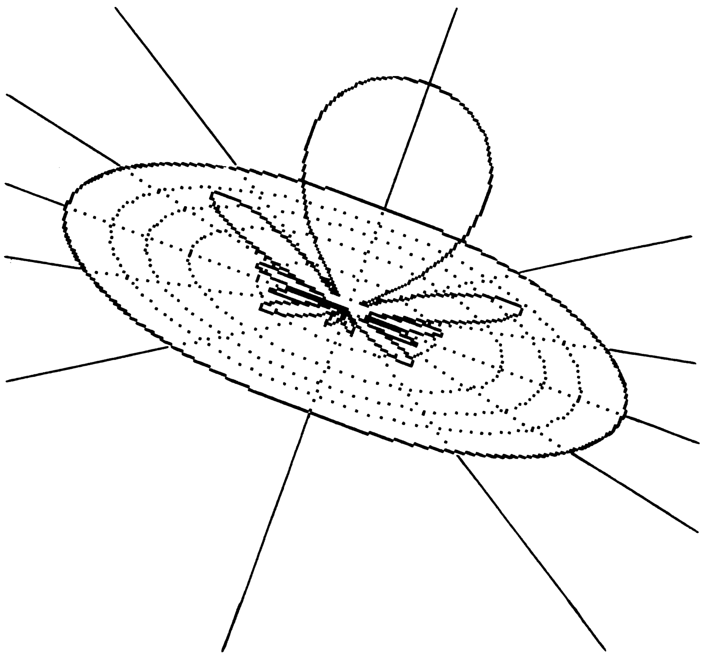
ANNIE
ANTENNA ANALYSIS
USER'S MANUAL



Preface to the 2001 Digital Preservation

Annie is an antenna analysis program written by myself on an Apple][computer in 1983. A series of five articles were written for QST magazine starting in February 1984, receiving the ARRL's Technical Merit award for that year. The software was then ported to the Commodore 64. Since it was entirely in assembly language on the Apple, I got some connectors from Radio Shack, and connected the computer's serial ports together and wrote some software to make a copy of a region of the Apple's memory on the Commodore. I then assembled Annie on the Apple as though it were running on the Commodore and copied it over. I did that for each copy sold. Those were the days!

Then I got my first IBM-PC. I re-wrote the software in Turbo-Pascal. That is what we are now distributing. The software is still copyrighted, but anyone who wants to copy or distribute it may do so as long as they do not charge more than the cost of copying and distributing.

This manual is written for the Apple, there are differences for IBM-PC use. For example you simply double click on Annie.com or Annie-87.com to run Annie, the second one uses the floating point co-processor. Annie comes up in a DOS window. To move to the next option on a menu, press F1. To move to a previous option, press F2. To select the next value (for example, "none" -> dipole"), press F3. To exit a menu press F10.

Annie was very successful in the early days. We sold about 250 copies world-wide. There are so many sophisticated tools out there now, it is primarily of historical and perhaps educational interest now. The primary benefit to me was that it gave me the confidence and knowledge to jump full time into the technical software business. Visit http://www.sonnetusa.com if you would like to see what we are up to now. The whole trip has been a lot of fun. Please enjoy!

Jim Rautio
Liverpool, NY
November 12, 2001

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TRADEMARK NOTICES

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WARNING

Do not modify any part of the software. Annie is a complex program and even simple modifications are likely to produce unexpected results. This warning does not apply to the files GDUMP, GDUMP.OBJO and DEFAULT.OBJO.

1.0 ANNIE'S EASY

Welcome to Annie, the most advanced, most flexible and fastest antenna analysis program ever written for a personal computer. Annie will provide you with the ability to analyze dipoles, sloping dipoles, inverted vee's, verticals and any number of driven arrays. In addition, given knowledge (or approximations) of element excitation, you can also analyze parasitic arrays such as Yagi's and quads. In short, Annie will let you analyze just about any HF antenna and most VHF antennas.

The variety of antennas which Annie can analyze is just part of her flexibility. Annie provides the most advanced analysis available by allowing you to *include the effect of real ground.* Not some imaginary, theoretical, perfect ground; Annie can include a real ground with a real conductivity and a real dielectric constant. Questions such as, "Can I get more dB's by doubling my antenna height or by doubling my transmitter power?" or "Where (or what!) is Brewster's angle?" are quickly answered.

Speed combines with Annie's flexibility for an unbeatable combination. Partly as a personal challenge, Annie was written entirely in assembly language. Assembly language is the native language of the personal computer's microprocessor. Thus, assembly language provides the fastest possible execution time. While other programs measure execution time in minutes and even hours, Annie executes in seconds or even fractions of a second--Annie's fast.

In addition, assembly language allows an incredible flexibility for communicating with you, the user. Assembly language has allowed us to devote a great deal of effort and creativity to make sure Annie is as user friendly as possible. Too many times, programs have been written where, it seems, the user is working for the computer. We have devoted more than half the program to Annie's user interface. And with one of the best user interfaces we have ever seen, Annie is a joy to use; Annie makes sure that "the computer is working for you". This is what we mean when we say... "Annie's Easy".

2.0 GETTING STARTED

To run Annie, you will need an Apple II+ (language card required) or an Apple IIe with at least one disc drive and DOS 3.3.

Although Annie is copyrighted, the disc is not copy protected. This means, consistent with copyright laws, you can make a backup copy for your personal use. So, the first thing to do with Annie is to make a back-up copy of the disc. Then take the copy and place it far from any children, pets or any other possible catastrophe.

Second, Annie is provided without the copyrighted Apple DOS. If you would like a copy of Annie with DOS, first initialize a blank disc. Next, with the DOS 3.3 master disc in a drive, type "BRUN FID". There is a description of FID in the DOS User's Manual. Use FID to copy each of the following files from the Annie master disc to the initialized disc:

1) ANNIE	5) T
2) MAIN.OBJ0	6) GDUMP
3) DEFAULT.OBJ0	7) GDUMP.OBJ0
4) MATHCORE.OBJ0	8) DEFAULTMOD.OBJ0

Once this is done, you may boot directly with Annie's disc. Otherwise you must boot DOS from another disc each time prior to running Annie.

Except for GDUMP and GDUMP.OBJ0 (the graphics hardcopy utility) do not modify any of the files in any way.

To run Annie, type "BRUN ANNIE". Annie will take about 30 seconds to load. During this time, the monitor will display Annie's "title page". When Annie is loaded, the title page will be replaced by Annie's main options (Figure 2.0-1). Each option is described in a separate section of this manual. To select an option, just type the option number and press return. The main options will disappear and the menu for the selected option will be displayed.

Before doing an example, we will describe how Annie tells directions.

Annie's coordinate system is pictured in Figure 2.0-2. This is the coordinate system usually used in antenna analysis. The Z-axis goes straight up toward the zenith. Theta is measured in degrees from the Z-axis. Theta is also called the zenith angle. This makes the Z-axis itself (the zenith) at theta = 0.0 degrees. The horizon (the X-Y plane) becomes theta = 90 degrees. Phi is the angle from the X-axis in the X-Y plane. Phi is also known as the azimuth angle. The X-axis itself is phi = 0.0 degrees, the Y-axis is phi = 90 degrees. Both the Y-axis and X-axis are at theta = 90

degrees. By specifying phi and theta, you can specify any direction from an antenna in three-dimensional space. We will look at a specific example in the next section.

When you are finished with Annie, select the last option, option 9, END. You will be asked to input 9 a second time, just to make sure you really want to stop. If you want to run Annie again, without changing any of the data you set up, type "CALL 16384" from Applesoft or "4000G" from Monitor. If you type "BRUN ANNIE", Annie will start with a clean slate.

```
            ANNIE MAIN OPTIONS

            1) GROUND PLANE
            2) SET ANGLES
            3) DEFINE ANTENNA
            4) TABULATE RESULTS
            5) PLOT RESULTS
            6) READ FROM DISC
            7) STORE TO DISC
            8) CALCULATOR
            9) END

 OPTION=
```

FIGURE 2.0-1. Annie's main options allow access to all options.

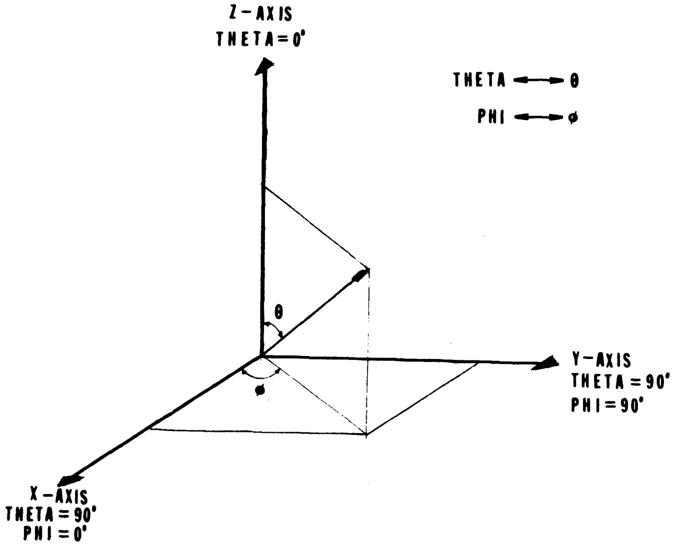


FIGURE 2.0-2. The standard coordinate system for antenna analysis. The X-axis is pointing out of the page.

3.0 THE FIRST EXAMPLE--A DIPOLE

This section will show you how to analyze the basic dipole antenna. You will also get a brief introduction to most of Annie's options. This will give you an understanding of "the big picture", Annie's overall structure. The next sections will then look at each individual option in detail.

To analyze a dipole, the first step is to run Annie as described in section 2.0. When the main options (Figure 2.0-1) are displayed, select option 3, DEFINE ANTENNA. After you have pressed "3" followed by return, the define antenna menu (Figure 6.0-1) will be displayed.

Note the blinking '>' sign near the top of the display. The position of the cursor (the blinking '>' sign) by the word 'ARRAY'indicates that you may change the array being defined. You may define up to four arrays (A, B, C and D). We will stay with array A, so no changes are needed here. Now, without typing anything else, press the "RETURN" key. Note that the blinking cursor jumps from ARRAY to ELEMENT. You can now change the element you will be defining. Each of the four arrays can have up to 16 elements. Since we will be specifying only one element (the dipole) in array A, no change is needed.

Press return once more and the cursor will jump to the next position marked by the word "NONE". None means that there is no antenna element in this position. We would like a dipole for the first (and, for now, only) element in Array A. To do this, press the space bar. The space bar will step the option from "NONE" to "DIPOLE". If you want, keep pressing the space bar and you can step through each available antenna element. Eventually, you will return to "DIPOLE". The assumed current distribution is shown in Figure 3.0-1.

Press the "RETURN" key and the cursor will jump to the length option. We wish to analyze a half wavelength long dipole, so no change is necessary.

Press "RETURN" four more times. This will jump the cursor through "X=", "Y=" and "Z=". X,Y, and Z are the position of the center of the dipole in terms of wavelengths. For now, we don't need to change them.

The next two menu positions are under "ELEMENT ROTATION". Press "RETURN" once more to position the cursor at "THETA=".

The initial orientation of the dipole (phi rotation=0, theta rotation=0) is shown in Figure 3.0-2. It is a vertical dipole. Since we would like to analyze a horizontal dipole, we need to rotate the dipole down 90 degrees. To do this, type "90" (the numbers will appear at the bottom of the screen, use the arrow keys to make any corrections) and press "RETURN". The 90 will appear beside the cursor. The effect

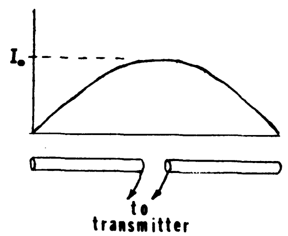


FIGURE 3.0-1. The current distribution along a half wave dipole is sinusoidal with no current at the ends and maximum current in the center.

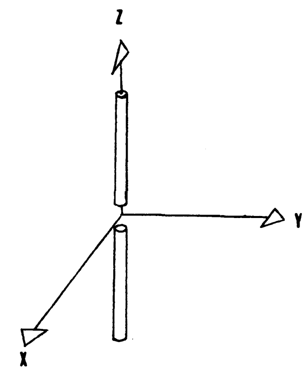


FIGURE 3.0-2. The initial orientation of Annie's dipole is vertical, along the Z-axis with the center of the dipole at the origin of the coordinate system.

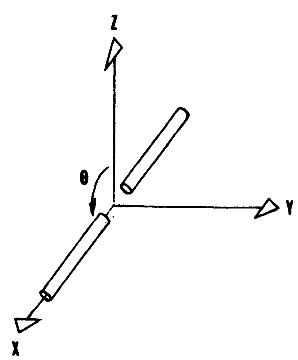


FIGURE 3.0-3. The effect of a theta rotation of 90 degrees on the initial dipole. For this orientation the phi rotation was 0 degrees.

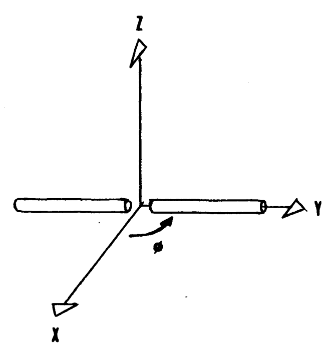


FIGURE 3.0-4. The effect of a theta rotation of 90 degrees with the phi rotation set to 90 degrees.

of a 90 degree theta rotation on the dipole is shown in Figure 3.0-3. Note that the phi rotation is zero. The 90 degree theta rotation moves the dipole down to the X(phi=0 degrees) axis. If we had set the phi rotation to 90 degrees, the dipole would be rotated down to the Y (phi = 90 degrees) axis, as in Figure 3.0-4.

By using different theta and phi rotations, it is possible to position the dipole to any desired orientation.

Now we have a horizontal (theta rotation = 90 degrees) dipole as the first (and only) element of array A. Let's leave the description of antenna weight for later and proceed directly to look at the antenna response.

To leave the define array options (now that we have defined our "array") press the ESC key, and the main options will appear. In fact, if you want to return from any option back to the main options, just press ESC.

There is a second way to leave any menu. That is by holding down the 'CTRL' key while pressing the letter 'D', usually referred to as 'pressing CTRL-D'. This will cause any current data in the menu to be replaced by the data that was in the menu when you first entered the option. Annie will pause for a moment to let you see the changes and then return to the main options.

Now that we are back in the main options, we would like to see the response of the dipole. Select main option 4, TABULATE DATA. When you do this, the tabulate data menu (Figure 7.0-1) will appear. Ignore the options for now, all we want is option 1, which is default anyway. So just press "RETURN". The response of the dipole will be tabulated on the screen. The display should correspond with Figure 3.0-5. The display lists the dipole's gain relative to a dipole in free space. Since this IS a dipole in free space, the peak gain will be 0 dB.

Next, return to the main options by pressing ESC twice. For a plot of the dipole pattern select option 5, plot results. After you press return, the plot menu will appear. All we want right now is option 1, which is default. So just press return again and the screen will flash. It will take a few moments for the grid to be drawn. When the grid is finished, press CTRL-P to draw the dipole pattern. Note that the angles are set up so only half the pattern is plotted. The plot should correspond with Figure 3.0-6. You may notice that the bottom of the plot is covered up by four lines of text. You may uncover the bottom of the plot by pressing CTRL-N. To return to the main options, press ESC twice.

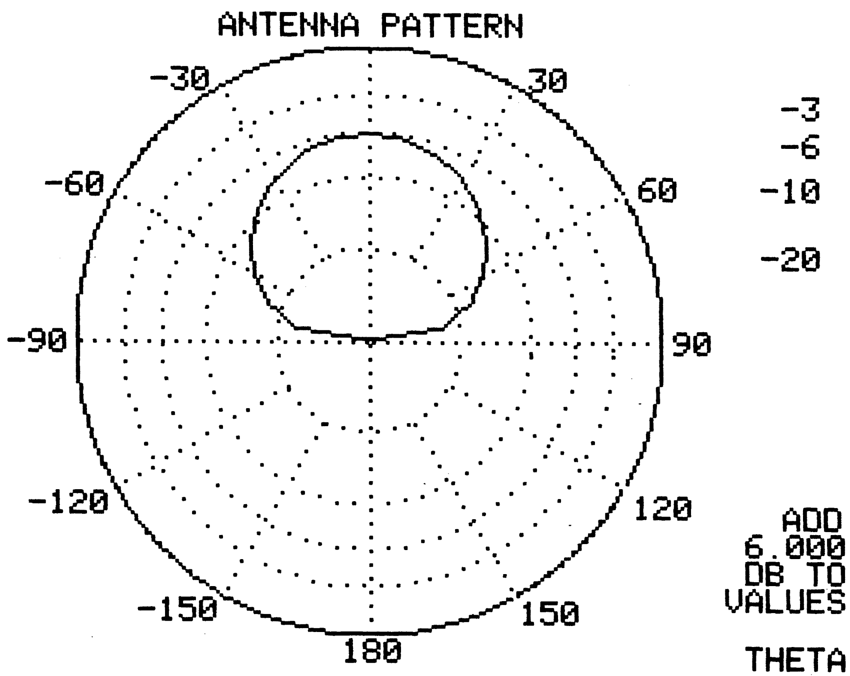
The next section will describe the ground plane menu in detail. In addition, the above example will be modified to include the effect of a real ground.

FIGURE 3.0-5. The example will generate the listing to the right.

I	A(1) PHI	A(2) THETA	A(3) GAIN	A(4) HORIZ	A(5) VERT
1	0.0	90.000	-385.3	-770.6	-770.6
2	0.0	80.000	-17.24	-770.6	-17.24
3	0.0	70.000	-11.16	-770.6	-11.16
4	0.0	60.000	-7.581	-770.6	-7.581
5	0.0	50.000	-5.053	-770.6	-5.053
6	0.0	40.000	-3.165	-770.6	-3.165
7	0.0	30.000	-1.761	-384.1	-1.761
8	0.0	20.000	-.7786	-383.1	-.7786
9	0.0	10.000	-.1942	-382.5	-.1942
10	0.0	0.0	0.0	-382.3	.00000
11	0.0	-10.00	-.1942	-382.5	-.1942
12	0.0	-20.00	-.7786	-383.1	-.7786
13	0.0	-30.00	-1.761	-384.1	-1.761
14	0.0	-40.00	-3.165	-770.6	-3.165
15	0.0	-50.00	-5.053	-770.6	-5.053
16	0.0	-60.00	-7.581	-770.6	-7.581
17	0.0	-70.00	-11.16	-770.6	-11.16
18	0.0	-80.00	-17.24	-770.6	-17.24
19	0.0	-90.00	-385.3	-770.6	-770.6

PRESS ANY KEY TO CONTINUE

FIGURE 3.0-6. A plot of the example dipole is below. Only the top half of the pattern was plotted.



4.0 THE GROUND PLANE MENU

This is the first main option. By using this option, you may select the characteristics of the ground to be used in your antenna analysis. As you will see, when we continue the example of the previous section, ground can have a significant impact on an antenna pattern.

After you have selected the ground plane option, you will be asked if you want to include the effect of ground. A 'Y' will be sufficient. Next, the ground plane menu of Figure 4.0-1 will be displayed.

```
GROUND PLANE CHARACTERISTICS

CONDUCTIVITY: OF THE GROUND
               1 = DESERT
               5 = AVERAGE
              20 = SWAMP

FREQUENCY:    LOSS DEPENDS ON FREQUENCY

EPSILON:      GROUND DIELECTRIC CONSTANT
               7 = POOR (LOW COND.)
              15 = AVERAGE
              30 = GOOD (HIGH COND.)

CONDUCTIVITY..>5.0000  MILLIMHOS/METER

FREQUENCY..... 3.5000  MHZ

EPSILON....... 15.000

-
```

FIGURE 4.0-1. The ground plane menu allows you to specify the characteristics of the ground beneath your antenna.

The top section of the menu provides some typical ground plane characteristics. The first characteristic is ground plane conductivity. Usually the higher the conductivity the better the ground. The units used here are millimhos/meter. Recent editions of <u>The ARRL Antenna Book</u> include a soil conductivity map of the continental United States. Keep in mind that the soil conductivity can vary, sometimes widely, with soil moisture content and temperature. A warm, moist ground will have a higher conductivity than a cold or a dry ground.

To input a value of conductivity, position the cursor (by pressing the RETURN key) to conductivity. Type in the desired value and press return. Note that you may also jump the cursor from option to option by pressing the arrow keys.

The second quantity is frequency. The rest of Annie is independent of frequency, everything is done in terms of wavelengths, there is no need to specify frequency. However the effect of ground is strongly dependent on frequency. Lower frequency has the same effect as a higher ground conductivity. In fact, the effect of ground is directly related to the ratio of frequency and conductivity. The effect of doubling one is identical to the effect of halving the other.

The final quantity is labeled 'EPSILON'. This is the relative dielectric constant of the ground, usually referred to by the greek letter epsilon. Higher dielectric constants are generally better because they imply the presence of water, with a dielectric constant of 80. The water, in turn, implies a high conductivity.

If you want to simulate a perfect ground plane, set the dielectric constant to 0 (don't worry, perfect ground planes are also impossible), conductivity to 100,000 (or any large number) and frequency to .001 (or any small number).

To return to the main options, press ESC. If you press 'CTRL-D', the menu will be restored to its original state, then Annie will pause briefly before returning to the main options.

To continue the example of the previous section, set the ground plane characteristics to whatever you want. Then return to the main options by pressing ESC.

Next, select the define antenna option. The menu with your dipole should appear. Using the arrow keys, move the cursor to the 'Z=' position under the 'ELEMENT POSITION' title. As you may have guessed, Z is the height of the antenna above ground in wavelengths. Presently, the height is zero, not a very good situation. Type in any value, for example 0.5 or 1.2 wavelengths, and press return. The number should appear opposite the cursor. Next, move the cursor to the PHI= position. Type '90' and press return. This will rotate the horizontal dipole (THETA = 90) from end on (PHI = 0) to broadside (PHI = 90). This rotation is illustrated in Figures 3.0-3 and 3.0-4. Now press 'ESC' to return to the main options. You may now plot or tabulate the resulting antenna pattern as you did in the previous section. You will note that the pattern has changed dramatically, feel free to check out several different heights.

In the plotted data, zero degrees is the zenith while + and - 90 degrees mark either horizon.

When you plot the data, you will note that the dipole

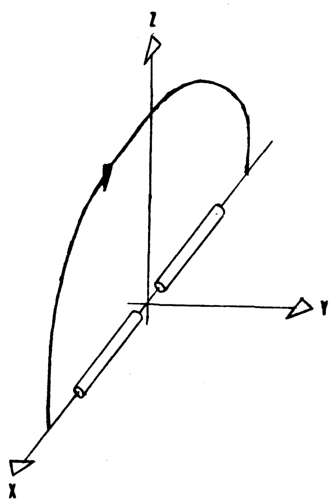
response with ground is sometimes greater than without. This is because the dipole is now radiating into only a half sphere instead of an entire sphere. In fact, if you have a perfect ground you will find that the average antenna gain will be 3dB greater than that same antenna in free space. Since the power will not be evenly distributed through that half sphere, the antenna may have nulls in some directions and an additional 3dB (for a total of 6dB) in other directions.

5.0 SET ANGLES MENU

Before calculating the antenna pattern, Annie must be told what directions (or angles) to analyze. This may be done in the set angles menu.

When you first run Annie, the angles are set up to analyze a slice starting at the positive X-axis (phi=0 degrees, theta=90 degrees) up to the zenith (theta=0 degrees) and back down to the negative X-axis (phi=0 degrees, theta=-90 degrees) in 18 steps. This is illustrated in Figure 5.0-1.

FIGURE 5.0-1. The "cut" or directions Annie is first set up to analyze is indicated by the arc. The dipole of the first example is also included.



The set angles menu is shown in Figure 5.0-2. This menu is accessed by selecting main option 2. The phi and theta angles are the angles used in the coordinate system described in section 2.0.

You may specify phi start and stop angles as well as theta start and stop. On the last line of the menu you may specify the number of steps. The number of steps and the difference between the start and stop angles will determine the step size, the number of degrees between each analysis angle. The step size (labeled 'STEP=' on the menu) is updated each time any changes are made. You may specify up to 218 steps. Purists will note that the number of analysis angles is one more than the number of steps.

Any conventional analysis will have the step in either phi or

theta equal to zero. If this is not the case, the resulting "cut" is difficult to visualize.

When looking at the pattern of an antenna with ground plane, it is usually best to look at a theta cut (Figure 5.0-1) to determine the angle theta at which maximum radiation occurs. Then, if you want to see the directive nature of your antenna, set both theta start and stop to that angle and let phi vary. If you just let theta start and stop equal 90 degrees, with a ground plane, you will wonder why the antenna response is always more than 100 dB down. This is because theta=90 degrees is exactly the horizon and the ground "shorts out" all sky wave radiation.

When you are finished specifying the analysis angles, press ESC for the main options. Depending on how many steps you specified, Annie will pause for a short time while a look-up table is loaded.

If you want to restore the angles to their original state, press CTRL-D. Annie will pause a moment to let you view the original angles and then return to the main options.

```
        SET ANGLES FOR ANALYSIS

PHI:    ANGLE ALONG HORIZON FROM X-AXIS.

THETA:  ANGLE FROM VERTICAL, HORIZON
        EQUALS 90 DEGREES.

PHI START.........>   0.0

PHI STOP..........    0.0 (STEP=    0.0)

THETA START....... 90.000

THETA STOP........ -90.00 (STEP=-10.00)

NUMBER OF STEPS... 18.000

_
```

FIGURE 5.0-2. The set angles menu determines the directions in which the antenna pattern is calulated.

6.0 DEFINE ARRAY MENU

The define array menu is listed in Figure 6.0-1. By using this menu you may define your antenna or set of antennas.

Annie looks at antennas as arrays and elements. A single element may be, for example, a dipole. An array is then a group of elements (even just one element is OK) radiating as a single antenna. Annie can calculate up to four arrays simultaneously. These four arrays are labeled A, B, C and D. Each of the arrays may have up to 16 elements. Each element (e.g., dipole) is referred to with a number, 1-16. In the introductory example, array A had one element, a dipole. Arrays B, C and D had no elements specified. When you looked at the pattern of array A, you saw the pattern of the dipole. You may choose from more than just dipoles for the elements in your antenna. More about this later.

```
                DEFINE ARRAY

        ARRAY>A       ELEMENT  1

 DIPOLE              .50000 WAVELENGTHS LONG

ELEMENT POSITION           ELEMENT ROTATION

   X =      0.0            PHI    =    0.0

   Y =      0.0            THETA  = 90.000

   Z =      0.0

ELEMENT WEIGHT = 1.0000 AT      0.0 DEG.

-
```

FIGURE 6.0-1. Four arrays with up to 16 elements each may be specified with the define array menu.

Next we will delve into the details of the menu itself. The define antenna menu is easily divided into five parts, so that is how we will divide the rest of this section.

6.1 ELEMENT LABEL

As mentioned previously, Annie refers to antennas in terms of four arrays (A, B, C, and D) with each array containing up to 16 elements (1-16). In the introductory example, array A,

element 1 was a dipole. In the define array menu, the second line (the first line after the title) lists the current array and element number. The remainder of the menu describes that particular element. To change either the array or element number, position the cursor, type the desired array or element number and press return. You may also use the space bar to step the number. If you type any character other than A, B, C, or D for the array, the character will be mapped into a valid array. For example, if you type '1', array A will be selected. If you watch the screen carefully as you press return, you will see a brief flicker as the screen is updated with the new information.

Once you have selected the desired element you may define or change that element. The next sections will show you how.

6.2 ELEMENT DESCRIPTION

The third line of the menu contains a description of the antenna element, the element type and its length in wavelengths. When Annie is first loaded, all elements are 0.5 wavelengths long. However, since all element types are 'NONE', no elements are calculated.

To change the element to a type that can be calculated, position the cursor in front of the element type. Press the space bar to step through each possible element type. For array A, there are three possible types:

1) Dipole. The dipole is the familiar antenna shown in Figure 3.0-1 and 3.0-2. Annie considers the dipole to be vertically oriented unless told otherwise (Section 6.4). The dipole length is specified in wavelengths from tip to tip. The usual half wavelength dipole would be specified as 0.5 wavelengths long. Annie assumes a sinusoidal current distribution.

2) Monopole. The monopole is exactly half of a dipole. By itself, it is not of much use. However, when a ground plane or other monopoles are included, some familiar antennas can be quickly analyzed.
The monopole is assumed to be vertically oriented with the high current end down and the high voltage (low current) end up. The length of the monopole is from tip to tip with an assumed sinusoidal current distribution. See Figure 6.2-2.

3) Isotropic. This antenna element radiates equally well in all directions. Even though no one has ever been able to build a truly isotropic antenna, it is still of practical interest. Since it is quite easy to calculate the pattern of an isotropic antenna (it's the same in every direction!) the computer can do it very quickly.

This is a big advantage when working with large arrays. Often, the main beam is influenced very little by what elements make up the array. If this is the case, then one may substitute the easily calculated isotropic element for any dipole elements.
This isotropic antenna element is somewhat unusual. It radiates equally well in all directions with the same gain as a dipole in its best direction. This is so that an isotropic element may be easily substituted for a dipole. The normal, textbook isotropic element has gain 2.15 dB down from a dipole. The isotropic radiation is normally vertical unless the element is rotated.

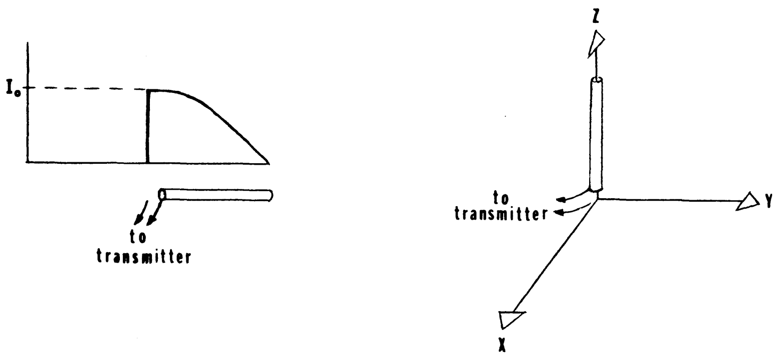


FIGURE 6.2-2. The monopole is identical to the right half of a dipole with the current distribution shown in the upper left diagram. The initial orientation (with no rotation) and postion is shown in the upper right diagram.

With the above three elements, an immense variety of antennas can be analyzed. However, there is still one more antenna element to be considered. You may use any previously defined array as an element in another array.

For example, say array A contains a single dipole and you would like to create an array of four identical dipoles. You could create three more dipoles in array A elements 2, 3 and 4. However, it would be faster to go to array B (see section 6.1), and use array A as the four elements of array B. If you added a second dipole to array A, array B would then become 8 dipoles because array B is composed of four identical copies of array A. This technique is described in more detail in Appendix V.

You may not use an array as an element of just any other array. For example, it would be difficult to decide what to do if array A were used as an element of array B and array B were used as an element of array A. Each array would have to

wait until the other array were calculated and nothing would get done. Thus, any array may be used as an element only in higher arrays. This is detailed in Table 6.2-3.

The capability of using entire arrays as individual elements means that the maximum number of elements that Annie can calculate at one time is 16**4 or over 65,000 elements.

Table 6.2-3. Available element types.

	ARRAY A	ARRAY B	ARRAY C	ARRAY D
YOU MAY USE THESE ELEMENTS	DIPOLE	DIPOLE	DIPOLE	DIPOLE
	MONOPOLE	MONOPOLE	MONOPOLE	MONOPOLE
	ISOTROPIC	ISOTROPIC	ISOTROPIC	ISOTROPIC
		ARRAY A	ARRAY A	ARRAY A
			ARRAY B	ARRAY B
				ARRAY C

The element description may not bê complete without a second item, its length. The length is requested in terms of wavelengths. If you have the length in feet or meters, use Annie's length conversion calculator (see section 10.0) to convert to wavelengths. The length conversion calculator is an electronic spread sheet specifically designed for this problem.

If the element type is a dipole, or monopole, the desired length is from tip to tip. If the element is isotropic or an array, the length is ignored.

6.3 ELEMENT POSITION

Once the element description is set, we need to tell Annie where it is located. This is done by setting the values of X, Y and Z.

If you are in free space (i.e., no ground) and there is only one element, the position does not matter. If the effect of ground is included and X, Y and Z are left at zero, the antenna will be analyzed flat on the ground. To raise your antenna, set Z to any desired height. Again, this will be in terms of wavelengths. Use the calculator option if you have the height in feet or meters.

The X and Y coordinates allow you to position the antenna element horizontally with respect to other elements. As with the Z coordinate, X and Y are in terms of wavelengths.

The X, Y and Z coordinate system is pictured in Figure 2.0-2. An example of two dipole antennas with coordinates is shown in Figure 6.3-4. Note that the coordinates of a dipole are measured from its center. The coordinates of a monopole are measured from the high current end of the element. This is just like the dipole except that the other half of the dipole is not there.

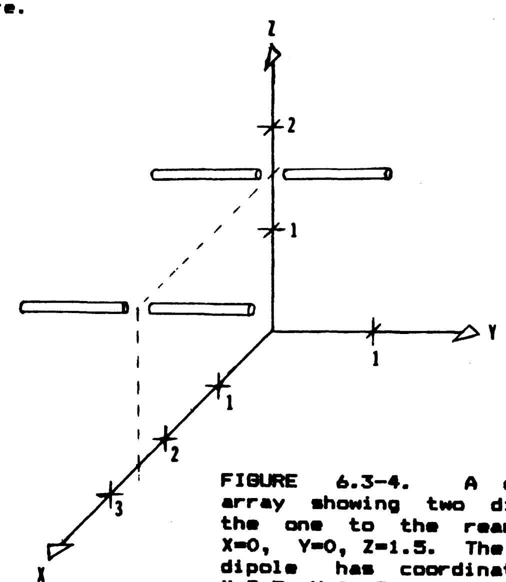


FIGURE 6.3-4. A example array showing two dipoles, the one to the rear is at X=0, Y=0, Z=1.5. The second dipole has coordinates of X=2.5, Y=0, Z=1.5.

When using arrays as elements in new arrays (as described in section 6.2), care is required when calculating coordinates. This is because, when using arrays as elements, any coordinates specified for the array will be added to the coordinates used in the original elements.

For example, suppose you have a dipole at X=1, Y=2 and Z=3 in array A. Then you use array A as an element of array B and you set the array B element coordinates at X=4, Y=5 and Z=6. The coordinates of the actual dipole in array B will be X=1+4=5, Y=2+5=7 and Z=3+6=9.

One very important final point about using arrays as elements, if you include the effect of ground, ALWAYS make the array Z coordinate equal to zero. In the example above the array B coordinate, Z=6, should be zero. The reason for this is that the effect of ground was already included when the dipole was calculated in array A (Z=3). With the array B coordinate equal to six, that ground is dragged six wavelengths up into the air, not a nice situation.

The important thing to remember is, if the ground plane is included, and your element is a previously defined array, make sure Z=0. The antenna's height should be specified in the previously defined array.

6.4 ELEMENT ROTATION

After positioning the antenna element, we must rotate it to the proper orientation.

Both the dipole and monopole start out as vertical antennas. Even the isotropic antenna starts out with vertical polarization. If you want any other orientation, you have to rotate the antenna element. Figures 3.0-2 through 3.0-4 illustrate the element rotation angles.

If you rotate an isotropic antenna, the normally vertical polarization will change. When using an array as an element, the rotation angles will be ignored.

Antenna experts will note that three angles are required to completely describe an arbitrary orientation. These angles are usually referred to as alpha, beta and gamma. Due to symmetry of the dipole and monopole about their own axes, Annie requires only two angles.

6.5 ELEMENT WEIGHT

When designing a phased array, it may be desirable to feed the elements of the array with different powers or with different phases. With the element weight (at the bottom of the define array menu) you may individually adjust the power and phase of any element in the array.

The default for all element weight magnitudes (i.e., power) is unity. This means that a given amount of power is divided equally between all elements of the array. For example, if we had one watt to drive five elements, each with unity weight, each element would receive 1/5 watt. Now, suppose we change the weight of the first element to 2 and leave the others at 1. Now the first element will receive 2/5 watt while the others will remain at 1/5 watt. This results in a total antenna power of 1.2 watts, while the 'reference dipole' will remain at 1 watt. If you want the total antenna power to remain at 1 watt, make sure all the weights add up to the number of elements. An important exception is parasitic antennas, as noted in Appendix V.

Adjusting or "tapering" the power fed to antenna elements is often used to reduce sidelobe levels of an array.

By changing the phase at which each element of the array is fed, one can electronically point an array in different directions. This is often used in phased arrays of vertical antennas. You may adjust the phase of each element using the second part of element weight.

Remember that it is the difference between antenna phases that matters. Two antennas, one at 0.0 degrees weight and the other at 30 degrees will have the same pattern as an array with 75 degrees and 105 degrees phasing.

7.0 TABULATE DATA MENU

After the antenna is defined, the tabulate data option (main option 4) can provide you with a tabulated listing of your antenna pattern. The listing may be directed to the monitor (CRT) or to a printer. A listing which describes each element of your antenna can also be generated. And, if the occasion arises, you may use a tabulate data option to send a control command to a printer to, for example, change print modes. Each option of the tabulate data menu will be described next.

```
        TABULATE DATA OPTIONS

   1) RESULT TO CRT
   2) RESULT TO PRINTER
   3) ANTENNA CONFIGURATION TO CRT
   4) ANTENNA CONFIGURATION TO PRINTER
   5) SEND COMMAND TO PRINTER
   6) SET TABULATE ATTRIBUTES


ENTER OPTION,
   START COLUMN (OPTIONAL),
   ARRAY (OPTIONAL)

-
```

FIGURE 7.0-1. Tabulated listings of the calculated antenna pattern may be quickly obtained at the crt or printer with the tabulate options.

7.1 RESULT TO CRT

This option will generate a listing of the antenna pattern on your monitor. A typical listing is shown in Figure 7.1-2. The parameters being listed (phi, theta, gain, horizontal, vertical) are described in detail in section 7.6. For now, we will just mention that phi and theta are the analysis angles specified in main option 2, set angles. The gain column is the total antenna gain which is composed of horizontal and vertical components.

Note that the very first line of each column is a letter followed by a number in parenthesis. The letter is the array being tabulated in that column and the number is the number of the column.

The next line contains the label for the quantity being printed (e.g., gain). You can specify what quantity and which array is to be printed for each column. This is described in section 7.6.

To send the listing to your monitor, select tabulate data option 1, RESULT TO CRT. After you press '1', you may optionally input a start column and array, separated by commas. For example, '1,3' will cause the list to start with column 3. To start with column 3 but to force all the columns to array B instead of the default array, type '1,3,B'. You may also leave numbers out, '1,,B' will force all columns to array B but will start with column 1, the default. In fact, pressing ',,B' will force all columns to array B, start with the default column 1 and do the default option 1.

When you enter the tabulate option and want a listing on your monitor, you may also just press return. The default option 1 will be selected and the list will start with column 1 and list the default array.

While up to 18 columns may be specified, only the number of columns which will fill the screen will be printed.

If you are in the middle of a listing and want to exit back to the tabulate options, just press ESC at the end of a page.

FIGURE 7.1-2. This is the type of listing that the tabulate options will send to your crt.

	A(1)	A(2)	A(3)	A(4)	A(5)
I	PHI	THETA	GAIN	HORIZ	VERT
1	0.0	90.000	-385.3	-770.6	-770.6
2	0.0	80.000	-17.24	-770.6	-17.24
3	0.0	70.000	-11.16	-770.6	-11.16
4	0.0	60.000	-7.581	-770.6	-7.581
5	0.0	50.000	-5.053	-770.6	-5.053
6	0.0	40.000	-3.165	-770.6	-3.165
7	0.0	30.000	-1.761	-384.1	-1.761
8	0.0	20.000	-.7786	-383.1	-.7786
9	0.0	10.000	-.1942	-382.5	-.1942
10	0.0	0.0	0.0	-382.3	.00000
11	0.0	-10.00	-.1942	-382.5	-.1942
12	0.0	-20.00	-.7786	-383.1	-.7786
13	0.0	-30.00	-1.761	-384.1	-1.761
14	0.0	-40.00	-3.165	-770.6	-3.165
15	0.0	-50.00	-5.053	-770.6	-5.053
16	0.0	-60.00	-7.581	-770.6	-7.581
17	0.0	-70.00	-11.16	-770.6	-11.16
18	0.0	-80.00	-17.24	-770.6	-17.24
19	0.0	-90.00	-385.3	-770.6	-770.6

PRESS ANY KEY TO CONTINUE

7.2 RESULT TO PRINTER

The second tabulate option, RESULT TO PRINTER, is similar to the previous option with output being sent to a printer. The size and slot number of the printer may be set as described in section 7.6.

Prior to actually sending the listing to your printer, you will be asked for a title for the listing. Type it in and when you press return, the title will be centered and printed. If you want another line in the title, type it in next. You may type in as many lines as you want. When you are finished, type nothing and press return, the listing will be sent to your printer.

Suppose you selected this option accidentally. To return to the tabulate options just press CTRL-D in response to the title prompt. ESC will not work here.

Annie is able to print up to 18 columns of data. This will just fill 132 characters per line. If your printer is set for less than this, only enough columns will be printed to nicely fill the page.

7.3 ANTENNA CONFIGURATION TO CRT

This is the third tabulate option. This option will list all the information on every antenna element in every array. Of course, elements which are 'NONE' (instead of, for example, 'DIPOLE') are not listed.

This option may be used to quickly check the current status of your antenna.

In the previous two options, you could specify a starting column and array. In this and all remaining tabulate options any additional input, beyond the option number, is ignored.

7.4 ANTENNA CONFIGURATION TO PRINTER

This option is similar to the previous option with output going to the printer.

As with the result to printer option, you will be asked for a listing title and you may also press CTRL-D at this time to skip the printer listing entirely.

7.5 SEND COMMAND TO PRINTER

Often it is desired to send a control character sequence to the printer to change print modes. You may use this tabulate option to do so.

Some printers begin control character sequences with ESC. The Apple monitor will delete these sequences from normal input. However, any sequences with ESC will be sent to the printer in their entirety when using this option.

7.6 SET TABULATE ATTRIBUTES

This, the final tabulate option , will allow you to do three things. First, you can specify what will be printed in any of the 18 data columns. Second, you can tell Annie the characteristics of your monitor. Third, you may do the same for your printer. With the tabulate attributes menu shown in Figure 7.6-3, we will discuss each of the three areas in turn.

FIGURE 7.6-3. The tabulate attributes will control what data is printed and informs Annie of the characteristics of your crt and printer.

```
SET TABULATE ATTRIBUTES

DATA              CRT

COLUMN.> 3        CHARACTERS/LINE.  40

ARRAY..  A        LINES/PAGE......  24

     GAIN

                  PRINTER

                  CHARACTERS/LINE.  80

                  SLOT (0-7)......   1

-
```

7.6.1 DATA COLUMN SPECIFICATION

With the cursor at its initial position, there are three items which may be changed. The first item, the number directly beside the cursor, is the column number. To select the data column you want to change, type the column number and press return.

Now, with the cursor in the same position, if you type a letter; A, B, C or D; the second item will change. This is the default array for the column, it is directly below the column number.

Next, with the cursor still in the same position, you may change the quantity to be printed (e.g., gain) in that column

by pressing the space bar. By repeatedly pressing the space bar, you can step through every quantity that may be printed. The quantity to be printed is listed directly below the default array. Some of the quantities may be new to you. Each will be described next. If the discussion of any of these quantities (except the first one) gets too complicated, just skip on to the next one.

1)GAIN. This is the total gain of the antenna in a given direction relative to a dipole in free space. The maximum gain of a dipole with a perfect ground plane is +6dB. This is because the dipole is radiating into half a sphere (3dB) instead of a whole sphere and its gain is less in some directions and more in others (another 3dB).

2)HORIZONTAL. This is the gain, again relative to the dipole maximum gain, of the horizontal component of the antenna pattern. For a horizontal dipole, the horizontal gain is equal to the total gain, in many directions. For a vertical antenna, the horizontal gain will be negative infinity dB, or, as far as Annie is concerned, less than -100 dB. The horizontal polarization is more precisely described as polarization in the phi direction.

3)VERTICAL. This is the gain of the vertical component of the antenna pattern relative to the dipole's maximum gain. For vertical antennas, the vertical gain will equal the total gain.

4)SENSE. This column will have one of three entries: LINEAR, RIGHT, or LEFT. Linear polarization can be vertical or horizontal (check the magnitude of the vertical and horizontal columns) or tilted at some angle in between. RIGHT refers to right hand circular or elliptical polarization. Experts on polarization will relax when it's stated that the right hand polarization corresponds to a clockwise rotating E field vector as viewed from the transmitting antenna, consistent with IEEE convention. LEFT, of course, refers to left hand circular or elliptical polarization.

5)AXIAL. This refers to axial ratio. For linear polarization, it will be infinite, printing out as all stars. For elliptical polarization, it will be the ratio between the major and minor axes of the ellipse. The larger the axial ratio, the more linear the polarization. Purely circular polarization will have an axial ratio of one because both the major axis and minor axis are equal.

6)TILT. For linear polarization, tilt is the angle between horizontal (the phi direction) and the actual polarization. Horizontal polarization will have a tilt of zero degrees while vertical will have a tilt of 90 degrees. For elliptical polarization, the tilt is the angle that the major axis makes with the horizontal or phi direction. Tilt is meaningless for pure circular polarization.

7) PHASE. Phase is the phase difference between the vertical (theta) and horizontal (phi) time-varying E field components. Its primary use is in the calculation of sense, axial ratio and tilt.

8) PHI. One of two spherical coordinates. It is the angle along the horizon from the x-axis.

9) THETA. The second of the two spherical coordinates. It is the angle from the zenith.

7.6.2 CRT ATTRIBUTES

Annie is initialized assuming that the monitor has 40 characters per line and 24 lines per page. If the actual situation is different, the two numbers on the right hand side of Figure 7.6-3 can be changed. Note that strange things will happen if you set the number of characters per line to a value less than the actual screen size. If a data line happens to end right on the right hand edge, Annie assumes that a CR/LF is performed automatically. If it is not, the data will be scattered across the screen.

7.6.3 PRINTER ATTRIBUTES

The number of characters per line for the printer may be set by changing the appropriate number on the right hand side of the attributes menu. The maximum value is 132 characters per line. This will handle just about any printer you want to use.

The last number of the attributes option is the printer slot number. Printers are usually set up in slot 1. If yours is different, you may change it here.

If you direct output to a slot with no printer, Annie will "hang". Just press RESET for the Main Options. If you have no printer, it is best to set the slot number to zero. Annie always checks for a printer slot number of zero before printing anything. If found, Annie informs you that there is no printer. This can save some frustration.

8.0 PLOT DATA MENU

No analysis program is complete without a plotting capability. Plotted results display your data as no other way can. As an ancient philosopher commented, pictures are 30 dB better than words.

Annie can plot the total gain or the horizontal or vertical gain component of any array. The antenna pattern is plotted on a polar grid. An example of a plot is shown in Figure 8.0-1. Angles in degrees are labeled around the circumference of the chart. The solid circle around the edge of the chart represents 0.0 dB while the four interior circles represent -3.0, -6.0, -10.0, -20.0 dB respectively. These values are listed along the right edge of the chart.

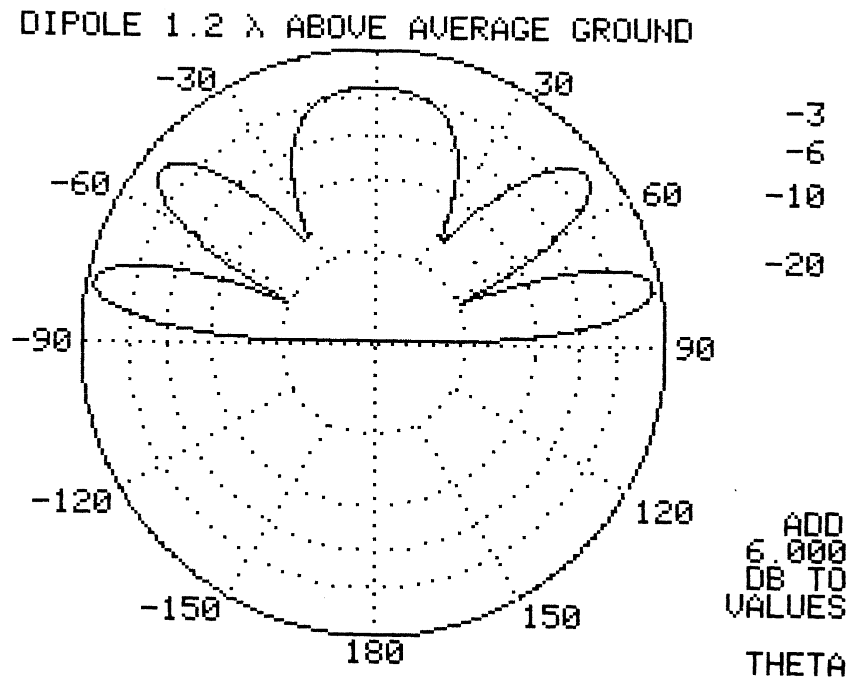


FIGURE 8.0-1. A sample of Annie's antenna pattern plotting capability.

The exact center of the chart is -100.0dB. The dB scale (which is not linear) is identical to that used on standard ARRL antenna pattern charts. A more detailed description of the grid is available in any recent edition of The ARRL Antenna Book.

Since antennas often have a gain which is different from 0.0 dB, you may subtract a constant from all plotted values. This value is listed on the lower right hand side of the chart. To obtain the actual gain of the antenna, you must add that value back in to the plotted gain. In the example, Figure 8.0-1, the offset is 6.0dB. This is because the antenna is analyzed with a ground plane which means a dipole gain may be as much as 6 dB above a dipole in free space. Section 4.0 explains why.

At the lower right hand corner is either the word 'THETA' or 'PHI'. This indicates which angle is being plotted. THETA will take a cut overhead while PHI will take a cut along the horizon.

With this brief introduction to Annie's plotting complete, we will investigate each of the plotting options of the menu listed in Figure 8.0-2. The plot options may be accessed by selecting main option 5. When done, press ESC and the main options will reappear.

FIGURE 8.0-2. The plot options will allow you to see the calculated antenna pattern.

PLOT OPTIONS

1) PLOT
2) DRAW POLAR GRID
3) SET POLAR GRID
4) STORE PLOT ON DISC
5) HARDCOPY

8.1 THE FIRST PLOT OPTION

The first plot option is called simply, PLOT. Selection of this option causes the high resolution graphics to appear. If this is your first time in the plot options or if you had changed the kind of plot to be drawn, the screen will clear itself and the grid for your plot will be drawn. An entire grid can be drawn in about 30 seconds. While the grid is being drawn, a flashing 'WORKING' sign will appear at the bottom of the screen.

You may notice that the bottom section of the chart appears to be cut off. This is because the screen is in mixed mode. The bottom of the graphics screen is "covered-up" by four lines of the text display. When Annie is finished drawing the grid, these four lines will display a menu. The top line of the menu allows you to select what curves will be drawn on the grid.

The top line of this menu contains three items. First, you may select the quantity; total gain, vertical gain or horizontal gain. As usual, you may step through each quantity by pressing the space bar. The second item is the array. You may plot the pattern in array A, B, C or D. The final item is the line type. You may select a solid, dashed, dot-dash or dotted line type. This is helpful when placing more than one curve on a plot. To change the line type, press the space bar.

After the grid is complete and you have selected what you want plotted, press 'CTRL-P' and the antenna pattern will be plotted.

There are several other control characters which may be used here. Each will be described next.

'CTRL-N' turns off the mixed mode. This will cause the bottom four lines of text to disappear revealing the bottom of the graphics display. You may still type commands just as though the bottom four lines were still there.

'CTRL-O' turns the mixed mode back on. This reverses CTRL-N.

'CTRL-T' allows you to replace the current plot title with a new title without having to redraw the entire grid.

'CTRL-C' dumps the graphics display to a printer if you have the required routine in place (see section 8.5).

'CTRL-G' redraws the entire grid.

Some of the above control characters are listed on the bottom line of the menu for your convenience.

To leave this option, 'ESC' or 'CTRL-D' will return you to the original plot options.

8.2 DRAW POLAR GRID

When the first option, plot, is selected, the polar grid will not be redrawn if you have not changed the grid (see section 8.3, Set Polar Grid). Selection of this option will cause the entire grid to be redrawn regardless of any changes. With this one exception, this option is identical to the first option.

This option is useful if the old grid has become cluttered. You may start with a clean grid.

8.3 SET POLAR GRID

Selection of option 3 of the plot options will display the menu of Figure 8.3-3. This menu will allow you to change the grid's title, relative position, magnification, aspect ratio and dB scale offset. This section will describe this in detail.

FIGURE 8.3-3. Many of the polar grid's parameters may be changed with the set polar grid option.

```
            SET POLAR GRID

>TITLE:
            ANTENNA PATTERN

ANGLE LABEL:     THETA


CENTER X...... 140.00

CENTER Y...... 96.000

MAGNIFICATION  1.0000

ASPECT RATIO.. 1.1300

SCALE OFFSET.. 6.0000(DB)

■
```

The title line for the plot is near the top of the menu in inverse video (dark characters on a light field). With the cursor positioned at the word 'TITLE' you may type any title up to 40 characters long. After you press return, the title will be centered and displayed in the menu. The title will appear at the top of your next plot.

A few punctuation marks are not included in the graphics character set. If you use such a character, it will print out as a blank on the plot. A special character, the Greek letter lambda (wavelength) will print out on the plot (but not on the menu) if you use the colon, ':'. Lambda is an extremely useful character for antenna descriptions.

After the title section of the menu is the next menu item, 'ANGLE LABEL'. Either phi or theta may be selected by pressing the space bar. If theta is selected, the antenna pattern will be plotted as a function of theta. This will plot the antenna pattern in an arc which passes overhead. If phi is selected, the pattern is plotted as a function of phi, an arc parallel to the horizon. The angle label you select will be listed on the plot in the extreme lower right hand corner.

If, while plotting, no antenna pattern appears when one should, check the angle label. If the set angles menu (Section 5.0) is set up for fixed theta (for example) and the angle label is also theta, a single straight line (at most) will be plotted.

The next two items on the menu are center x and center y. These are the coordinates of the center of the polar grid. While they may take on any value, it is useful to keep at least a portion of the grid on the screen.

The high resolution screen coordinates start at 0 in the upper left corner of the screen. The x coordinate goes along the top up to 280 at the right.edge of the screen. The y coordinate goes down the screen to 192. The default values for center x and y are 140 and 96, the center of the screen. By changing the center of the plot and increasing the magnification (described next), you may view portions of the polar grid in greater detail.

The next item on the menu is magnification. As might be expected, this value will set the size of the polar grid. As with center x and y, any value may be used and it is wise to use only values which will allow at least a portion of the grid to be displayed. While not of much use, negative magnification is fun to try.

If you have a graphics printer, it may be useful to find the magnification which will allow you to overlay and trace a pattern onto polar graph paper. When using an EPSON FX-80 and ARRL standard paper, a magnification of 1.28 works well.

Keep in mind that Annie takes the time to plot every point in the entire grid, whether it is on or off the screen. If the center and magnification cause a large portion of the grid to be off the screen, there may be a long pause as off the screen points are calculated. To remove any fears that something went wrong, Annie displays a flashing "WORKING" while doing a plot in mixed (graphics/text) mode.

The next to last item on the menu is aspect ratio. This is the ratio of the height of the screen to the width of the screen. Many monitors do not have a 1:1 aspect ratio. The default value for the aspect ratio is 1.13, a common value. For some fun, experiment with different values.

To set the aspect ratio for your monitor, set the aspect ratio to 1.0 and plot the polar grid (the first plot option, Section 8.1). If the plot is oval shaped (actually, an ellipse), you must calculate the aspect ratio. Simply measure the vertical diameter and divide by the horizontal diameter. When the aspect ratio is set to this value, the polar grid will be circular.

To complicate matters more, the supplied graphics dump routine sets up the FX-80 for an aspect ratio of 1.0. If you are going to get hardcopy of your plot, you may want to tolerate an oval grid on the screen.

The final item of the set polar grid menu is the scale offset. The offset (in dB) will be subtracted from each point of the antenna pattern prior to plotting. Then, near the lower right hand corner of the plot, the value of the offset will be listed. Thus if your antenna has a peak gain of 6 dB (as is the case with a dipole above a perfect ground), you can make the scale offset 6 dB and the antenna pattern will not go outside the solid zero dB circle of the polar grid. (Experts will note that the offset really should be 6.021dB.)

To exit the set polar grid menu, press ESC. If you made any changes at all in the grid, the next time you plot, the entire grid will be redrawn.

If you want the grid parameters returned to their original values, press CTRL-D. Annie will bring back the old values, pause for you to look at them and then return to the plot options. Any changes that you tried to make will not cause the grid to be redrawn.

8.4 STORE PLOT ON DISC

This option is useful if you want to save a plot for later reference. It may also be used with any software you have to send the plot to a printer at a later time.

When you access this option, you will be asked for a file name. To keep files somewhat organized, it is good to append '.PIC' to the file name. You may also specify a disc or slot number in the usual manner. Typical file names would be: 'SLOPER.PIC', 'VEE.PIC,D2' or 'VERT.PIC,D1,S6'. If a DOS error is encountered, you will be returned to Applesoft. Type 'CALL 16384' to reenter Annie. If there is no error, your file will be stored on disc in a one for one bit image format.

8.5 GRAPHICS HARDCOPY

Selection of this option (or the equivalent 'CTRL-C' while the plot is on the screen) will cause the image on the graphics screen to be transferred to a printer.

Since the graphics capability of most printers is incompatible, you will likely require a special routine for this option to work. An assembly language routine is already included for the EPSON FX-80 printer. The source is in 'GDUMP' and the object code is in 'GDUMP.OBJ0'. Some printers may require only minor modification of this code. The graphics dump routine (and only the graphics dump routine) is not copyrighted, so do with it as you please.

When you first run Annie, the code in GDUMP.OBJ0 is loaded starting at $300. It may be no longer than $D0. When you select the hard copy option, the GDUMP.OBJ0 routine is executed. If you have an EPSON FX-80 printer, or you have modified the GDUMP code for your printer, the graphics display will be transferred to your printer.

9.0 DISC ACCESS

Once an antenna has been created, you may want to store the description of the antenna (positions, rotations, phasings, etc.) on disc for later retrieval. Main option 8 will allow you to store the data and option 7 will let you read the data back into Annie.

Use of both options is similar. Select the desired option and then type the file name and press return. If you want to specify a slot or drive number, do so using the usual DOS command structure for the file name. For example "SLOPER, D2,S6" typed in as the file name will cause the file "SLOPER" located on disc 2, slot 6 to be found.

You may also store graphics data using the appropriate plot data menu option (see section 8.4). If you wish to read a graphics file, use main option 7. This option is intended primarily for antenna data files but if you specify a plot file, the file will be read into the hi-res memory properly.

If you store a large number of files (or even if you don't!) it will be desirable to append ".ANT" to your antenna files and ".PIC" to your plot files. For example, "SLOPER.ANT,D2,S6" and "GRID.PIC". This will clearly state what kind of data is in the file right in the file name.

You may also want to create an antenna file called "ZERO.ANT" with absolutely no antenna in it. Then, when you finish with one antenna analysis and want to start another, just read ZERO.ANT and you will start with a clean slate.

If a DOS error is encountered during execution of the read or write, the error will be printed and you will return to Applesoft. If you type "CALL 16384" you will immediately be returned to Annie with all data still intact.

10.0 ANNIE'S LENGTH CONVERSION CALCULATOR

Meters and feet and wavelengths. Converting between them can be a pesky chore. It is not everyone who can instantly come up with, for example, the speed of light in feet per second. And chances are when you need to do the conversion, your calculator is not within reach.

It is for just such problems that a length conversion calculator was developed for Annie. When you need a dimension in wavelengths, just select Annie's Main Option 9, CALCULATOR. The menu in Figure 10.0-1 will then be displayed.

You may change any of the five numbers (labeled meters, feet, inches, wavelengths and MHZ) in the menu. When you change any number, all the other numbers will be instantly updated to reflect the number you changed.

For example, with the cursor pointing at meters, if you type 10 and press return, you will see how many feet and inches equals 10 meters and what fraction of a wavelength 10 meters is at 3.5 MHZ.

```
LENGTH CONVERSION CALCULATOR

>21.414 METERS

    70 FEET, 3.0605 INCHES

 .25000 WAVELENGTHS

 3.5000 MHZ
```

FIGURE 10.0-1. Conversions between wavelength, feet and meters are easy with Annie's length conversion calculator.

When the cursor is at feet and inches, you may type in two numbers separated by a comma. The first number is feet and the second is inches. If, for example, you typed "0,1000", you would find out how many feet and inches are in 1000 inches.

Annie's length conversion calculator is also an excellent instructional aid for those just learning the relationship between frequency and wavelength. It's a good way to get a solid grasp on what might otherwise just be abstract equations.

11.0 DEFAULT MODIFICATION

You may have noticed that when you first run Annie, all menus already have values for all options. These are the default values. Nearly all the default values are stored in one area of memory. If you would like to change any of these defaults, the procedure is as follows:

1) Run Annie. This is so that you will have a fresh copy of the software.

2) Change the value of all options to the values you want to be the default (i.e., the values you want when Annie is first run).

3) Exit Annie using main option 9.

4) Make sure the Annie disc is in slot 6 and drive 1 and is not write protected.

5) Type "BRUN DEFAULTMOD.OBJO" and press return.

After performing this procedure, Annie will always start out with the new values. You may now run Annie by typing "BRUN ANNIE" or "CALL 16384". If you type "CALL 16384" you may notice that a small part of the hi-res screen has been over written.

APPENDIX I: ANALYSIS ACCURACY

An asymptotically exact analysis of arbitrary wire antennas has been realized on personal computers. Using a numerical technique known as method of moments, the analysis of a single antenna typically requires an overnight run. To shrink the analysis time from hours to a fraction of a second, Annie does make some approximations.

In order to do a fast analysis, Annie assumes a sinusoidal current distribution. Not only is this assumption quite accurate, it is tolerant of errors. This is because the antenna pattern is insensitive to small changes in the antenna current distribution. A small change in the current distribution will produce an even smaller change in the antenna pattern.

To include the effect of ground in an antenna pattern, Annie uses reflection coefficients. Two rays are added together to determine the gain in any direction. The first ray is the direct ray. The second is a ray reflected from the ground. It is equal in magnitude to the direct ray multiplied by a complex reflection coefficient with an additional phase length added. An implication implicit in this type of analysis is that only the sky wave pattern is calculated. The ground wave is not included. Thus the antenna pattern goes to zero (minus infinity dB) at the horizon. Any of Annie's pattern calculations printed out as -100dB or more can all be treated as minus infinity dB.

Ground will have another influence on antenna patterns. If ground is very close, the antenna current distribution will be disturbed. In analogy with transmission lines, the closer an antenna gets to the ground, the lower its impedance and thus the higher the antenna current. The worst case for this situation is a sloping dipole. Now only one end is close to the ground and we have an asymetric current distribution.

The next section, which analyzes a sloping dipole, also compares Annie's result with the answer provided by a popular mini-computer based numerical analysis program. The result for the main lobe is very close while the backside is off by up to 2dB.

All in all, if your antenna is more than 0.4 wavelength high, Annie's results are quite good. Below 0.4 wavelength, there may be some error, approaching about 2dB in the worst case.

In arrays of antennas, power radiated by one element will actually be received by the other elements. This is called mutual coupling. Mutual coupling will effectively change power and phase of the elements of the array. Annie does not automatically include the effect of mutual coupling. This is especially important in a parasitic array such as a Yagi. If the magnitudes and phases of the excitation of the elements

can be obtained, then Annie may be used for a fast analysis of such antenna types.

One final point, Annie's analysis does not account for end capacitance. So, as usual, a half wave dipole will physically be about 5% shorter than a half wavelength.

APPENDIX II: THE SLOPING DIPOLE

A sloping dipole is a simple antenna which is often used to provide some directivity and front to back ratio on the low HF bands. The dipole drawn in Figure II-1 will exhibit some gain to the right and rejection off the back (left).

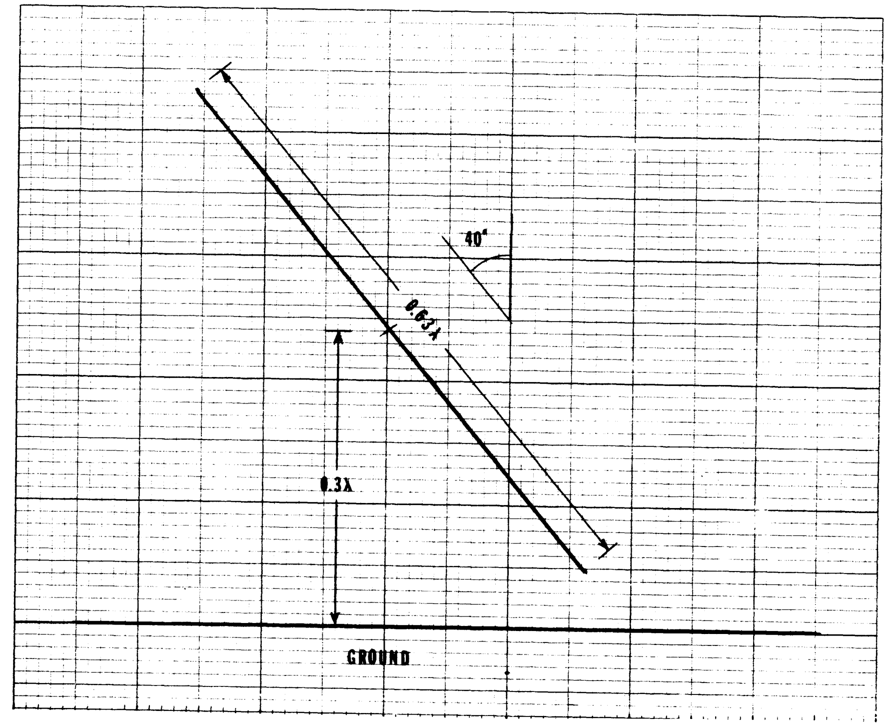
Figure II-1 also illustrates a convenient way to figure antenna geometry without use of a calculator and trig functions. Just draw the antenna to scale on graph paper.

Annie's description of the sloping dipole is also shown in Figure II-1. The ground plane is 5 millimhos/meter with a dielectric constant of 15 at 3.5 MHZ. If this analysis were performed with a perfect ground, the antenna pattern would, surprisingly, have equal gain to both the front and rear. It is a lossy ground that makes the sloping dipole work.

The result of a theta (vertical plane) cut in the plane of the dipole is shown in Figure II-2. This particular dipole has a front to back ratio of better than 7 dB.

The dashed line in Figure II-2 is the result of a numerical analysis program known as NEC. After NEC's results were adjusted for equivalent real power and the effect of end capacitance, the pattern was plotted. The results compare very well for what is an acid test of Annie's analysis. See Appendix I.

Figure II-3 shows the gain of the dipole in a phi (horizontal) cut. For this analysis, theta was fixed at 60 degrees (30 degrees above the horizon) and phi was swept through 360 degrees. The sloping dipole has a broad main lobe and has maximum gain off to either side of zero degrees.



SLOPING DIPOLE EXAMPLE

**** ARRAY A ****

1) DIPOLE, LENGTH=.63000, X= 0.0, Y= 0.0, Z=.30000, PHI= 0.0,
THETA=-40.00, WEIGHT=1.0000, ANGLE= 0.0

FIGURE II-1. A sketch of the sloping dipole and Annie's description.

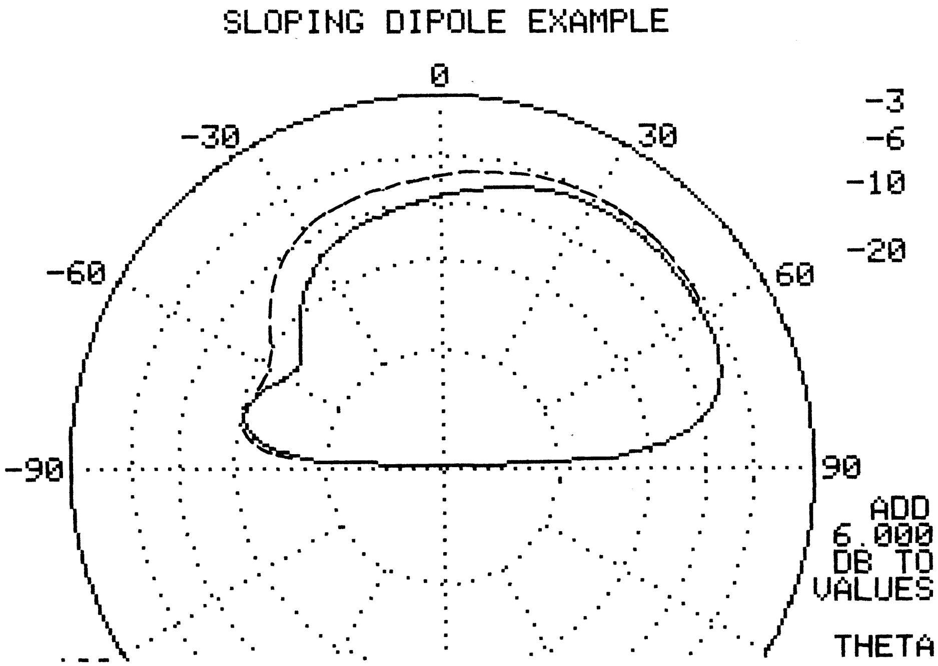


FIGURE II-2. A theta cut with the dipole in the plane of the paper. Zero degrees is overhead. The sloping dipole has rejection off the back (to the left). The dashed line is the result calculated by a numerical analysis program using the method of moments.

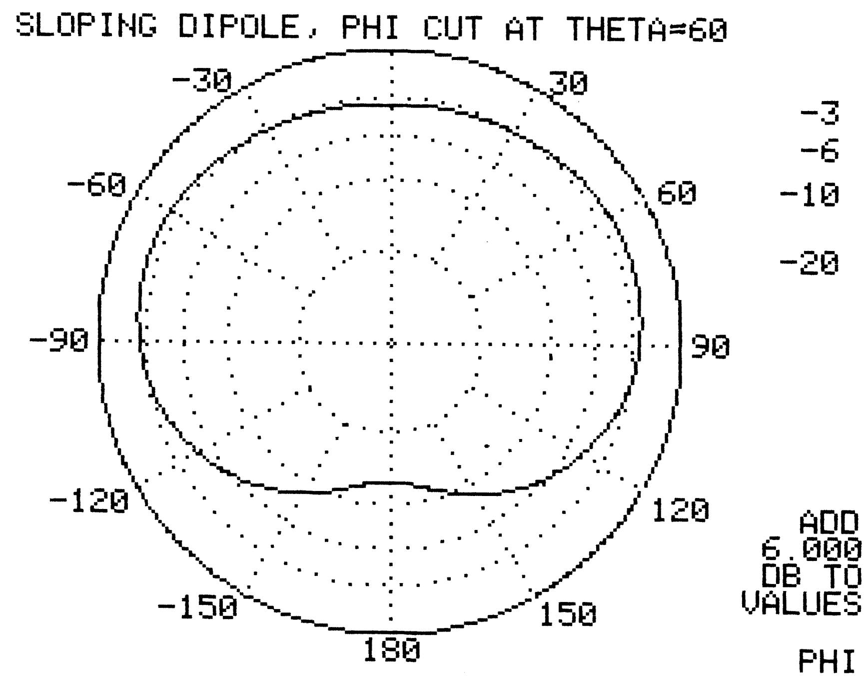


FIGURE II-3. The directivity of the sloping dipole. The null at 180 degrees is off the back of the dipole. The dipole has maximum gain on either side of zero degrees.

APPENDIX III: THE INVERTED VEE

A sketch of an inverted vee antenna is shown in Figure III-1. The apex is 0.225 wavelengths above the same ground used in Appendix II. Annie's description of the inverted vee is listed in the same figure.

Since the inverted vee is not straight, a dipole can not be used to analyze the antenna. Instead, we can butt two monopoles together as a single antenna. In the Annie description, the first element is the right leg of the inverted vee, the second element is the left leg.

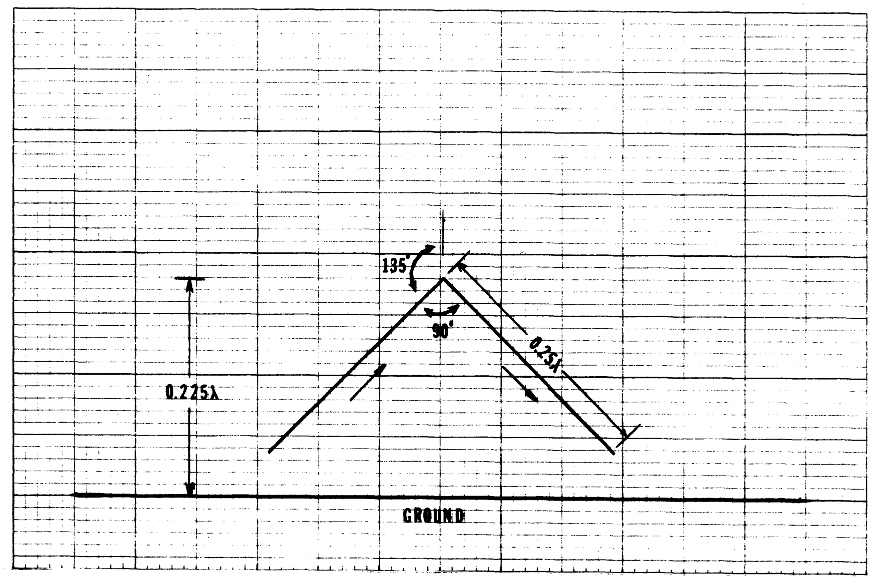
Recall that the monopole is normally oriented vertically with the high current end down. Setting Z=0.225 for both elements raises the high current end 0.225 wavelengths into the air. The first element is then rotated in the phi=0 direction (toward the X-axis) by 135 degrees. The second element is rotated in the other direction (phi=180) by 135 degrees. If you want to be different, the second element could have been rotated in the phi=0 direction by -135 degrees. The same antenna would result.

The phase of the weighting (the last item in each element description) is important to note. The direction of the arrows in Figure III-1 indicate the proper direction for the current. If one or the other were reversed (both reversed is OK), we would not have the proper current distribution and we would get incorrect results.

Before rotating each element down from their vertical positions, both elements have current going in the same direction. When the monopoles are rotated down, the first to the right and the second to the left, we will have the incorrect situation just described. To correct this we have to give one of the currents a 180 degree flip. This is done in the phase of the second element's weight. Only when one of the currents is flipped will the current in each leg of the antenna flow correctly.

The response of the inverted vee is shown in Figure III-2. The plot is a broadside (phi=90) theta cut. Note that we have reduced the normal 6dB offset to 0dB. This is because the inverted vee, at this height and configuration is not the best of performers.

Raising the apex or increasing the apex angle can bring improved performance. If you have an inverted vee, experimenting with these parameters could prove useful.



INVERTED VEE ANTENNA

**** ARRAY A ****

1) MONOPOLE, LENGTH=.25000, X= 0.0, Y= 0.0, Z=.22500, PHI= 0.0,
THETA=135.00, WEIGHT=~~1.0000~~ 4.0, ANGLE= 0.0

2) MONOPOLE, LENGTH=.25000, X= 0.0, Y= 0.0, Z=.22500, PHI=180.00,
THETA=135.00, WEIGHT=~~1.0000~~ 4.0, ANGLE=180.00

FIGURE III-1. A sketch of the inverted vee showing the proper direction of the currents. Annie analyzes the antenna as two separate monopoles. Note that the phase of the second monopole has been flipped 180 degrees so as to keep the proper direction for the current.

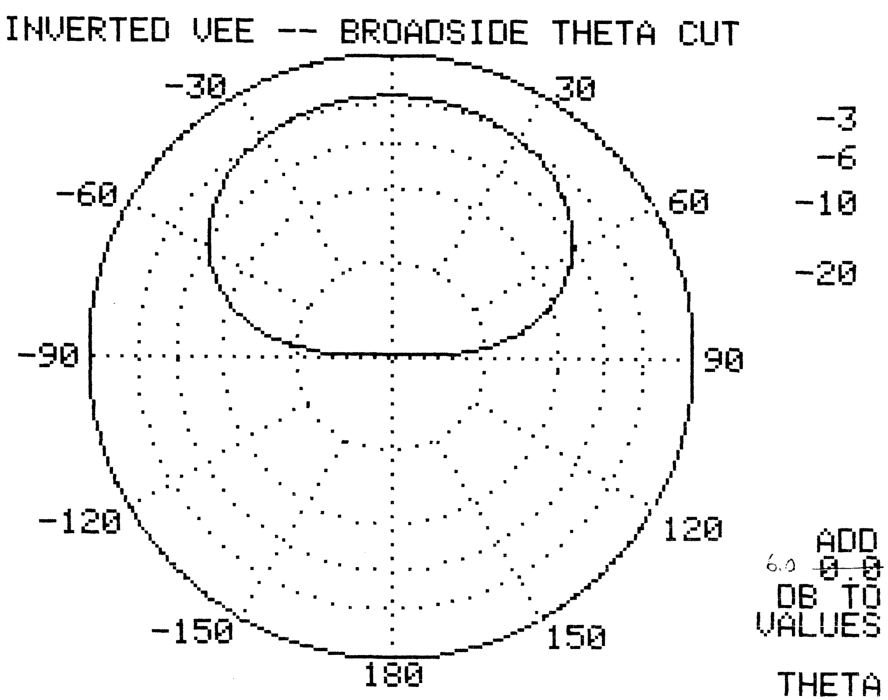


FIGURE III-2. The performance of the inverted vee could be better. If the antenna could be raised or the apex angle increased, improved performance could result.

APPENDIX IV: THE VERTICAL ANTENNA

The 1/4 wave or 5/8 wave long vertical antenna with a ground plane is often used to realize an omni-directional antenna with a low radiation angle. At HF, the 1/4 wave vertical has also been described as an antenna which "radiates equally poorly in all directions". What does Annie say?

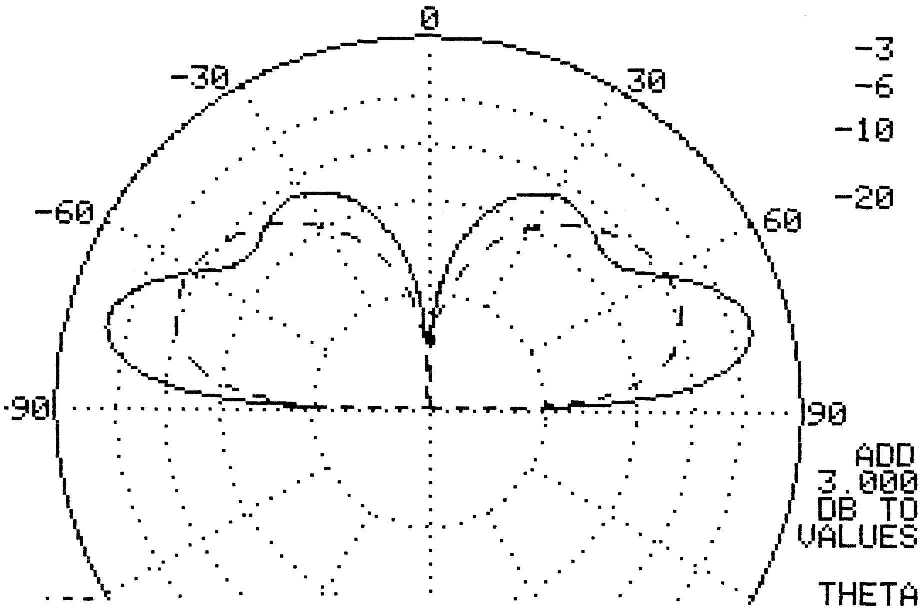
Figure IV-1 shows both a 1/4 wave (dashed line) and a 5/8 wave, (solid line) vertical above a 5 millimho ground at 28 MHz. The 5/8 wave is superior by 4 dB at low radiation angles. In addition, a 1/4 wave vertical is theoretically capable of up to 3 dB gain over a free space dipole (3 dB less than a dipole above ground). This 1/4 wave vertical falls nearly 6 dB short.

Note that the weight for the 1/4 wave vertical is 2.0 instead of 1.0. This is because the input impedance for the vertical is half that of a dipole. Half the input resistance means that, given constant real input power, the antenna current will increase by the square root of 2. This, in turn, will result in an increase of 3.0 dB for the antenna pattern. Since Annie does not know that the impedance of the vertical antenna is different, we must increase the weight to compensate. In general, the weight of an element should be set equal to the ratio of a dipole's input impedance (73.2 ohms) to the real part of the element's input impedance. For this case, both antennas require a weight of 2.0 before we compare the results with a dipole. Of course, if you are only interested in the shape of the pattern, any weight will do.

Most vertical antennas have some sort of ground system. If this ground system is good, the actual current distribution on the antenna will closely match the distribution assumed by Annie. If the ground system is not good, the distribution will be different from that assumed by Annie, the difference being used to heat up the ground. In this case, Annie's pattern would be optimistic.

A very good ground system would improve the high angle (towards the zenith) radiation. However, since most of the low angle radiation is determined by reflection from the ground at some distance from the antenna, the low angle radiation will be determined primarily by the actual ground, not by a good ground plane system.

1/4 λ VERTICAL VS. 5/8 λ VERTICAL



**** ARRAY A ****

MONOPOLE, LENGTH=.25000, X= 0.0, Y= 0.0, Z= 0.0, PHI= 0.0,
THETA= 0.0, WEIGHT=2.0000, ANGLE= 0.0

FIGURE IV-1. The vertical antenna is modeled as a single monopole over a real ground. The 5/8 wave vertical (solid line) is about 4 dB better than a 1/4 wave vertical. An extremely good ground, such as sea water, will give a dramatic improvement. A poor antenna connection to the ground will cause the above plots to be optimistic.

APPENDIX V: THE PHASED ARRAY

Annie is capable of analyzing arrays with over 65,000 elements. In this section we will look at two arrays. The first has only six elements and is shown in Figure V-1. Array A is composed of two dipoles. The second dipole, at X=-.25, is driven with unit weight and 90 degrees out of phase with the first element at X=0. Since the two elements are a quarter wavelength apart and are driven 90 degrees out of phase, Array A will show gain in the +X direction and a null in the -X direction.

Array B is then formed from three copies of Array A spaced at 0.75 wavelength intervals along the Y-axis. The combination of the three form a narrower and stronger beam. The Array B pattern is plotted in Figure V-1. The effect of ground is not included.

You may have noticed that the dipoles of Array A are both at Z=1.0. This was included in anticipation of including the effect of ground. The Z coordinates of Array B are all zero. This is necessary if the effect of ground is to be included as described in Section 6.3. If the Z coordinates of Array B are not zero, then the ground will be dragged up into the air. This is because the effect of ground (at the dipole height of one wavelength) was included in Array A. Thus, when defining Array B, no additional change in the Z coordinate can be tolerated.

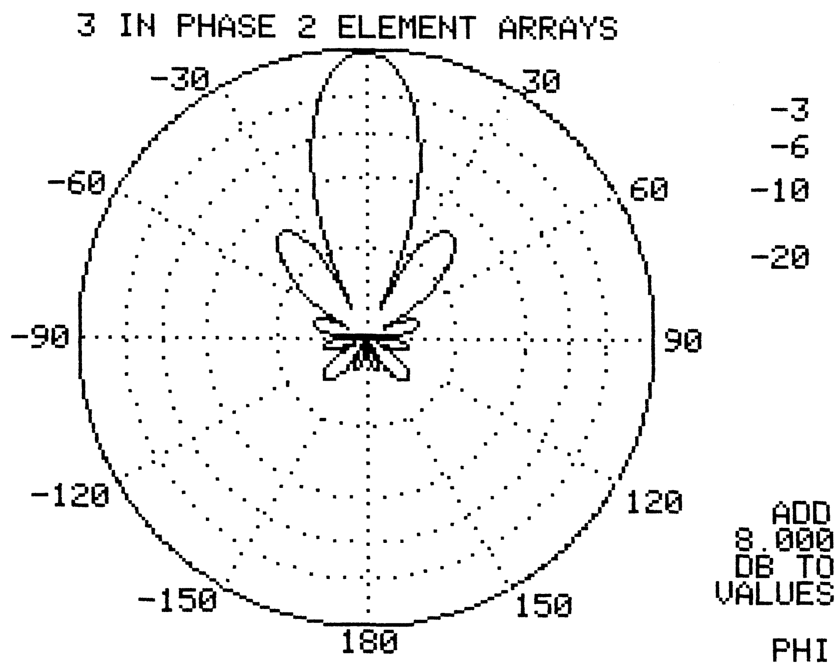
Figure V-2 shows a theta cut of the antenna's pattern with ground included. Since ground can add up to 6 dB, the offset has been increased to 14 dB.

There are two patterns. The larger pattern with two large lobes is the original, horizontal, antenna previously described. The smaller pattern is the same antenna, only all dipole elements are now vertical. It is this second antenna that is listed below the plot.

The horizontal version performs much better (up to 6 dB better) than the vertical array. One exception is when the desired angle of arrival happens to be around 60 degrees (30 degrees above the horizon). The vertical array has no null at that point.

The vertical array, in general, is poorer than the horizontal array because of Brewster's angle. Brewster's angle is the angle at which all (or nearly all) the reflected wave is absorbed. As fate would have it, this happens for vertically polarized waves only. For the average ground used in the analysis, Brewster's angle is about 10 degrees. Note that this is the point where the vertical pattern dips to about 6 dB below the horizontal pattern. This dip is Brewster's angle.

A high ground conductivity will result in a Brewster's angle



**** ARRAY A ****

1) DIPOLE, LENGTH=.50000, X= 0.0, Y= 0.0, Z=1.0000, PHI=90.000, THETA=90.000, WEIGHT=1.0000, ANGLE= 0.0

2) DIPOLE, LENGTH=.50000, X=-.2500, Y= 0.0, Z=1.0000, PHI=90.000, THETA=90.000, WEIGHT=1.0000, ANGLE=90.000

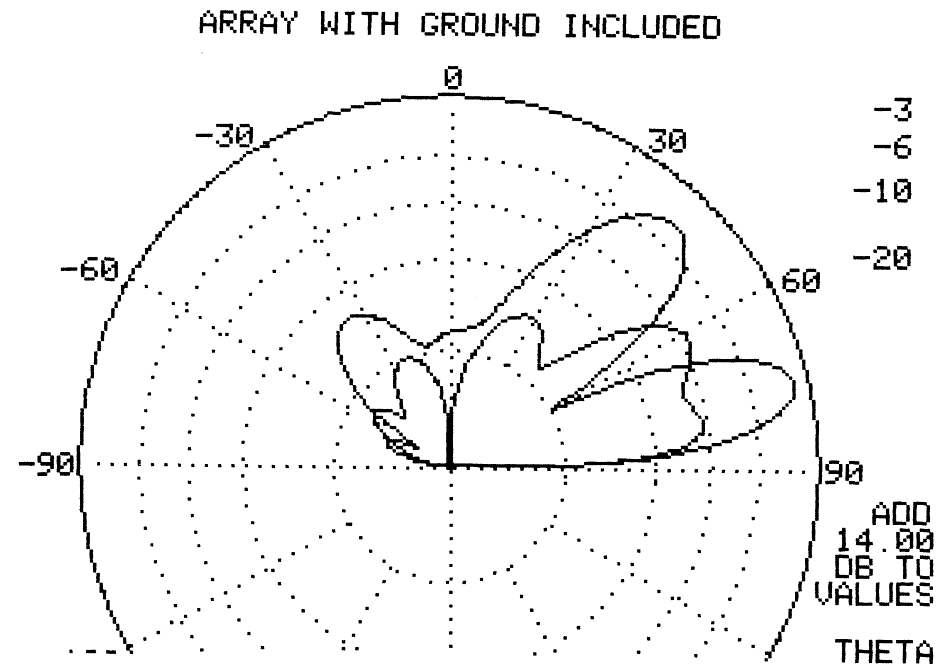
**** ARRAY B ****

1) ARRAY A, LENGTH=.50000, X= 0.0, Y= 0.0, Z= 0.0, PHI= 0.0, THETA= 0.0, WEIGHT=1.0000, ANGLE= 0.0

2) ARRAY A, LENGTH=.50000, X= 0.0, Y=.75000, Z= 0.0, PHI= 0.0, THETA= 0.0, WEIGHT=1.0000, ANGLE= 0.0

3) ARRAY A, LENGTH=.50000, X= 0.0, Y=-.7500, Z= 0.0, PHI= 0.0, THETA= 0.0, WEIGHT=1.0000, ANGLE= 0.0

FIGURE V-1. This six element array in free space is composed of three copies of the two element array A.



**** ARRAY A ****

1) DIPOLE, LENGTH=.50000, X= 0.0, Y= 0.0, Z=1.0000, PHI= 0.0, THETA= 0.0, WEIGHT=1.0000, ANGLE= 0.0

2) DIPOLE, LENGTH=.50000, X=-.2500, Y= 0.0, Z=1.0000, PHI= 0.0, THETA= 0.0, WEIGHT=1.0000, ANGLE=90.000

**** ARRAY B ****

1) ARRAY A, LENGTH=.50000, X= 0.0, Y= 0.0, Z= 0.0, PHI= 0.0, THETA= 0.0, WEIGHT=1.0000, ANGLE= 0.0

2) ARRAY A, LENGTH=.50000, X= 0.0, Y=.75000, Z= 0.0, PHI= 0.0, THETA= 0.0, WEIGHT=1.0000, ANGLE= 0.0

3) ARRAY A, LENGTH=.50000, X= 0.0, Y=-.7500, Z= 0.0, PHI= 0.0, THETA= 0.0, WEIGHT=1.0000, ANGLE= 0.0

FIGURE V-2. When ground is added to the array of the previous figure, the larger, two lobed, theta cut pattern results. The smaller pattern is found when the horizontal elements become vertical.

very close to the horizon. A low conductivity will move Brewster's angle toward the zenith.

In an area closely related to driven arrays, a very popular antenna is the parasitic array, for example, a Yagi. In a parasitic array, one or more elements are driven and the remaining elements are excited by coupling to the driven elements. If the magnitudes and phases of the parasitic element excitation relative to the driven elements are known, Annie may be used to look at the antenna pattern. Calculation of the parasitic excitations is lengthy, even for a computer. Such an analysis has been performed (it took 4-1/2 hours on an Apple) for a three element Yagi. The following results were obtained:

	CURRENT	PHASE
REFLECTOR:	1.700	108
DRIVEN:	3.834	313
DIRECTOR:	2.755	156

From the above information, one must obtain the desired weighting for each of the three elements. The phase of the weight is taken directly from the phase column. The magnitude is more complicated. First, the power driving the Yagi is NOT divided between each element, as is in a driven array.

All the power sent to the driven element appears in the driven element. The parasitic elements then act much like LC circuits, they store energy. This means that the current on the parasitic elements can get as large or even larger than the current on the driven element. Since Annie assumes the power is divided between the elements, each weight in a parasitic array must be multiplied by the number of elements in the array.

Also, just to make things complicated, Yagi antennas have a lower input impedance than a dipole. This means that the current, for the same power, will be higher. Since it is current which determines the pattern, we must include a factor for this in the weight.

To calculate the magnitude of the weight, use the following equation:

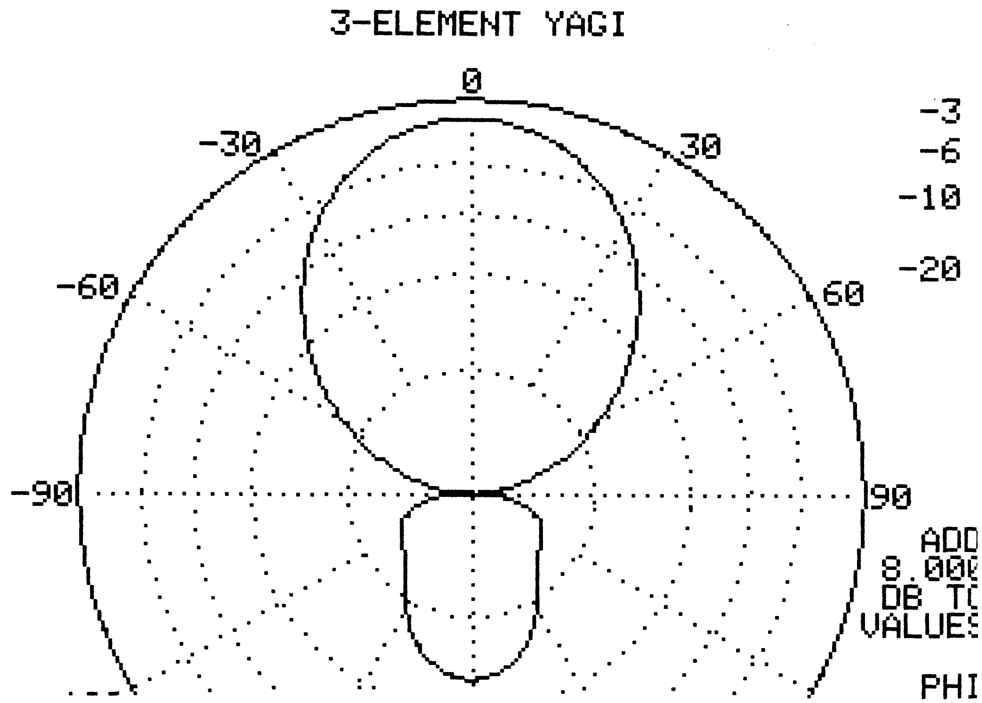
$$W = N \frac{73.2}{R} \left(\frac{I}{I_o} \right)^2$$

W = magnitude of weight
N = number of elements
73.2 = impedance of dipole, ohms.
R = real part of Yagi impedance, ohms.
I = peak current in element
I_o = current in driven element

For this Yagi antenna, N=3, R=18 ohms and the currents have already been listed. The ratio of the input resistance of a dipole (73.2) to the Yagi was close enough to 4.0 that 4.0 was used. The weight for each element was calculated and the plot of Figure V-3 was generated. The difference between Annie's calculation and that of the numerical analysis program is on the order of the width of the line used for the plot.

Now that Annie can analyze the Yagi, one may quickly investigate things such as the effect of real ground and the effect of different heights. Since the current distribution is unlikely to change much with different orientations, the effect of rotation of the Yagi about the main boom can also be analyzed. This can reveal the pattern of the Yagi with vertical elements.

If no capability for calculating the required element phasings and weights is available, one can use the Yagi we just described for approximate results for a three element antenna.



**** ARRAY A ****

1) DIPOLE, LENGTH=.52310, X=-.2000, Y= 0.0, Z= 0.0, PHI=90.000, THETA=90.000, WEIGHT=2.3593, ANGLE=108.00

2) DIPOLE, LENGTH=.50220, X= 0.0, Y= 0.0, Z= 0.0, PHI=90.000, THETA=90.000, WEIGHT=12.000, ANGLE=313.00

3) DIPOLE, LENGTH=.48260, X=.20000, Y= 0.0, Z= 0.0, PHI=90.000, THETA=90.000, WEIGHT=6.1973, ANGLE=156.00

FIGURE V-3. The pattern of a three element yagi, this result agrees almost exactly with the result of a numerical analyis program. The effect of real ground and antenna position may now be quickly examined.