Operating Instructions for YT.EXE, Version 2.0
(Yagi Terrain Analysis)

[YT Version 2.0 implements higher-resolution graphics than in previous versions, giving much smoother plots of elevation response. It also corrects several minor errors involving diffractions that result in subsequent diffractions. Thanks to John Stanley, K4ERO, for pointing out the anomalies.]

YT is a ray-tracing program designed to evaluate the effect of foreground terrain on the elevation pattern of up to four HF Yagis in a stack. See Chapter 3 in the 18th Edition of The ARRL Antenna Book for details about YT.

YT has a vastly improved operator interface compared to older versions of its predecessor program YTAD. YT also adds several more diffraction models to those in earlier YTAD versions (before 3.3). This includes diffraction resulting in later diffractions. YT is demonstrably more "believable" than earlier versions because of these new models. In general, you will see that gains at very low elevation angles are less dramatic than in older YTAD versions, especially for extremely complex terrains such as K5ZD's. In general, the effect of diffraction is to "even-out" extremes in elevation response created by a reflection-only analysis.

YT only models horizontally polarized Yagis. The effects of Fresnel horizontal ground reflection coefficients are taken into account, meaning that the ground conductivity and ground dielectric constant are inputs to the program through the Other submenu. You will find that these ground coefficients have only a minor effect on the elevation pattern at low angles, gradually becoming more significant at higher elevation angles. Please note: YT does not work with vertical polarization, only horizontal, and it only works with directive arrays such as Yagis or quads.

YT's default internal antenna model is a four-element Yagi, similar to a HyGain 204BA, but scaled internally to any frequency of operation. Through the "Other" menu selection from the main menu, you may also choose other Yagis, ranging from a two-element design to a monster eight-element Yagi.

YT's output response is referenced to an isotropic radiator in free space; that is, in dBi. The free-space gain assumed for the internal four-element Yagi model is 8.5 dBi.

PREPARING A TERRAIN DATA FILE

YT needs an ASCII input file with the terrain data in a particular azimuthal direction from the base of the tower. The terrain data file is entered in feet. Some sample data files are included with the program: for example, N6BV-EU.PRO and N6BV-JA.PRO, standing for N6BV to Europe and to Japan. These files have "PRO" filename extensions, meaning "PROFILE." The data were taken from a topographic chart (the "7.5 minute series," published by the US Coast and Geodetic Survey; call 1-800-USA-MAPS.) As a reference, a FLAT.PRO file is included as well, for flat ground.

If you examine the contents of N6BV-EU.PRO using an ASCII word processor, you will find that the data is arranged in two columns, separated by a tab or comma; each line is terminated by a carriage-return/linefeed. Each line represents a single point. For N6BV-EU.PRO, I drew a line from the base of my tower at an azimuth of 45 degrees towards the center of Europe. Where this line crossed each contour on the topographic chart, I measured the distance from the tower and entered it into the disk file. Here is a sample of what is in N6BV-EU.PRO file.

```
0       430
200     420
500     410
700     400
800     380
900     360
1000    340
1550    360
2200    340
4800    340
5000    360
5200    380
5450    400
5700    420
7600    440
```

The first line starts at the base of the tower, at 0 feet. The elevation height above mean sea level (also known as ASL, standing for Above Sea Level) at my tower base is 430 feet. The next line in the data files shows that 200 feet from the tower base the elevation is 420 feet; at 500 feet the elevation is 410 feet, etc. I enter data at distances from the tower for more than 6000 feet, because even at that distance the effect is noticeable on elevation pattern for low frequency Yagis, like 40-meter Yagis.

Make sure that you terminate data input to the file with a single blank line at the end. [Earlier versions of the program required that you enter a figure of 100,000 feet or further at the end of a file. This is no longer necessary, since the program takes care of that detail internally.] YT will accept input of up to 150 data points in an input file.

RUNNING YT

Run the YT program by keying in YT, followed by <Enter>. The main menu will appear, showing the parameters chosen during the last YT session. These were saved to disk in the YT.DEF default file.

By the way, if you ever get in trouble with a corrupted YT.DEF file, simply go back to DOS and delete the file YT.DEF. YT will then create a new file when it first boots up. Similarly, if you find yourself hopelessly lost in the program for some reason, hit the key combination <Ctrl> Break. This will take you back to DOS, but the white border generated by YT will still remain on screen. Type MODE CO80 [Enter] to bring back your normal screen.

YT can overlay up to three different elevation patterns on a single graph. I regularly compare any patterns I generate to a reference Yagi over flat ground, usually at a height of 60 feet on 21 or 28 MHz, or 100 feet for 14 or 7 MHz. (These are also the reference antenna heights I specify when using the IONCAP or VOACAP propagation-prediction programs.)

The following is a typical main menu screen-shot in YT.

```
------------------------------------------------------------------

                  YT, Yagi Terrain Analysis
   Ver. 2.0, Dec 8, 1997, Copyright 1995-1997 ARRL, by N6BV

Present antenna: Four-element Yagi, 8.5 dBi free-space gain

    Terrain Files:      Antennas:
A = BV-EU.PRO            90/ 60/ 30 ft
B = K1ZZ-EU.PRO         120/ 80/ 40 ft
C = FLAT.PRO            100 ft

E = Elevation-statistics file: W1-MA-EU.PRN
Frequency: 14.0 MHz
G = GO
O = Other                      Diffraction is ON
P = Plot profile of terrain
Q = Quit to DOS
T = Terrain file and stack height(s)

Select:
------------------------------------------------------------------
```

Selections: A, B or C = Terrain file and stack height(s)

If YT detects no YT.DEF file on bootup, it will automatically create a new one, using FLAT.PRO for its choice of terrain A, together with a single four-element Yagi, 100 feet high. Terrains B and C will be blank.

If you wish to change the terrain file at either "A," "B" or "C," touch the key for the letter you want. You may enter either an upper-case or lower-case letter. Keep in mind that you MUST have a terrain filename showing in at least the A position, followed by blanks in B and C, if you wish. Further, you cannot specify a filename in A and then one in C, with a blank in the B position; you must specify first A, then B, then a blank in C.

When prompting you for a filename, YT will show you within square brackets the default filename for A, B or C, if one has already been specified in YT. To retain the present selection, hit [Enter]. Otherwise, type in the name of one of the terrain files showing on the screen directory. You needn't type in the "PRO" filename extension because YT does that automatically for you. However, if you type the wrong name or if the file you want doesn't exist, YT will complain and make you do it all over again.

Once you've selected a profile name, YT will prompt you to enter the number of antennas in a stack. The default is one antenna, at 100 feet height -- you choose this by hitting "D" [Enter]. To retain the same antenna heights already chosen, hit "S" or just simply [Enter]. Note that you may use either upper-case or lower-case letters from the keyboard.

For any other choice of number and heights of antennas, enter first the number of antennas you want in a stack. Enter 1 for a single antenna, or up to 4 for a stack of 4 four-element Yagis. YT will next ask for the height of each antenna in the stack, specified in feet. Note that the present values, if any, for each antenna in a stack are listed on the prompt line in square brackets. If you want to keep the present value, hit [Enter]. Once you've specified the height(s) for a terrain, YT will put you back to the main menu.

The internal Yagi model in YT is simple and does not compute interactions between individual Yagis in a stack -- YT assumes that each antenna is a point source. For antennas stacked more than about a half wavelength apart this is not a problem. For example, you should be cautious specifying spacings less than about 20 feet on 20 meters (and proportionately scaled on other bands) because of mutual-coupling effects between real antennas.

E = Elevation-statistical file:

Hitting "E" (or lower-case "e") takes you into a function where you may specify the name of an elevation-angle statistical file. Again, you needn't enter the "PRN" filename extension. The statistical elevation-angle data will be plotted along with the computed elevation-pattern response(s) for the terrain(s) you wish to evaluate.

For example, the main screen above shows the elevation-statistics filename W1-MA-EU.PRN, meaning "W1 in the state of Massachusetts, pointing towards Europe." For each amateur HF band from 80 to 10 meters, this file shows the percentage of time each elevation angle is effective. These statistics were computed for all the times over the 11-year solar cycle when each band is actually open. (If you run this example, you will find that the peak percentage for the 20-meter band is 18%, occurring at an elevation angle of 11 degrees from Boston to all of Europe.)

As usual, you may simply hit the [Enter] key to retain the present data file, rather than retyping the name. You may also select no data file at all by entering "0" [Enter] -- that's the number zero. YT will display "none" on the screen.

Each elevation-angle statistic file is named in the generic format "W?-*.PRN," and comes from the disk shipped with the 18th edition of The ARRL Antenna Book (in the \ELEVAT subdirectory). The Antenna Book's disk contains files for all regions of the USA to Europe, the Far East, South America, South Asia, Southern Africa, and the South Pacific, plus data files for a wide variety of transmitting sites throughout the world.

Before running YT, copy the files from the Antenna Book disk applicable to your QTH (i.e., W3, or W4, etc.) into the subdirectory on your hard disk containing the rest of the YT files.

Selection: F = Frequency

Hitting "F" will bring up a prompt to enter the frequency, in MHz. The elevation-angle statistical data is automatically updated when you enter a different frequency.

Selection: G = GO

Hitting "G" will compute and display a graph of the elevation response(s) for all the data you have specified on the main screen. Hitting any key will erase the graph and take you back to the main menu. [Those of you who have become accustomed to earlier YTAD versions will find YT's operator interface much easier to use!]

YT then computes the elevation pattern by shooting rays from +35 degrees to -45 degrees at the terrain model in 0.25-degree increments. It vectorially combines all the outputs due to reflection and diffraction in the far field. The computation will be lengthy if a stack of four Yagis is modeled over complex terrain. If your computer doesn't have a numeric coprocessor, the computations will be excruciatingly long...I highly recommend that you use a computer with a built-in numeric coprocessor, such as a Pentium.

Selection: O = Other

Pressing the letter "O" will take you to a submenu with three choices:

A: Antenna type
D: Diffraction, toggle on/off
G: Ground constants

Pressing "A" will take you to another submenu, where you may choose the type of Yagi used by YT as its internal model. The default Yagi YT uses when it boots up is a four-element model that is similar to a HyGain 204BA. However, you may choose from among two, three, four, five, six or eight-element designs, with free-space gains ranging from 5.5 to 12 dBi.

Pressing "D" will toggle the diffraction mechanism on and off. When diffraction is off you will find that only a reflection-analysis is run. In general, diffractions "fills in the holes" and "knocks down the peaks" in an elevation pattern. This "fuzzing up" of the computed response is what happens in the real world, where things are rarely very peaky or full of holes.

Pressing "G" allows you to choose the conductivity and dielectric constant of the ground in the foreground of the antenna. See the Ground chapter in The ARRL Antenna Book for typical values. YT's default values are a ground conductivity of 5 mS/m and a dielectric constant of 13, typical of average to better-than-average ground. You will find that changing the ground constants for a horizontally polarized antenna like that used in YT changes the elevation pattern only a small amount.

Selection: P = Plot profile of terrain

Hitting "P" will take you to a submenu that shows which terrain files and antenna height(s) are already in use. Hitting "A" or "B" or "C" will then generate a plot of terrain height versus distance from the tower base. The position of the antennas selected for that terrain will be shown as blue arrows, with the base of the tower shown as a red "x" symbol.

The Y-axis (maximum and minimum height) values on-screen are computed by YT to show the maximum possible detail. They will change automatically when the file is changed, so be careful when making assumptions about a steepness of a terrain! The maximum resolution is 25 feet between marker lines, and the minimum is 1000 feet, but the maximum distance from the tower remains fixed at 10,000 feet. (The program uses data beyond 10,000 feet to make its internal computations, but the Plot display only shows the terrain out to 10,000 feet from the tower base.) To return to the main menu after looking at a plot of the terrain, hit any key, including [esc] or the spacebar.

Selection: Q = Quit to DOS

Hitting "Q" will immediately save the present data stored in YT to YT.DEF and then go to DOS.

YT OUTPUT

The on-screen graph shows the elevation response (calibrated in dB below the peak dBi level) from 1 to 30 degrees above the horizon, in one-degree increments. YT will also write data to a disk file called OUT.PRN. This file is used by the utility program MAKEVOA.EXE to create a custom antenna file for VOACAP, the sophisticated propagation-prediction program.

OUT.PRN contains the elevation data for each angle used to create the on-screen graphs in YT. This data is delimited with commas. Character labels are delimited with double quotation marks. This sort of data can be imported easily into a spreadsheet or database management software for other types of manipulation, if you like.

If you want to print the on-screen graph using the [Shift]-[Print Screen] command, you will need to load GRAPHICS.COM before you run YT. I use a Hewlett Packard LaserJet IIP printer, and I load GRAPHICS LASERJETII in my AUTOEXEC.BAT file. Check your DOS manual or HELP GRAPHICS for the setup parameters for your printer. The DOS GRAPHICS.COM program automatically turns the background color from the on-screen black color to white on the printed paper.

If you are operating YT in a DOS window under Windows or Windows 95, you may hit the [Print Screen] key by itself to put a copy of the YT graph onto the Clipboard. This can then be used by another Windows program, such as Word for Windows or Paint Shop Pro. Paint Shop Pro is particularly useful because by selecting Color, Negative, I can print the pattern with a white background.

CAVEATS

The YT program is still under development. For validation of its results, there is precious little experimental data available showing careful measurements of HF elevation angles versus terrain contours. Very few radio amateurs have access to a helicopter to really measure their elevation patterns!

Further, the terrain data itself from topographic maps is often "sparse." Irregularities that can be seen with the naked eye from the base of the tower are often not shown on the maps. The terrain model used by YT assumes that the terrain is represented by flat "plates" connecting the elevation points in the *.PRO file with straight lines. The model is two dimensional, meaning that range and elevation are the only data for a particular azimuth.

Obviously, the real world is three dimensional. To get a true picture of the full effects of terrain, a terrain model that shows azimuth along with range and elevation point by point would be necessary. The computational requirements for such a 3-D model, even if the detailed terrain data were readily available, would be pretty horrendous. After you have struggled to create a terrain file by hand for a single azimuth, you will begin to appreciate the data-entry problems involved in trying to come up with a real 3-D terrain map!

You can get a feel for how your terrain affects signals launched in various azimuthal directions by creating separate data files for these directions. For example, from my QTH in New Hampshire, my coverage to central Europe goes from about 30 degrees to 60 degrees. I have thus evaluated azimuth shots for 30, 45 and 60 degrees. The overall effect for the three azimuths for a single antenna height can be plotted together on one screen to visualize the effect of azimuth as well as terrain shape.

Some of you may have access to digitized terrain databases. I have examined the data output from one such database, and I find that the data is relatively coarse, with rather large range steps, and elevation data which doesn't match very well a file created manually from a paper topo map. I suppose that the digitized data is good enough for many military and commercial purposes, but it doesn't seem adequate for elevation predictions using YT.

ACCURACY AND TESTING THE RESULTS

What would I estimate as the "accuracy" of YT elevation predictions? I would say that I would trust the results within plus/minus 3 dB. In other words, take YT results with a grain of salt. Don't obsess with changing the height of your antenna by fractions of a foot to see what happens!!

Having said that, now I must state that it IS a good idea to compare elevation patterns in intervals of perhaps 1 feet to assess whether YT is generating reasonably smooth results. Often, the 0.25-degree steps used in the program don't align exactly and artificial "spikes" (or "holes") can be created. This is inherent in any ray-tracing program and can only be eliminated by using extremely small angular step increments -- and doing so would slow down execution even more.

After I do an evaluation for a particular antenna height, I will often specify an overlay of three heights separated by one foot each. For example, if you are interested in a single antenna at a height of 80 feet on 14.0 MHz for the N1MM-EU terrain, you might first compare three heights of 83, 82 and 81 feet. The three curves overlaid on each other look smooth compared with one another. Then run three heights of 80, 79 and 78 feet. Now, the curves for 80 and 79 feet look smooth, but the 78-foot curve has obvious spikes and holes. This means that spurious artifacts of the ray-tracing process are occurring at 78 feet in the program -- but these would not occur in the real world. The solution: don't use the 78 foot point in the computer analysis, but you could mount your real antenna at that height if you like the response at 79 or 80 feet!

FEEDBACK, PLEASE

I would greatly appreciate feedback from you about this program. If you have access to validation data, I'd surely like to hear about it!

GL and 73,

R. Dean Straw, N6BV
Senior Assistant Technical Editor, ARRL

e-mail: n6bv@arrl.org

regular mail: ARRL
225 Main Street
Newington, CT 06111
U.S.A.