YA YAGI ANALYZER

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YA.EXE is a simple but accurate program for analyzing Yagi-Uda antenna designs on your PC.

YA analyzes Yagis hundreds of times faster than NEC- or MININEC-based antenna-modeling programs. YA's modeling algorithm is more complex than the W2PV Yagi model, simpler than the MININEC model, and more accurate than either. YA is calibrated to NEC, the high-accuracy Numerical Electromagnetics Code from the Lawrence Livermore National Laboratory. YA and NEC typically are within 0.05 dB for forward gain, within a dB or two for F/B, and within a couple ohms for input impedance. Radiation patterns calculated by YA and NEC are virtually identical for most designs.

---- USING YA ---

You can directly execute YA with an EGA or VGA display. For an HGC or CGA, first do the following:

HGC Load the HERCULES.EXE graphics driver. To do this, type HERCULES at the DOS prompt. Since this must be done just once per boot, it's often convenient to load HERCULES from AUTOEXEC.BAT.

CGA Load GRAFTABL and GRAPHICS. You can load them from AUTOEXEC.BAT. These DOS utilities provide additional CGA fonts and let you print CGA graphics screens.

YA stores information for Yagi designs in individual files. Yagi files contain element dimensions, analysis frequencies, and other information. You specify the name of a Yagi file when you start YA. After YA loads the file, you can examine or modify the design. You can save the current design in a file at any time. Yagi files use the extension .YAG.

If you know which Yagi file you want, give the filename on the YA command line, for example, YA PV4 (the extension isn't needed). Otherwise, type YA and Yagi files in the current directory will be listed. To list Yagi files in a different directory, specify the directory name on the command line.

Select a file by moving the lightbar with the arrow keys, PgUp, PgDn, Home, or End. Press Enter to select the highlighted file. Alternatively, you can enter a filename by typing it. As you type, the lightbar moves to the first filename that matches the characters entered. Press Enter whenever the desired file is highlighted.

Select "Other" to enter a file or directory name not listed. If you enter a directory containing Yagi files, YA lists them and you can select one.

Press Esc to hide the Main Menu to view the whole screen. Press Esc to return to the Main Menu from a submenu. You can also return by pressing the command key a second time (but not from Save). This feature is handy when making a quick check.

You can terminate data entry and return to the Main Menu with one keystroke by pressing Esc instead of Enter. If you do this, whenever you return to the submenu the cursor will be positioned at the item last entered. This makes it easy to change a parameter repeatedly to experiment with its effect.

You can exit most submenus (not Save or Notes) by pressing a valid command key. YA will immediately execute the command, bypassing the Main Menu. This is a quick way to go from one submenu to another. Whenever you press a command key during data entry, YA accepts the data and then executes the new command.

Use an arrow key with numerical input to enter data and simultaneously move the cursor up, down, right, or left to another item. Use the spacebar to enter data without advancing to another item. This is particularly useful with the Match Menu and Bracket Menu to change a parameter value repeatedly to experiment with its effect.

To reduce screen clutter, YA does not label the numbers within Yagi patterns. They have the following meaning:

Frequency
Forward Gain
Front-to-Rear Ratio
Input Impedance
Standing-Wave Ratio
Elevation Angle

YA defaults to a generalized definition of front-to-back ratio described in the next section. YA displays elevation angle only for Yagis over ground.

The notation 12.7-j15.4 means a resistance of 12.7 ohms in series with a reactance of -15.4 ohms. Z stands for impedance. The letter w appended to boomlength means wavelengths. The path and name of the current Yagi file appear in the lower-right screen corner.

Although YA doesn't require a math coprocessor, it will run up to twenty times faster when one is present. YA will run several times faster if you disable your memory manager.

---- F/B AND F/R ----

YA uses a generalized notion of front-to-back ratio as a measure of pattern quality. Conventional F/B is the ratio of forward power (at 0 degrees) to power radiated in the opposite direction (at 180 degrees). YA's generalized F/B is the ratio of forward power to the peak power in the region 90 to 180 degrees to the rear of the antenna. This pattern-quality measure is called front-to-rear ratio. The F/R backlobe region is the rear half-plane for azimuth patterns and free-space elevation patterns. For elevation patterns of Yagis over ground, the backlobe region begins at the rear horizon and extends to the zenith. In general, the F/R figure differs in each analysis plane.

Yagi designs maximizing conventional F/B may have large backlobes at angles other than 180 degrees. These backlobes can cause unwanted signal pickup, but F/R takes them into account. YA uses F/R by default. Use the Options Menu to select conventional F/B.

---- FREQUENCY MENU ----

YA models Yagi designs at a spot frequency or over a frequency band. You specify a single analysis frequency for spot-frequency designs, and low, middle, and high frequencies for designs covering a band. YA models Yagis to 2 GHz.

You can add, change, or delete analysis frequencies with the Frequency Menu. You must use one or three frequencies--YA doesn't allow two. To change to a spot-frequency design, enter zero for the low or high frequency.

---- HEIGHT MENU ----

Use the Height Menu to specify antenna height above ground. YA orients Yagis for horizontal polarization when modeling over ground. Set height to zero to model a Yagi in free space. YA computes forward gain, F/R, and the azimuth pattern at the elevation angle specified.

YA takes into account mutual impedances between Yagi elements and their ground images. This lets you see the effect of ground proximity on azimuth patterns and input impedance. However, YA models perfectly conducting ground, not real earth with finite conductivity and dielectric constant. Yagis over real earth may have several dB less gain overhead and up to 1 dB less gain near the horizon than the figures YA computes. Elevation-pattern nulls may be less deep. Nevertheless, you can use YA to make accurate relative comparisons among Yagi designs over ground.

---- ELEMENTS MENU --

Use the Elements Menu to change element positions and lengths. YA displays element half-length, the distance from the center of the boom to element tip. For tapered elements YA displays the lengths of electrically equivalent untapered elements. These are not physical lengths and should not be used for antenna construction. Use the Taper Menu to inspect and change physical lengths of tapered elements.

YA can model Yagis with up to 17 elements. Use the Ins and Del keys to add or delete elements. Press Del to delete the element at the cursor. Press Ins to add an element below the cursor. When you add or delete an inner element, YA respaces elements to avoid bunching or gaps. When you add or delete an end element, YA does not respace and the boomlength changes.

YA expects every Yagi to have a reflector element. You can model two-element Yagis with a driven element and director by placing a dummy reflector a great distance behind the two active elements. This arrangement will satisfy YA while having negligible effect on the response of the two-element array.

YA accounts for antenna losses due to imperfect element conductivity and skin effect. These losses usually are small for tubing elements at HF, but they can be significant for rod elements at VHF/UHF. YA assumes all elements are made of 6061-T6 aluminum alloy. 6061-T6 material has a volume resistivity 23% higher than that of 6063-T832 alloy and 51% higher than that of pure aluminum.

---- TAPER MENU ---

Fast Yagi-modeling algorithms represent each element as a thin cylinder of constant diameter. A tapering algorithm is necessary to convert elements of tapered telescoping tubing to untapered cylindrical equivalents. For practical purposes, tapered and untapered elements are electrically equivalent when their self-impedances are equal. Tapered elements are always physically longer than their untapered equivalents. Tapering must be accurately modeled to realistically characterize HF Yagis.

YA uses a modified version of the tapering algorithm developed by James Lawson, W2PV, from the ARRL book "Yagi Antenna Design." The modified algorithm yields untapered equivalents with self-impedances much closer to those of the tapered originals. It also better predicts the real-world performance of Yagis with heavily tapered elements.

YA can model Yagis with up to eight taper sections. Use the Taper Menu to change the diameter or length of any section. For any length change except to the tip section itself, YA readjusts tip length to maintain an electrically equivalent design. Use the Ins and Del keys to add or delete taper sections. You can enter a taper length of zero for elements that don't use a particular tubing diameter.

---- BRACKET MENU --

A conductive element-to-boom mounting bracket increases element effective diameter at the bracket. The amount of increase depends on the size and shape of the bracket. YA uses the equations of D. Jaggard to model flat, rectangular mounting plates and Hy-Gain element clamps. For details of the method, see the ARRL book "Physical Design of Yagi Antennas" by Dave Leeson, W6QHS.

Use the Bracket Menu to define or modify a mounting bracket. Select bracket type with the tab key. After you enter bracket dimensions, YA calculates the length and diameter of an equivalent taper section. The length of the section is the half-length of the bracket. Its diameter is electrically equivalent to the element and bracket combined.

When you return to the Main Menu, YA updates all elements of the current design with the new taper section. Whenever the length of the existing first taper section is less than 5% of the element half-length, YA assumes that the section already represents a mounting bracket. YA will modify the section instead of adding a new one.

If you enter zero for a bracket dimension so that YA lists "None" for the equivalent taper, when you return to the Main Menu YA removes the first taper section if it represents a mounting bracket (length less than 5% of the element half-length).

If the Yagi uses mounting brackets of more than one size, calculate equivalent taper sections with the Bracket Menu and add them by hand to individual elements with the Taper Menu. (YA uses reflector tapering to calculate the numbers displayed in the Bracket Menu. You may need to temporarily modify the taper schedule of this element to do calculations for other elements.) Use a taper length of zero for elements that don't use a particular taper diameter.

To avoid disrupting a complex taper schedule entered by hand, YA will not update the taper schedule when you leave the Bracket Menu if the length of the first taper section is zero for any element. It also won't update if some elements have mounting brackets and others do not.

The length of a mounting bracket is its dimension along the element. Enter the total length (both sides of the boom). The width of a bracket is its dimension perpendicular to the element. The thickness of a Hy-Gain clamp is the total thickness of the flat part.

It's important to take element mounting into account when modeling Yagis. Large mounting brackets may significantly alter antenna characteristics. In extreme cases they can move a desired response completely outside a band. Small brackets can upset a carefully optimized pattern at a spot frequency. However, mounting methods that use compact hardware no larger than the element diameter generally require no correction.

---- BOOM COMPENSATION --

When an element is close to or passes through a conductive boom, its electrical length changes. YA does not model this boom effect, but you can use the information in this section to manually compensate. All correction values apply to element half-lengths. Apply the corrections by increasing calculated element lengths when constructing a Yagi. Conversely, to model boom effects you must shorten measured element lengths.

For elements mounted on flat plates in contact with a boom, W2PV found that element half-lengths should be corrected by 3% of the boom diameter. He stated that this small effect diminishes rapidly as the element is spaced away from the boom, even by a small distance.

For noninsulated through-the-boom mounting, measurements by Guenter Hoch, DL6WU, were curve-fit by Ian White, G3SEK, to yield the following boom-correction formula:

$$C = (12.5975 - 114.5 * B) * B * B$$

C is the element half-length correction and B is boom diameter, both in wavelengths. * means multiply. For example, a 0.01-wavelength-diameter boom requires element half-lengths to be corrected by 0.00115 wavelength. The experimental data underlying this formula came from booms with diameters smaller than 0.055 wavelength; the formula isn't valid for larger booms. G3SEK says that the correction required for insulated through-the-boom mounting is close to 50% of C.

---- MATCH MENU --

The Match Menu lets you design a variety of matching networks. Use the tab key to select one of the following network types:

1. Perfect Match

The perfect match is an idealized matching network. Because it's always perfectly matched at one frequency, it's very handy. You can set this frequency in the Match Menu. SWR is always 1 at the match frequency. YA uses the antenna input impedance at the match frequency as the SWR reference impedance at all frequencies. This effectively models a perfectly broadband matching network. Therefore, SWR variation using the perfect matching network reveals the inherent impedance-bandwidth properties of the antenna.

2. Hairpin Match

The hairpin match is an L-network using distributed reactances. The driven element is shortened from its resonant length to raise the equivalent parallel input resistance to that of the feedline. The hairpin acts as a shunt inductance to cancel the capacitive reactance of the shortened driven element. Hairpin matches are commonly fed with coax through a balun. YA models the hairpin as a transmission line of parallel rods.

You specify rod diameter, rod length, and center-to-center rod spacing. You can also specify balun-lead length. Enter the length of one lead. YA assumes the leads use #12 wire. At HF, YA models the leads as fanning out from a spacing of 1.5" at the balun to the hairpin-rod spacing at the element. For frequencies above 30 MHz, YA assumes the leads fan out from 0.15". This lead spacing is typical of 3/8"-diameter coax (presumably loaded with a few ferrite beads).

You can specify the shunt capacitance between driven-element halves. This is particularly useful with Hy-Gain element clamps. Use 26.5 pF for 20-meter clamps and 9.5 pF for 15- and 10-meter clamps.

Hy-Gain calls its version of the hairpin match a beta match. It uses two rods that straddle the boom and a shorting strap that connects all three together. The presence of the boom has a negligible effect on hairpin inductance, so a beta match is electrically equivalent to a conventional hairpin match.

NOTE: Driven-element current nearly vanishes between the hairpin-rod attachment points. Therefore, measure driven-element half-length from the attachment point rather than the center of the boom. Except for shunt capacitance, it's not necessary to model the driven-element mounting bracket.

3. Gamma Match

YA uses equations developed by Harold Tolles, W7ITB, to model gamma matches. You specify gamma-rod diameter, rod length, center-to-center spacing from the driven element, and series capacitance. To model lead inductance, specify the lead length from the gamma rod to the coax connector. YA assumes the lead uses #12 wire. When the lead runs parallel to the driven element, include its length as part of the gamma rod rather than specifying it separately.

4. T Match

A T match is a balanced gamma match. Rod length and capacitance values apply for each side of the driven element. Some T matches are fed with 50-ohm coax through a 4:1 balun. Enter a feed impedance of 200 ohms for these systems (which often have negligible lead length). You can also feed a T match with wire leads from a 1:1 balun. YA makes the same assumptions about these balun leads as it does for a hairpin match. YA assumes the distance between T-match rod ends is half their distance to the driven element. To model a T match without capacitors, enter a high capacitance value. To model a folded dipole, extend the T-match rod to the end of the element.

Gamma- and T-match rods increase the effective diameter of the inner part of a driven element. Because YA does not model this effect, you may need to compensate by increasing driven-element length when constructing a Yagi.

The impedance value YA reports is always the natural impedance at the center of the driven element with no matching network. The SWR value is that in the feedline and includes matching-network effects.

YA uses a velocity factor of 0.975 for the transmission lines formed by gamma- or T-match rod and driven element, hairpin rods, and balun leads. For driven-element diameter, YA uses a weighted logarithmic average of the diameters of the taper sections spanned by gamma- or T-match rods (diameters are weighted by taper-section length). YA draws rod length to scale on the Yagi sketch, but not rod spacing.

Matching-network performance depends critically on a number of parameters that are difficult to measure and to model accurately. Calculated and actual matches may differ due to input-impedance modeling error, series- or shunt-capacitance estimation error, lead-spacing variation, proximity of other antennas or guy wires, etc. When constructing a Yagi, always make the matching network adjustable!

---- SAVE MENU --

Use the Save command to save the current Yagi design. You can specify path and filename. If you enter the name of a Yagi file that already exists, YA asks permission before overwriting it. For fast periodic saves, press Enter to overwrite the last file saved (YA doesn't ask permission). When no file has been saved, YA saves the design in SAVE.YAG. YA does not save matching networks or mounting-bracket dimensions.

In case you forget to save a design, YA automatically saves the current design in the file OUT.YAG whenever you exit the program. You can recover the design by specifying OUT.YAG as an input file.

---- ALGORITHM LIMITATIONS ----

YA closely predicts actual antenna performance as long as you accurately characterize element tapering and mounting and you follow the guidelines in this section.

YA is calibrated to NEC, the Numerical Electromagnetics Code. MININEC-based antenna-analysis programs may give different results. The MININEC algorithm has an inherent frequency-offset error. MININEC gives results similar to those of YA and NEC but at a frequency up to 2% higher, depending on element diameter.

YA closely tracks NEC for element diameters up to 0.01 wavelength (0.27" at 432 MHz). Yagis with thicker elements may exhibit some frequency offset from calculated designs, although YA gives reasonable agreement with NEC for diameters up to about 0.04 wavelength.

YA uses a narrowband modeling algorithm. Accuracy may degrade at frequencies more than about 5% away from the central design frequency.

YA models with input impedances of a few ohms are not likely to be accurate. At these impedance levels element currents are very large and fields nearly cancel. This condition greatly magnifies small model inaccuracies. Low-impedance Yagis should be avoided for practical reasons as well. Dimensions become critical, skin effect can cause considerable loss, impedance matching becomes difficult, and bandwidth is severely restricted.

Input-impedance accuracy decreases for maximum-gain or long-boom designs. YA is typically a couple ohms high for maximum-gain designs with impedances under 10 ohms. YA is typically a few ohms low for designs with a dozen or more elements and impedances in the 20- to 30-ohm range.

Modeling accuracy may degrade for elements spaced closer than about 0.05 wavelength. In practice, HF elements spaced this close may move enough in the wind to affect the response of critical designs. Accuracy may decrease somewhat for Yagis with element half-lengths shorter than about 0.19 wavelength. Elements this short normally aren't used for designs of 17 or fewer elements.

To prevent gross modeling errors, YA won't let you enter element half-lengths shorter than 0.15 wavelength or longer than 0.3 wavelength. It won't let you position elements closer than 0.03 wavelength. Finally, it won't let you enter taper diameters greater than 0.05 wavelength.

---- NOTEPAD ----

You can enter, edit, and display design notes with the Notes command. YA displays the Yagi title at the top of the notepad and you can edit it, too. The title and notes are saved in all output files.

The notepad editor automatically wraps words within a paragraph. A blank line or a line with leading space begins a new paragraph. Use the arrow keys, Home, End, PgUp, and PgDn to move the cursor. Use Del or Backspace to delete characters and Alt-D to delete a line. Use PrtSc to print the notepad screen.

---- GRAPHS ----

YA graphs forward gain, F/R, SWR, and impedance curves versus frequency. Regular command keys are active while viewing graphs. For example, you can press M and G to alternate between the Match Menu and graphs when adjusting a matching network. F5 changes screen colors, while PrtSc prints the screen.

YA scales graphs automatically. The F/R or F/B curve reflects the backlobe region selected in the Options Menu. The impedance curve graphs input resistance.

---- PATTERNS ----

YA displays patterns using the standard ARRL log-dB polar scale. Half-scale is about 12 dB down and quarter-scale is about 24 dB down. You can directly compare YA patterns with those in ARRL publications since both use the same scale. To reduce screen clutter, YA draws pattern sketches without grids or scale markings. The sketches have 5-degree resolution.

Use the Plot command to generate high-resolution patterns with grids, scale markings, and annotation. YA calculates these patterns at the middle analysis frequency with 1-degree resolution. The Plot command generates a plot file and then displays it. YA saves patterns in files so that you can review and compare them later. A plot file uses the Yagi filename and the extension .PLT. If you plot, change antenna geometry, and press P again, YA overwrites the plot file with new patterns. But if you press Alt-P, YA generates a new plot file. Each new file has an incrementing digit appended to its name. Use Alt-P to avoid overwriting plot files generated earlier in a session. (For both P and Alt-P, YA writes a plot file only when the pattern has changed.)

You can review a plot from DOS by typing YA PLOT. This bypasses the analysis part of YA and lists plot files in the current directory. Specify a directory name to list plot files in a different directory. You can specify the name of a plot file, for example, YA PLOT PV4, to display a pattern immediately.

Use the O key to overlay two patterns. YA displays filenames instead of plot titles for overlays. YA coordinates overlay annotation with patterns by color for EGA/VGA systems.

YA identifies free-space patterns as E-Plane or H-Plane. It uses the annotations Azimuth or Elevation for over-ground patterns.

Dots in the sparse radial lines are spaced 2 dB apart. Dots in the outer two circles are spaced 1 and 2 degrees apart. These calibrations allow you to read directivity values from plots with good accuracy.

YA plots are perfectly circular on monitors with standard 4:3 aspect ratio. Adjust your monitor's vertical-height control to correct elliptical plots.

---- OPTIONS MENU --

The Options Menu lets you control some additional aspects of YA.

The E-plane is the plane containing Yagi elements. Select this plane to analyze the azimuth pattern of a Yagi over ground. The H-plane is the plane perpendicular to the elements. Select this plane to analyze the elevation pattern of a Yagi over ground.

YA displays gain figures in dBi by default. Gain in dBi is antenna response compared with that of an isotropic radiator in free space. An isotropic antenna radiates uniformly in all directions. Select dBd to compare antenna response with that broadside to a free-space, half-wave dipole. Gain figures are 2.15 dB lower when expressed in dBd.

YA uses a backlobe region of 90 to 180 degrees for the pattern-quality figure by default (F/R). For conventional F/B, select a backlobe region of 180 degrees.

YA defaults to a 24-pin printer. Select Laser for DeskJet printers. YA does not print color images.

YA uses units of inches by default. Select mm to use millimeters. YA reads Yagi files defined either way and converts file dimensions to the units currently selected.

YA automatically saves all settings in the Options Menu (and all screen colors for EGA/VGA systems) when you exit the program. The settings are saved in the YA.INI initialization file. If this file is present when YA begins execution, it sets the options and colors accordingly. Delete YA.INI to return to default options and colors.

---- SCREEN COLORS ---

Press F5 to change screen colors for EGA and VGA systems. Use the left-arrow and right-arrow keys to select a screen item (an item blinks once when selected). Then use the up-arrow and down-arrow keys to cycle forward and backward among the 64 available colors. YA saves color codes in the YA.INI initialization file. Use F5 to change colors for any screen.

---- SCREEN PRINT --

YA prints monochrome screen images on most printers (but not PostScript printers). For EGA, VGA, and HGC systems, use the Options Menu to specify and save printer type. For CGA systems, load the DOS GRAPHICS program before starting YA. See your DOS manual to specify printer type when using GRAPHICS. Press PrtSc to print any screen.

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