By L. B. Cebik, W4RNL

A Beginner's Guide to Modeling with *NEC*

Part 1: Getting settled and getting started

Antenna modeling has become a popular engineering and amateur activity. You can see the results in almost any issue of *QST*. Among the modeling products you might encounter are azimuth patterns, such as Figure 1, or elevation patterns, such as Figure 2, or even an SWR graph, such shown in Figure 3. Almost every ham knows that antenna-modeling software is available at reasonable prices. So only two important questions remain:

1. Can I model antennas, too? Can I master the software and produce the same kinds of results that I see in *QST*?

2. Is antenna modeling worth the effort? Does antenna modeling really offer me any information that I cannot easily get elsewhere?

The answer to both questions is a definite "yes." With a little coaching and a little practice, virtually any ham can effectively model many kinds of antennas. The result will be a better understanding of one's own antennas and of antennas in general. The purpose of this 4-part series is to provide the "little coaching" part of the effort. The practice is up to you.

In this first episode, we'll try to understand what antenna modeling is and become oriented to the many parts of a good antenna model. In future episodes, we'll take a closer (but still incomplete) look at crucial details that will make the task smoother and the output more understandable.

In all of our work, we'll focus our attention on the antenna-modeling core known as *NEC*-2. This public domain software is the heart of numerous commercial implementations that provide ways for the user to input data and also that supply tabular and graphical outputs. There is another modeling core called *MININEC*. Rockway and Logan developed it when PCs could not handle the *Fortran* of *NEC*. There are two versions available, a public domain version and a totally revised proprietary version.[1] The nature and limitations of *MININEC* have been covered in past ARRL publications, and so they need not be repeated here.[2]

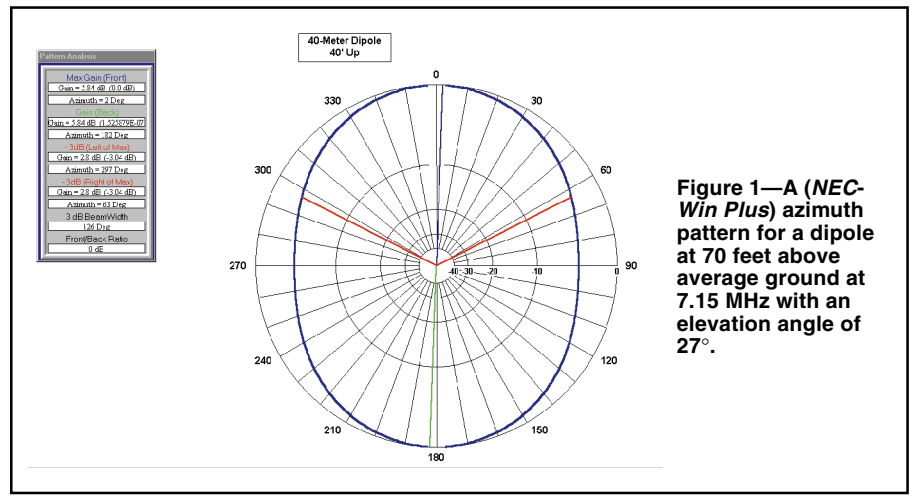

Figure 1—A (*NEC-Win Plus*) azimuth pattern for a dipole at 70 feet above average ground at 7.15 MHz with an elevation angle of 27°.

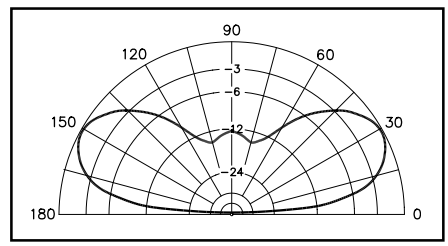

Figure 2—An (*EZNEC*) elevation pattern for a dipole at 70 feet above average ground at 7.15 MHz with an azimuth angle of 0 degrees.

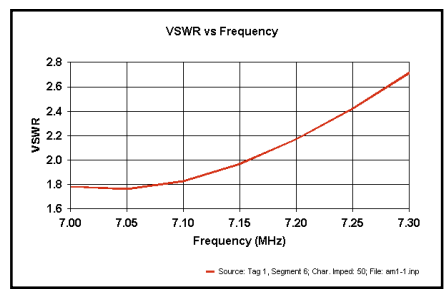

Figure 3—A (*NEC-Win Plus*) SWR graph for a 40-meter dipole at 70 feet above average ground.

Our focal software, *NEC*-2 is neither the newest nor the oldest modeling software.[3] It is the latest public domain core available and appears in several commercial implementations, as well as in "raw" form that one can download from more than one ftp site. For the beginner, one of the commercial versions is recommended, since the raw form requires that the user develop appropriate input and output systems.[4] I happen to have two different commercial versions of *NEC*-2—*EZNEC* 3.0 and *NEC-Win Plus*. Therefore, without prejudice toward or against any version, I shall be illustrating these guidelines by alternating among the programs I have. Figure captions will identify the program used for each graphic.

What is Antenna Modeling?

One common misconception of antenna modeling is that it is similar to making model boats and cars. The result sort of looks like—

[1]Notes appear on page 38.

and may even behave a little like—the real thing. Still, the model is a pretty but pale shadow of reality. Nothing could be further from the truth. So let's start all over again.

If you have ever referred to a formula to cut a dipole, you have done some rudimentary antenna modeling.

$$L_{ft} = \frac{468}{f_{MHz}} \qquad \text{Eq 1}$$

If we choose 7.15 MHz for our design frequency, then we need an antenna wire that is 65.45 feet long. Of course, the basic dipole formula always carries with it the advice to leave some extra wire and trim the length for the best SWR.

The formula does not include the diameter of the wire or the material out of which it is made. Nor does the formula account for the height of the antenna above ground or the properties of the soil that makes up the ground. Suppose we had a formula that would account for all of these factors?

We do. The oversimplified cutting formula for dipoles is just one small extract from a large body of mathematical analysis of antennas. If we place all of the most accurate equations into a single calculating piece of software, we would achieve much higher accuracy with our wire cutting. Not only could we analyze or predict the correct wire length for a resonant dipole, we could also calculate the field strength at any elevation above ground and in any direction from the antenna. This is exactly what *NEC* does. For many antenna types, *NEC*-2 is as accurate as engineering mathematics can make antenna analysis.

The basic antenna analysis used by *NEC*-2 relies on the "method of moments," a mathematical technique that subdivides an antenna element into segments, calculates the correct properties, and then combines the results to provide a set of results for the entire element (or an array of elements).[5] The results can be adjusted using standard engineering equations for material resistance, element loading, and ground effects. For the beginning modeler, two points are important to remember: (1) The method, when used within the limits of the software, is very accurate and (2) we have to think in terms of segments of our antenna elements. Instead of dwelling on the math behind the core, let's learn how to think in modeling terms.

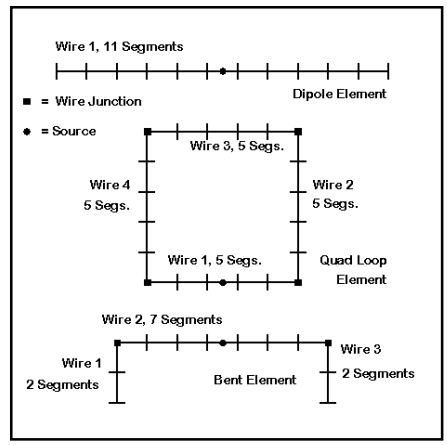

Figure 4—Several types of antenna elements with their segmented wire components.

The Language of Modeling

Clearly, we'll have to add some new terms to our antenna language in order to get a good grip on antenna modeling. We have already encountered one of them: the *segment*. In fact, we may find it useful to think of three different terms to sort out pieces of an antenna and pieces of an antenna model.

Figure 4 shows several different types of antenna *elements*, a dipole, a quad loop, and a bent element such as might be used in a half square or a Moxon rectangle. *NEC* can only work with individual straight *wires*, although we can form complex geometric shapes by joining straight wires at their ends. In fact, if we needed to form a circle, we would have to approximate it with a collection of straight wires, perhaps an octagon. Whatever the shape, each wire composing each antenna element has the dimensions of that part of the real antenna element. Of course, the single wire dipole element brings together the "wire" and the "element," but we should always keep the ideas of an element and a modeling wire separate.

Next, each wire in an element should be segmented. For beginning modelers, the following two guidelines are useful to stay on the safe side of *NEC* limits for segmentation:

1. A wire should have at least 9 segments per half wavelength. If a wire is only a quarter wavelength long, then perhaps 5 segments is a good minimum number. We'll shortly see why we're using so many odd numbers.

2. The segment length should be at least 4 times larger than the wire diameter. There is a complex equation for figuring the absolute minimum segment length that is reliable, but in the beginning, the 4:1 ratio of segment length to wire diameter is a safe guideline.

Let's add one more guideline:

3. To the degree possible, make all segment lengths equal within a model. If we have a dipole consisting of one wire and specify 11 segments, then the program will automatically make them all the same length. However, for elements consisting of more than one wire, we'll have to look at the number of segments we assign in order to equalize their lengths. Dividing the wire length by the number of segments gives the segment length. If we know the segment length we want, then dividing the wire length by the segment length gives the number of segments.

The next step is to set up a model element. Let's remain with our simple 1-dipole wire. In order to model the element, we must know the orientation of the dipole. For this first model, we shall make it horizontal. In fact, let's play with a 40-meter dipole cut for 7.15 MHz. To determine the wire's length, we'll initially use our traditional formula and arrive at a length of 65.46 feet for our antenna.

In order to place the antenna into the model, we must master the world of 3 dimensions, also called *Cartesian coordinates*. This system is just a way of specifying directions, as shown in Figure 5. Relative to the earth, we can think of the X-axis and the Y-axis as two lines at 90° angles, both of which are parallel to the Earth's surface. Then, the Z-axis becomes another word for height above ground. Since we are going to start with a dipole above the Earth, the Z-value can never be below zero, although—as we shall see—it

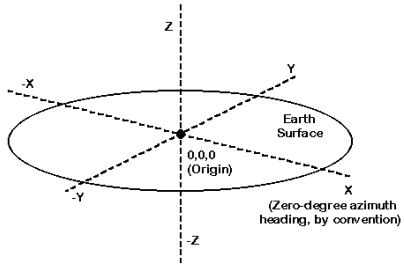

Figure 5—The Cartesian coordinate system with an "earth surface" shown.

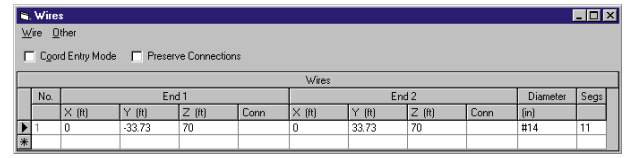

Figure 6—The *EZNEC* wire spreadsheet with 40-meter dipole components.

might be very close to zero.

As we begin to model, we need to begin to think systematically about antenna geometry. One of the most convenient (but not the only workable) systems for setting up a horizontal antenna is to place the ends equal distances along the Y axis. For most horizontal designs based on $^1/_2$-wavelength dipoles, this orientation will result in a pattern of radiation that is strongest along the X-axis, and the pattern value of zero degrees lies along this axis. So let's center the antenna on the X-axis and make the End-1 Y value –33.73 feet with the End-2 Y value +33.73 feet. Since we have only one wire, the X-value at both ends can be zero.

However, we must not neglect Z, the antenna height. Since a fairly common backyard value for the height of a 40-meter dipole is about 70 feet, let's use this value for Z—at both ends of the wire. Figure 6 shows the *EZNEC* wire window with exactly these values plugged in. Note that we have defined the wire by its end coordinates. If we had other wires as part of the same element, we would have added them by using either the End-1 or End-2 coordinates as the coordinates of one end of the extra wire. We shall explore more complex geometries in a future episode. For now, let's focus on mastering the language of the coordinate system of wire entry.

We can check our work for errors by looking at a diagram of the antenna that we have just entered. Most *NEC* programs have a "view antenna" option. Figure 7 shows the *EZNEC* view, with the antenna positioned above ground on the Z-axis and extending along the Y-axis on either side of the "origin," that is, the 0, 0, 0 point of the coordinate system.

Although the elements in all of our figures show feed points as small dots, we haven't yet added them to our model. In modeling language, a feed point is the source. We will have to specify both the position and the electrical conditions of the source. In *NEC*, the source is always the position within a segment, and for simplicity, we take its position to be centered.[6] If we wish to have a feed point or source positioned exactly at the center of an element wire, then we must have an odd number of segments on the wire. *NEC* was designed for voltage sources, so we shall specify a value of 1.0 for the magnitude and 0.0° for the phase for most common antennas having only a single feed point. For these kinds of antennas, changing the values we insert for the source will make no difference to the antenna pattern, gain or source impedance. We might as well keep it simple.

Different commercial implementations of *NEC* handle source setting in slightly different ways. The *NEC-Win Plus* system appears in Figure 8. We "drag and drop" the source symbol onto a picture of the wire that shows all of the segments. For an 11-segment dipole, we drop the symbol on segment 6. We then select the source type and values in a box that automatically appears. (The *EZNEC* system specifies the source position as a percentage of the wire length. For a center feed antenna, we specify 50%.)

The Other Parts of the Model

The work we have just done corresponds to cutting a piece of wire and stringing it up between supports. With a wire in place and having the correct dimensions, we can turn to the other parts of the program that we must set up before running the model. For example, the wire has a diameter that we can express in either the same dimensional units as the wire length (feet, in this case) or as an AWG wire gauge. Figure 9 shows the *NEC-Win Plus* wire diameter window that allows us simply to select a common wire gauge or provide a custom entry.

Not only does the wire have a diameter, it is also composed of a conductive material. We need to specify this material so that the program can account for any resistive losses in it. In Figure 9, we also see the separate *NEC-Win Plus* selection box for common materials. There is a place for entering the conductivity of materials not listed, a topic we shall look at down the line. For now, checking "copper" will get us started. Incidentally, the corresponding materials window in *EZNEC* will allow custom entries in terms of resistivity, which is simply the inverse of conductivity.

Next, let's look at the ground over which our antenna hangs. *NEC* has two "real" ground systems, but for our modern fast PCs, there is no reason not to select the better of the two. It goes under different names in different implementations of *NEC*. You can find it as the "high accuracy" ground, the Sommerfeld-Norton ground, or simply as *SOMNEC*, the name of the calculating module within *NEC*. Whatever the program-matic name, it is the most accurate available system for calculating the behavior of an antenna above ground. While other systems tend to become inaccurate for antennas below 0.1 to 0.2 wavelengths above ground, the Sommerfeld-Norton system is accurate down to a tiny fraction of a wavelength above ground.

Once we have selected the ground type, we need some values for ground conductivity (in Siemens per meter) and for the relative dielectric constant (also called permittivity). We usually derive these values from maps of our local area (available in *The ARRL Antenna Book*). However, the ground quality values do not make a big difference in horizontal dipole performance, so we can initially use the program default numbers. Most programs default to what is called "average" ground, which has a conductivity of 0.005 S/m and a dielectric constant of 13.

We have neglected the test frequency. *EZNEC* is set up for single frequency runs, so we would just click on the frequency button and enter 7.15 MHz in the box that appears. *NEC-Win Plus* is always setup for frequency sweeps, that is, multiple runs defined by start and stop frequencies, plus a frequency interval between runs. For a

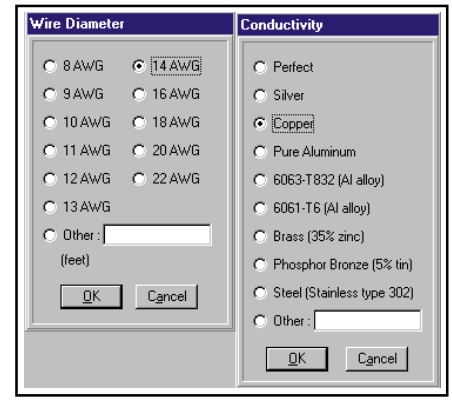

Figure 9—The *NEC-Win Plus* wire-diameter window and wire-material window.

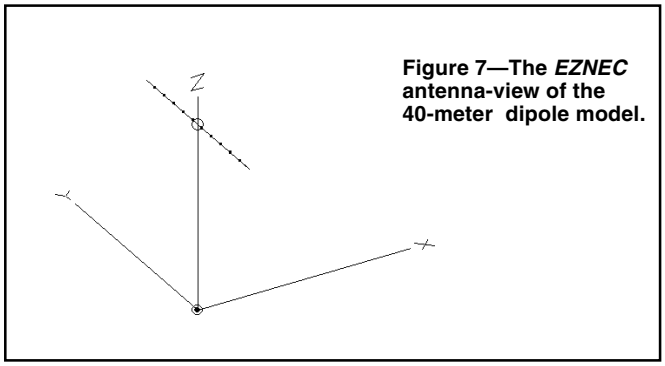

Figure 7—The *EZNEC* antenna-view of the 40-meter dipole model.

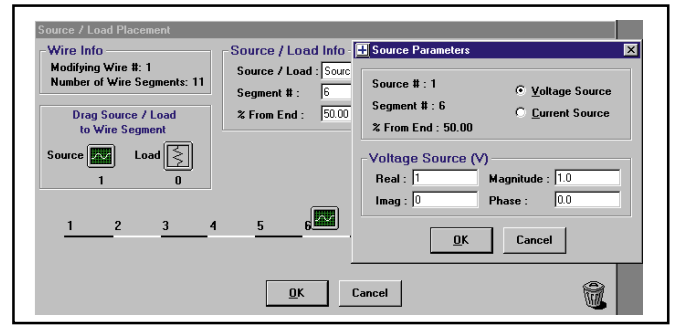

Figure 8—The *NEC-Win Plus* source-placement window.

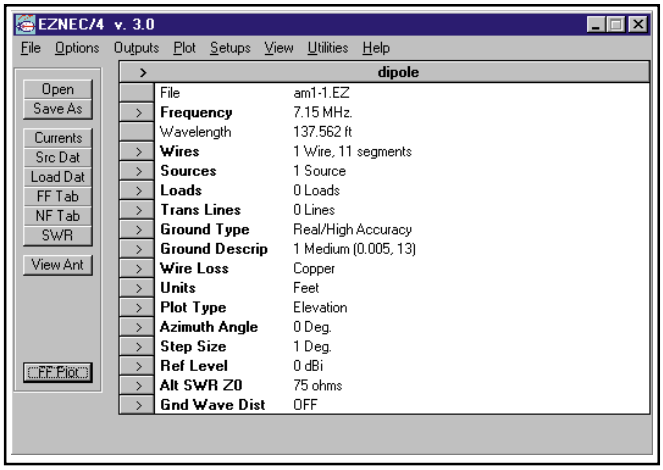

Figure 10—The *EZNEC* elevation pattern data on the main screen.

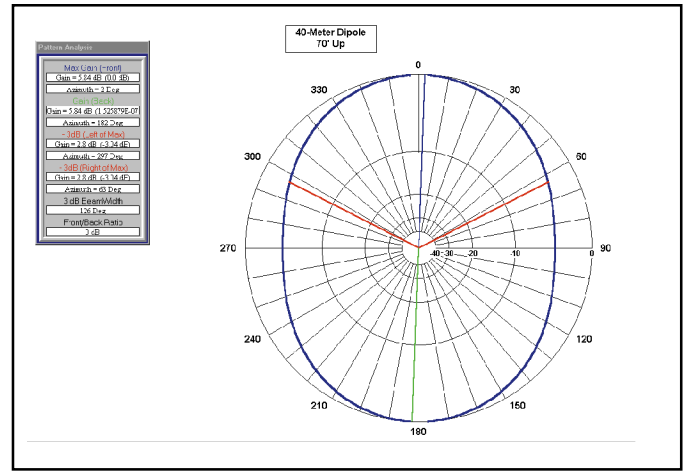

Figure 13—A (*NEC-Win Plus*) azimuth pattern for a dipole at 40 feet above average ground at 7.15 MHz with an elevation angle of 49°.

single run, we just enter the same frequency on both the start and stop lines. The interval or "step" will not matter.

We have now completely specified our model. We created the wire element and gave it an environment. Part of the environment was geometric as we set the coordinates to position the wire. A second part of the environment was electrical as we positioned the source. A further part of the environment was physical as we specified the wire material and the ground beneath the antenna. Essentially, we would go through all of these thinking processes when erecting a real antenna.

We should notice two things about the model that may differ somewhat from reality. First, there is nothing in the model's backyard except the antenna. All of the power lines, trees, and other objects that can affect antenna performance are missing. Much of this "ground clutter" can be modeled, but it takes special techniques that go beyond the scope of the basics of modeling. Second, the ground is continuous to the horizon and homogenous to any depth beneath the antenna. In advanced modeling, we can add a second set of ground properties at a distance from the antenna, but we cannot capture the stratified nature of the subsurface ground that occurs in many places. For most purposes, neither of these limitations of the modeling program will invalidate the results of the modeling calculations.

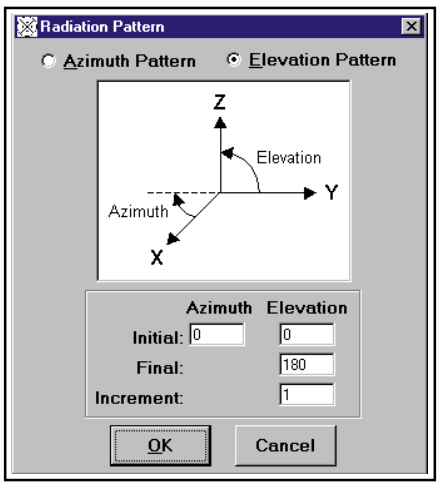

Figure 11—The *NEC-Win Plus* elevation pattern specification box.

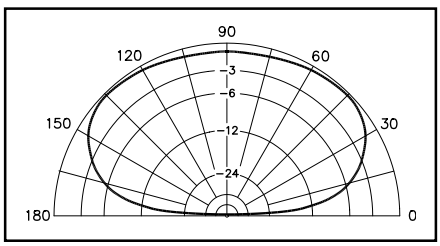

Figure 12—An (*EZNEC*) elevation pattern for a dipole at 40 feet above average ground at 7.15 MHz with an azimuth angle of 0 degrees.

What Output Pattern Do We Want?

If we have completely constructed our model and its environment, we have only one more step to go before we can hit the **RUN** button. We need to tell the program what kind of output pattern we want to see. The program will always calculate the source impedance, but most of us want to see a vivid graphic that tells us something about the gain and pattern shape of our antenna.

The entry is called the specification of a far field radiation pattern for our dipole. However, we may be initially at sea about what pattern to call and what specifications to enter for it. We know that the dipole radiates broadside to the wire and that this direction is an azimuth angle of zero (and 180) degrees. Let's begin, then, with an elevation pattern along the zero-180-degree line, usually specified as an azimuth angle of zero degrees. Most programs have a set of default values that you can use as starters. Figure 10 shows the *EZNEC* elevation data on the main screen, while Figure 11 shows the *NEC-Win Plus* elevation data selection box.

Now we are finally ready to run the model. We hit the right button and let the program do its calculations—very rapidly for this small model. After the run, *EZNEC* will bring up the pattern generated by the complex calculations, while in *NEC-Win Plus*, the design philosophy is to let the user call up any of the tables, graphs, or patterns desired. Figure 12 shows the *EZNEC* elevation pattern for our dipole.

Notice that the pattern provides us with several important pieces of information. First, we can see that low height (just above 1/4 wavelength) sends much of the radiation at very high angles, too high for most skip paths. Looking at the available data gives us a gain of 5.87 dBi maximum at an angle of 49 degrees above the horizon. *NEC* calculates all gain figures as dBi values, that is as gain in decibels greater than a theoretical isotropic radiator that would send radiation equally in all possible directions. Since *NEC* does not have any built-in range test data or similar baselines, everything must be calculated against the isotropic radiator. If we are interested in using some other standard, we can always model the standard antenna and compare gain figures. We add and subtract gain in decibels, using the same reference standard. Notice also that the gain is given to two decimal places. For most operational purposes, a value of 5.9 dBi would be sufficient for any comparisons between antennas. Even so, the difference among 5.5, 5.8, and 6.0 dBi would not be detectable in amateur operation.

Figure 13 provides a *NEC-Win Plus* azimuth pattern taken at the elevation angle of maximum radiation. Note that there is a 1° difference in the elevation angles of maximum radiation—sometimes called the

"take-off" angle—reported by the two programs. This difference is largely due to the complexity of the calculations involved as well as where and how a given program does its rounding from the long string of digits that computers use in their calculations. Also note that there is a 0.03-dB difference in reported gain, which is also insignificant. Of far greater importance is the pattern shape—a broad oval. Signals off the ends of the antenna will be weaker than those broadside to the antenna, but they may still be strong enough for contacts. The classic figure-**8** pattern is nowhere to be seen. The reason is the relative closeness of the antenna to the ground.

Before we leave the model, let's look at the source impedance data available as a table in most programs. The impedance listed is not the classic 72 Ω resistive that we associate with a resonant dipole. Instead, it is about 91 + *j* 20 Ω. The original cutting formula that we used to create our dipole model turns out to yield an antenna that is too long, as indicated by the inductive reactance at the feed point/source. As well, the resistive part of the impedance is considerably above the number used as the dipole standard. The numbers generated by *NEC* may be surprising. Nonetheless, they are accurate within the limits of the program, with its homogenous ground and clutterless field for the radiation.

Even though our main purpose in this episode was to get oriented to and started with antenna modeling, that does not mean that we can't discover some things about antennas—even using the simplest antenna possible. Even the most familiar antennas have new things to teach us about their behavior, and antenna modeling is a good way to learn them.

There remains much to be said about creating models out of wires and segments. The more complex the antenna structure, the more careful we must be. As well, we should look more closely at the information that the azimuth and elevation patterns can present to us, including some pitfalls to avoid. Next month we'll look more closely at the "ins" and "outs" of *NEC*.[7]

Notes

[1]Public domain *MININEC* is available in the following programs (with Web URLs listed):

NEC4WIN (*Windows*) from Orion: **http://www.cam.org/~mboukri**.

ELNEC (*DOS*) from W7EL: **http://www.eznec.com**.

Another version still used by numerous modelers is *AO* from K6STI. *AO* is a *DOS* program. For information e-mail **k6sti@n2.net**.

Expert *MININEC* is a proprietary program available at various levels from E.M. Scientific: **http://www.emsci.com/**.

[2]See the following references to using *MININEC* in ARRL publications:

John S. Belrose, "Modeling HF Antennas with *MININEC*—Guidelines and Tips from a Code User's Notebook," *The ARRL Antenna Compendium*, Vol. 3, pp 156-164.

L. B. Cebik, "A Beginner's Guide to Using Computer Antenna Modeling Programs," *The ARRL Antenna Compendium*, Vol. 3, pp 148-155.

Roy Lewallen, "*MININEC*: The Other Edge of the Sword," *QST* (February, 1991), 18-22.

The latter two items are republished in *Vertical Antenna Classics*.

[3]For a succinct history of method of moments programs for antenna analysis, see R. P. Haviland, "Programs for Antenna Analysis by the Method of Moments," *The ARRL Antenna Compendium*, Vol. 4, pp 69-73.

[4]There are at least three commercial implementations of *NEC*-2 readily available to amateurs at reasonable prices:

EZNEC 3.0 (*Windows*) from W7EL: **http://www.eznec.com** (reviewed in the September 2000 *QST* "Short Takes").

NEC-Win Plus (*Windows*) from Nittany Scientific: **http://www.nittany-scientific.com**.

Antenna Solver (*Windows*) from Grating Solver Development Co: **http://www.gsolver.com/**

[5]The actual equations used in developing antenna characteristics are available in the *NEC*-2 manuals. Although most users encounter only the final "Users" volume, the foundational volumes are available on-line at **http://www.qsl.net/wb6tpu/swindex.html** and at **http://members.home.net/NEC2**.

[6]In *MININEC*, the fundamental point of concern is not within the segment, but at segment junctions, called *pulses*. Hence, to center a source on a wire element, we would use an even number of segments and specify the centered junction as the source location.

[7]Those interested in pursuing each facet of basic *NEC* modeling more thoroughly may wish to consult *Basic Antenna Modeling: A Hands-On Tutorial*, available from Nittany Scientific (**http://www.nittany-scientific.com**). Although written to accompany *NEC-Win Plus*, with about 300 exercise files in *.NEC* format, the volume can be used with other implementations. A disk holding all of the exercise files in .EZ format for use with *EZNEC* is available from AntenneX (**http://www.antennex.com**).

You can contact the author at 1434 High Mesa Dr, Knoxville, TN 37938-4443; **cebik@utk.edu**.

STRAYS

QST Congratulates...

◊ *75 Year Member*

Robert Reid, W4TK, Jacksonville, FL

70 Year Members

Kenneth Gardner, W2BGN, Walworth, NY
Alfredo Sambolin, KP4CI, Ponce, PR
Wayne Cooper, AG4R, Alexandria, VA
John Holmes, Jr, W6BUY, Reno, NV

60 Year Members

Robert White, W1CW, Seffner, FL
Robert Wallace, W1HH, Chelmsford, MA
A. Warren Nelson, W1LWB, Hope, RI
William Beal, Jr, W1PNR, Jackson, NH
Fred Albert, W1QP, Fort Myers, FL
Arnold Wilson, N2EZ, Audubon, NJ
Orion Arnold, W2HN, Ho Ho Kus, NJ
Harrison Moore, Jr, W2JQS, Bronxville, NY
Herbert Klein, W2NCM, Brooklyn, NY
Edwin Kephart, W2SPV, Pennsauken, NJ
P. S. Christaldi, W2TF, Montclair, NJ
Douglas Morick, W3NNT, Ocala, FL
Michael Loria, K4CD, Fort Myers, FL
John Pearson, KE4CR, Melbourne, FL
Marc Molyneux, Jr, N4EM, Mobile, AL
Marshall Goldblatt, W4EMB, Miami, FL
John Spark, W4LHP, Lakeland, FL
Lyman Treaster, W6IFC, Visalia, CA
Joseph Roark, W6JGI, Solvang, CA
John Kemper, W6JN, Torrance, CA
Veikko West, K6ORP, San Mateo, CA
George Badger, W6TC, Portola Valley, CA
Howard Shepherd, Jr, W6US, McArthur, CA
Robert Roberts, K6VK, Livingston, TX
Emmett Freitas, AE6Z, San Jose, CA
Robert Leo, W7LR, Bozeman, MT
James Young, W7JL, Long Beach, CA
Nelles Roth, W8UPR, Wauseon, OH
Wayne Flickinger, W9BKJ, Marietta, GA

50 Year Members

Anthony Fiore, W1LKM, Center Ossipee, NH
Guy Gianino, W1OPI, Lynn, MA
Samuel Strauss, W1SS, Royal Palm Beach, FL
Max Norman, W2IQE, Winter Haven, FL
Joseph Flaherty, K2IQM, Port Washington, NY
John Bann, Jr, W2KPV, Garden City, NY
Donald Field, W2UAE, Lawrenceville, NJ
Emery Flinn, Jr, N4DX, Carrollton, GA
Frederick Ritter, W4FI, Longwood, FL
Paul Van Nostrand, W4HVD, Tallahassee, FL
Elbert Wood, W4JFL, Lithia Springs, GA
Frank Butler, Jr, W4RH, Fort Walton Beach, FL
Wallace Borger, W4VBZ, Trussville, AL
Morris Guzick, W5IO, Sherman, TX
Daniel Droemer, W5KUV, Houston, TX
James Cotten, W5PYI, Weatherford, TX
Fred Ellis, AC5SO, Edinburg, TX
Dean Manley, KH6B, Hilo, HI
Salvatore Teresi, W6EOA, Los Altos, CA
Jay O'Brien, W6GO, Rio Linda, CA
Charles Allessi, W6IEG, Oakhurst, CA
Carl Stengel, W6JEO, Goleta, CA
Paul Williams, W6LHY, Bishop, CA
Stanley Andrews, Jr, K6MO, San Carlos, CA
Sam Lalande, W6OXX, Mammoth Lakes, CA
Donald Burr, AJ6X, Fresno, CA
Herbert Hoover, III, W6ZH, San Marino, CA
Clifford Kurtz, N6ZU, Stockton, CA
Hobart Paine, K7CC, Tucson, AZ
W. Dean Figgins, WA7EPU, La Mesa, NM
James Groll, W7KRW, Avilla, IN
Norman Ray, W7LFA, Kirkland, WA
John Swafford, II, W7MEU, Seattle, WA
H. W. Middleton, Jr, W8CXD, Forest, VA
Kenneth Humbert, W9EDU, Michigan City, IN
Leroy Stalions, K9IEY, West Frankfort, IL
Adolph Jelen, W9IT, Marengo, IL
Edmond Metzger, W9PRN, Springfield, IL
Paul Ripple, W9SIZ, West Bend, WI
Edward Martinson, W0GYH, Mounds View, MN
Edward Hardt, W0JS, Minneapolis, MN
William Kordik, W0LDO, St. Louis, MO
Emanuel Block, W0PIG, St. Paul, MN
David Robb, W0YRN, Salina, KS

Next Stray

FEEDBACK

◊ Please refer to Rick Littlefield, K1BQT, "A Wide-Range RF-Survey Meter," *QST*, Aug 2000, p 44, Figure 1. The 0.1 µF capacitor near C5 should be labeled C6, not C1.—*tnx Rick Littlefield, K1BQT*

Next Feedback