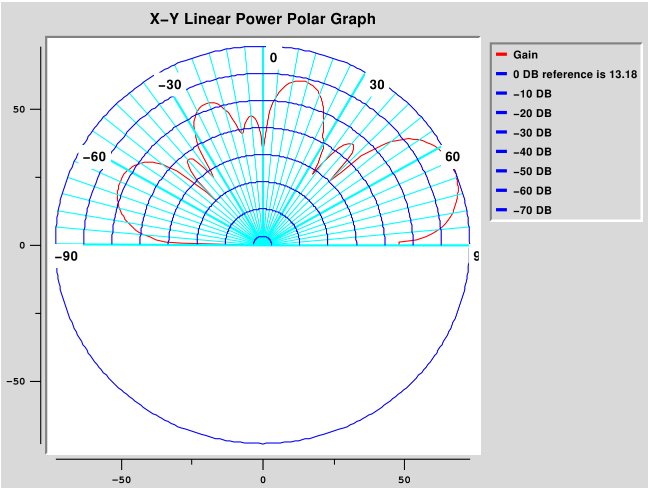
Looking at the “ARRL” plot we see that the antenna is showing some “gain”, but that the directional characteristics of this antenna are not really spectacular, and the lobes are occurring at rather high angles.

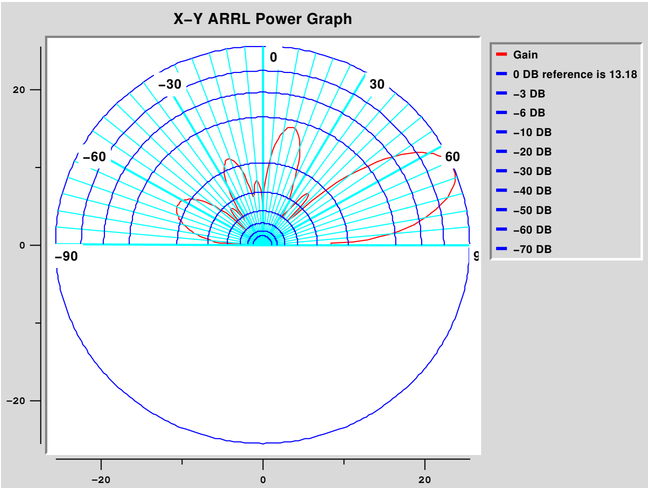
Since this antenna was not “terminated” we have to wonder if providing a termination resistor might help. We add a pure resistance to the antenna at the “far end”. I chose 600 ohms because that is what the “folklore” says I should use. (The “right” answer is embedded in the output of NEC. There is really no need to guess, but I can’t resist.) The datafile now becomes:

```
CM NEC Input File for Rhombic
CE
GW  1 10   -120.0     0.0     50.0       0.0    60.0    50.0   0.01
GW  2 10   -120.0     0.0     50.0       0.0   -60.0    50.0   0.01
GW  3 10    0.0      60.0     50.0     120.0     0.0    50.0   0.01
GW  4 10    0.0     -60.0     50.0     120.0     0.0    50.0   0.01
GS  0  0    0.3048
GE  1
GN  1  0      0    0     0.0      0.0  0.0  0.0      0.0      0.0
FR  0  1      0    0    14.0      0.0  0.0  0.0      0.0      0.0
EX  0  1      1    0     1.0      0.0  0.0  0.0      0.0      0.0
EX  0  2      1    0    -1.0      0.0  0.0  0.0      0.0      0.0
LD  0  3     10   10   600.0      0.0  0.0  0.0      0.0      0.0
LD  0  4     10   10   600.0      0.0  0.0  0.0      0.0      0.0
RP  0  180    1 1001   -90.0      0.0  1.0  0.0  10000.0      0.0
EN
```

Running NEC against this data file and then using “elevpatterns.tcl fort.2” as before we now see these patterns:


X–Y Power Plane Cartesian Coordinates
Max Gain is 13.18
0
−20
−40
−60
−60
0
60


X–Y Linear Power Polar Graph
Gain
0 DB reference is 13.18
−10 DB
−20 DB
−30 DB
−40 DB
−50 DB
−60 DB
−70 DB
0
−30
30
−60
60
−90
50
0
−50
−50
0
50

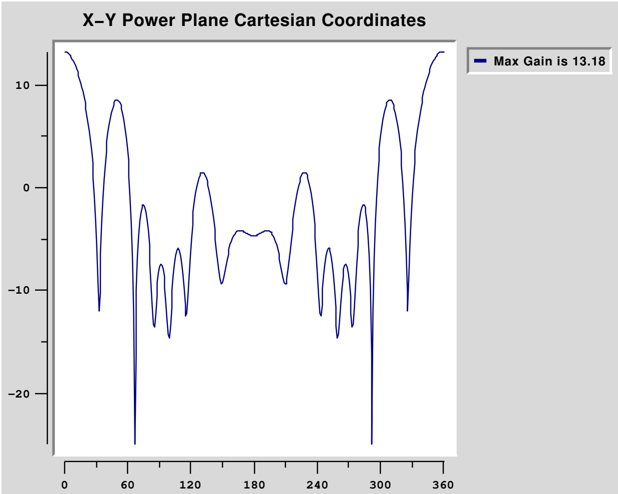


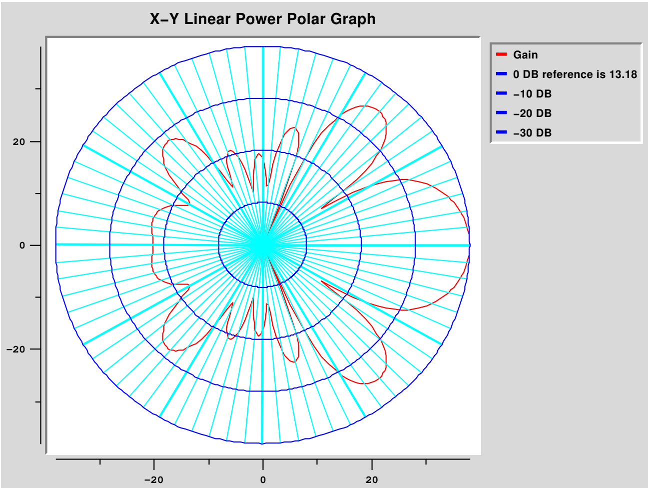
Much better! We now see that there is a major lobe at an angle of about 67.0 degrees. (NEC measures its elevation angles with 0 degrees being "straight up" and 90 degrees being parallel to the ground.)

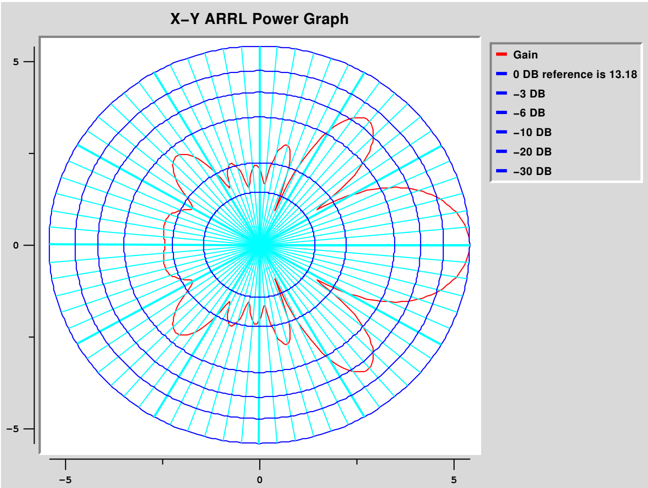
6.2 Generating an Azimuth Plot

We now process the data file with the command "preazimuth.tcl datafile 67.0 > hold" to place an appropriate "RP" card in the data file. This "RP" card will compute azimuth patterns at an elevation of 67.0 degrees.

Running NEC on this new data file we attain these plots:


X–Y Power Plane Cartesian Coordinates
Max Gain is 13.18
10
0
−10
−20
0
60
120
180
240
300
360


X–Y Linear Power Polar Graph
Gain
0 DB reference is 13.18
−10 DB
−20 DB
−30 DB
20
0
−20
−20
0
20



7 So What Have We Got?

Looking at the various plots we see a quite respectable gain and front-to-back ratio. There are a couple of side lobes that may be of consequence, and the elevation angle is a little too high for comfort, but probably acceptable since the -3 DB beam width (easy to see on the ARRL elevation plot) indicates some useful gain at angles down to about 75 degrees or so.

The "folklore guess" at 600 ohms impedance evidently was not far off, given the effect on the patterns, and shucks, I have a 30 year old Viking Matchbox that only requires a heavy dew to match a barbed wire fence. Build it!

This decision is reinforced if we change the frequency of excitation to 28 mhz, just to see what will happen. The 600 ohm terminating resistor is off quite a bit, and the matchbox may warm up a little, but the elevation lobe has pulled down and antenna looks like a performer.

In practice, since I can see that I have a chance at building a pretty good antenna, I would expand the model a bit by changing the ground characteristics and varying other inputs (especially the value of the terminating resistor) in order for NEC to describe more closely the exact physical situation that I am dealing with. If I was satisfied with the potential of the antenna after that experimentation then I would build it.

8 Conclusions

The whole design process for this antenna took less time than reading this article probably did. It involved no cost, other than about 20 minutes of my time, and offered a clear indication of whether or not the result might be worth it. The process was assisted considerably by the visualization software. (Author's note: My one previous article in QST [11] was concerned with antennas also. How I wish I had NEC available at that time!)

Incidentally, this was all done on my Free SCO Unix system. While I was preparing this article (with LaTeX) in one window, I was running NEC and the visualization software in another window. A third window was occupied running K5JB (SK) TCP/IP on the local packet frequency, while my wife Anita (a full professor of Mathematics) was using LaTeX on a second terminal connected to the same machine via ethernet. This is actually a modest machine, although my professional needs (I am a professor of Computer Science) are probably more stringent than the average user's needs. If your family is like ours you need either multiple computers or a multiuser system.

If you haven't given some flavor of Unix or Linux a trial run, may I respectfully suggest you are missing something? At all events, have fun! Antenna visualization software helps, no matter where you run it. It only takes a "Jiffy"!

73 de Bill W5GFE

9 Acknowledgements

The author is grateful to Ray, WB6TPU who read this article in manuscript form and offered many suggestions. He also offered many helpful improvements for the software itself, and pointed out some obvious flaws.

Pinoz, I2KFX, graciously offered permission to reference his excellent work based on yorick. A great many ideas for the "Jiffy" software are "borrowed" from his work.

I am grateful to both of these individuals.

10 Why Not In ARRL Publications?

I originally offered this article to QST. It was not deemed to be appropriate for that magazine. The editor informed me that about 85 percent of the readership of QST is heavily involved with some form of MicroSoft Windows. The Unix/Linux segment of the readership is apparently only a very small segment. The editor of QST suggested that the article might be appropriate for the Antenna Compendium.

I contacted the editor of the Compendium, who was willing to accept the article, but insisted that the software not be released to the public domain. Evidently, the idea was that the software should be included on the diskette which accompanies the Compendium.

At that point, we parted company. I'm a full professor, with tenure, and absolutely no need to publish yet another article anywhere.

I have withdrawn the article from ARRL hands, and now present it, for better or worse, on the Internet. I hope someone can use it. If so, kindly don't make a profit on it, and kindly remember where you got it.

73 de Bill W5GFE March 3, 1998

11 Where to Get It

The W5GFE ("Jiffy") visualization packages is available from "ftp://ftp.ecok.edu/hamradio/W5GFE.tar.gz".

References

[1] W7EL software is available from Roy Lewallen, W7EL, PO Box 6658, Beaverton, Oregon 97007.

[2] A really useful and rich reference for NEC documentation, code, and utilities is found at http://www.qsl.net/wb6tpu/

[3] The GNU archives are located at ftp://prep.ai.mit.edu/

[4] The egcs project is located at ftp://egcs.cygnus.com/

[5] KD6PAG, in private communication. This package depends on having the Perl language available.

[6] See http:/www.intercoop/ham/Antenne/nec2pp_1.2.tar, or http://www.qsl.net/wb6tpu/

[7] "yorick" is available from ftp://wuarchive.wustl.edu/languages/yorick/

[8] TCL/TK and BLT are available from http://www.smli.com/

[9] NEC documentation is downloadable from http://www/dec.tis.net/ richesop/nec/index.html

[10] Cebik, L. W4RNL, *A Beginner's Guide to Using Computer Antenna Modeling Programs*, ARRL Antenna Compendium, Volume #3.

[11] Walker, Bill *Predicting Radio Horizons at VHF*, QST, June 1978.

[12] Belrose, J. VE2CV, *Modeling HF Antennas with MININEC — Guidelines and Tips from a Code User's Notebook*, ARRL Antenna Compendium, Volume #3.