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By R. Dean Straw, N6BV

Antenna Ads in ARRL Publications

After more than 35 years, antenna manufacturers may once again advertise performance figures in League publications. Why has this changed and what should the astute amateur consumer be looking for in an antenna ad (or a product brochure)?

Since 1933, *QST* has administered an Advertising Acceptance Policy, designed "to protect ARRL members from companies that offer unsatisfactory products and services, deal dishonestly or unfairly, and/or misrepresent their products and obligations." This policy applies to all products advertised to the amateur market in League publications.

Many types of measurements on amateur gear can accurately be performed in the laboratory. For example, the ARRL Laboratory can easily verify a claim for harmonic suppression in a linear amplifier, or a claim for a receiver's dynamic range. Back in the early 1960s, however, some antenna manufacturers became engaged in a "horsepower race" with each other—and they stretched the credibility of their advertising claims to the breaking point.

The ARRL Lab folks are a talented bunch, with access to lots of top-notch measuring equipment. Even they, however, would have a tough time verifying the absolute gain of, let's say, a 3-element 80-meter Yagi by actually measuring the performance of such a beast! Indeed, accurately validating the gain of even a small 2-meter Yagi is not an easy thing to do. Absolute, repeatable measurements of gain and pattern measurements for antennas are very difficult, unless one has access to a large professional antenna range and to very sophisticated (and expensive) measuring equipment.

Back in the 1960s, rather than allowing misleading ads that couldn't be validated with verified in-field measurements, the League simply amended its Advertising Acceptance Policy to forbid *any* advertising of specific antenna performance figures, such as forward gain, front-to-back ratio or radiation patterns.

Some 35 years later, the problems involved in real-world antenna measurements haven't changed much, but the state-of-the-art for both software and computers *has* advanced tremendously. At HQ we now have desktop computers with greater number-crunching capability than a typical early-1990s mainframe computer. More importantly, the ARRL now has available in-house the very latest software for antenna modeling. We are now using models previously available only to research universities and firms doing secret military work.

The ARRL Board Acts

We all know that the main purpose of a product advertisement is to catch the attention of a prospective customer—and to entice him to buy that particular product. From the beginning, the ARRL Board of Directors has promoted the dissemination of reliable technical information in League publications. The key is to ensure that performance claims are indeed reliable, using consistent methodology so that ARRL members can make intelligent buying decisions.

At the January 1998 meeting, the Board thus set in place certain rules to ensure that the interests of ARRL members are protected when antenna performance figures are claimed in an ad. Advertisers must submit their antenna computer models, and the ad itself, to the ARRL Laboratory for validation *before* they can advertise performance claims in League publications.[1]

Highlights of the New Ad-Acceptance Policy

The new policy continues to allow a manufacturer to advertise actual measurements made using a certified antenna test range. The test range must qualify under the very rigorous EIA (Electronic Industries Association) standard called RS-329, Part 1. (You might be interested in knowing that for the last 35 years only one antenna manufacturer has availed himself of this option, simply because the expense of making such certified measurements is quite high.)

Modeling Software

Once an advertiser has submitted his modeling files to the ARRL Laboratory, the Lab will validate the models, using one of two software packages. The first is *NEC-4*, the latest of a long line of general-purpose Method of Moment programs developed and validated by the US government laboratories at Lawrence Livermore National Laboratories.[2] The second is the *YO* program (*Yagi Optimizer*, by K6STI), which is designed strictly for evaluating Yagi antennas.[3]

Many readers are already modeling antennas on their own, often using some version of *NEC-2*, an earlier generation of the *NEC-4* program. The native *NEC-2* code is available on the Internet and is the core for several commercial modeling programs. *NEC-2* is very powerful and can properly evaluate many, but not all, amateur antenna designs. The newer *NEC-4* program has numerous accuracy enhancements, making it the most appropriate standard for the ARRL Lab. (Note that older software based on the original *MININEC* code, also widely available on the Internet, is essentially obsolete for this discussion.)

NEC-4 can be used to analyze almost any type of antenna used by amateurs, Yagis included. The advantage to such a general-purpose modeling program is its versatility, but its drawback is its slow operating speed, especially when analyzing a Yagi. *YO*, the Yagi standard-bearer in the ARRL Lab is custom-designed only for monoband Yagis. *YO* is hundreds of times faster in operation than *NEC-4*.

Brian Beezley, K6STI, has been developing the *YO* program since the late 1980s. As the name *Yagi Optimizer* implies, the software not only analyzes monoband Yagis, but can also optimize them, using parameters set by the designer. Over the years, Beezley has polished *YO* to a highly refined state.

YO was the program used by the League to create the many optimized Yagi design files on the diskette bundled with both the 17th and 18th Editions of *The ARRL Antenna Book*. (Also bundled with these editions is the "little brother" of *YO*, called *YA*, standing for *Yagi Analyzer*. *YA* does not optimize a Yagi design, but it can accurately analyze the performance, since it uses the same core algorithms that its bigger brother *YO* uses.)

[1]Notes appear on page 56.

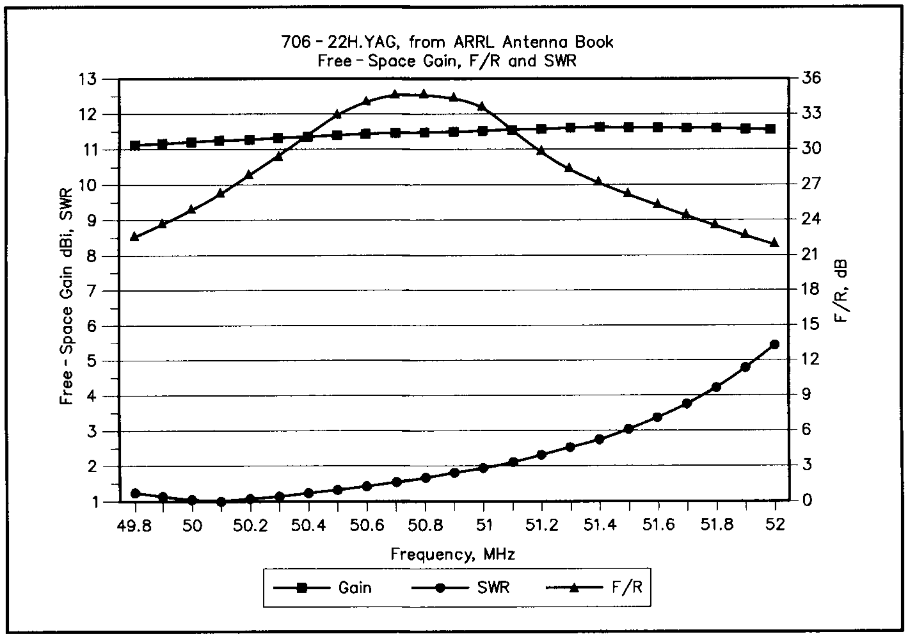

Figure 1—Graph of gain, F/R (front-to-rear ratio) and SWR over the 49.8 to 52.0-MHz range for 706-22H Yagi from *The ARRL Antenna Book*. The gain peaks at 51.6 MHz; the F/R peaks at 50.7 MHz. The matching network has been adjusted for a 1:1 SWR at 50.1 MHz.

Improved Designs

Sophisticated modeling tools such as these have led to many improved antenna designs. In particular, many modern-generation Yagis perform far better than antennas available in the old, pre-computer days. Ten years ago, the process of "designing" a Yagi consisted of tweaking an element length or spacing by a fraction of an inch, raising the test antenna up in the air, measuring the resulting pattern, and then lowering the antenna for another tweak. The painstaking process of tweak-and-raise-and-measure-and-lower might go on for hundreds of iterations before the experimenter got tired, distracted or confused and then decided to call it quits, freezing the design at that point!

Nowadays, in the course of five minutes, a fast computer using *YO* can do *tens of thousands* of iterations to optimally configure a multi-element monoband Yagi for whatever performance parameters are deemed important to the designer. Designs created using *YO* have been built and validated by many individuals and manufacturers alike. Virtually all commercial Yagis are now designed in software before going into production.

One note of caution should be raised at this point: Yagi design using optimizing software such as *YO* is not entirely science—there is some "art" involved as well. We'll delve more deeply into this important topic later in this article, when we describe what to look for in an ad or a catalog brochure.

Other forms of directional antennas have benefited from computer modeling as well. Over the last 30 years, successive generations of *NEC* programs have improved the analysis of various geometries that used to give problems—such as tapered aluminum-tubing elements or wires joining at acute angles (such as are used in quads). Again, this is not to say that every possible type of antenna can be evaluated accurately using modern software, but the vast majority of antennas actually found in the amateur market can be.

NEC-4 is the very latest computer code for antenna modeling, but it is highly regulated in distribution because of government national-security restrictions. The ARRL was graciously allowed to use the software because of our unique position in the field of Amateur Radio. *NEC-4* is also relatively expensive, at $850 for the uncompiled Fortran source code—you must compile it yourself for your own computing platform. It is unlikely that many amateurs will have access to *NEC-4*, except for the fortunate ones who use it at work. But then again, how many hams have access to $30,000 spectrum analyzers or $15,000 synthesized signal generators to make sophisticated receiver or transmitter measurements themselves?

What *Must* Appear in an Ad

One goal of the new ad-acceptance policy was to set up as few restrictions as possible for the advertiser, while still protecting the interests of our members, of course. The Board required that at least one fundamental property *must* be shown if *any* performance claims are made–the gain in free space at a specified frequency. This must always be shown referenced to a free-space isotropic antenna, meaning that gain must be shown in dBi. If the advertiser wishes to show, in addition, the gain with reference to a half-wave dipole in free space, he can do so by showing both dBi and dBd.

There is a fixed relation between gain in dBd of a half-wave dipole in free space and gain in dBi of an isotropic antenna in free space: The gain in dBd is always 2.15 dB less than the gain in dBi. For example, a 7-element 6-meter Yagi on a 22-foot boom from *The ARRL Antenna Book* might be shown as:

Model 706-22H—11.36 dBi (9.21 dBd) free-space gain at 50.2 MHz.

This type of listing meets the minimum requirements for the new policy and it gives useful information for a potential customer to compare one product with other ones.

Covering the Band

Most hams operate over frequency ranges rather than on spot "channelized" frequencies. The ARRL Ad-Acceptance Policy encourages as much disclosure of performance as possible—to show the warts and all, so to speak. Many antennas, particularly shortened designs, are narrowband in nature; some are very narrowband. Where ad space is available, we feel that radio amateurs deserve to know the trade-offs inherent in any particular design.

While gain is often considered the most important single measure of an antenna's performance, the shape of the radiation pattern and the SWR at the feed point are also very important parameters. And the way the gain, radiation pattern and SWR all change with frequency reveal a great deal about the design of an antenna.

Let's look again in more detail at the 7-element 706-22H Yagi just described above, but this time over the frequency range from 49.8 to 52.0 MHz. Figure 1 shows the computed performance, with gain, F/R and SWR overlaid together on the same graph. Here, the match has been adjusted for a 1:1 SWR at 50.1 MHz, yielding a 2:1 SWR at roughly 51.0 MHz. At 52.0 MHz, the SWR rises to over 5:1.

You can see that the gain rises gradually, peaking at 51.6 MHz, while the F/R (worst-case front-to-rear ratio) peaks at 50.7 MHz, at almost 35 dB. The rearward pattern remains more than 20 dB down from peak response over the whole range from 49.8 to 52.0 MHz. Note that the matching network could be adjusted for a 1:1 SWR anywhere from 50.0 to 52.0 MHz, and the Yagi's performance would still be excellent at that frequency.

Note that we chose to display the F/R performance parameter in Figure 1, rather than F/B (front-to-back ratio). We feel that F/R, which describes the worst-case lobe occurring anywhere in the rearward hemisphere behind the antenna, is a more useful performance parameter for directional antennas than is F/B. The details are covered fully in Chapter 11 of *The ARRL Antenna Book* (in the 17th and the 18th Editions), but the main reason is that unwanted signals don't always come from directly behind you—interference can come from any direction.[4]

Showing just the front-to-back ratio can be potentially misleading. For example, the 706-22H antenna has an F/B of almost 50 dB at 50.7 MHz. A completely legitimate, but incomplete description of the three performance figures for this Yagi might be:

Model 706-22H
Free-space gain = 11.72 dBi at 50.6 MHz
F/B = 49.1 dB F/B at 50.7 MHz
SWR = 1:1 at 50.1 MHz.

As already noted, this antenna has an F/R of almost 35 dB at 50.7 MHz, an excellent number to be sure, but not as spectacular as more than 49 dB for the F/B. Clearly, the old adage that "one picture is worth a thousand words" is particularly poignant in the field of antenna performance. The graph in Figure 1 depicts the performance of the antenna in a far more comprehensive fashion than any table of numbers could.

To an advertiser, however, the drawback to the kind of graphical presentation in Figure 1 is that more ad space is needed for each model of antenna advertised, raising the ad cost. Many advertisers will choose to print such detailed graphical information only in their product brochures, rather than putting it all in expensive print ads. As a consumer, you should petition those manufacturers who don't provide such detailed information to do so!

Most 6-meter weak-signal activity occurs in the bottom 300 kHz of the band, so someone might legitimately ask the question about Figure 1: "Why extend the performance so high in the band?" The answer is that if an antenna is highly optimized for maximum gain in a narrow frequency range, the design will be in all likelihood very "touchy" in terms of dimensional tolerances. The performance may even drop off precipitously (pun intended!) in precipitation such as rain or snow. This is where "art" is involved, as well as science. A more conservative design may compromise the maximum gain slightly, but it will favor performance over a wider bandwidth, in all types of weather. This is what was done for the 706-22H Yagi.

What About Gain Over "Typical" Ground?

The advertiser may want to show performance over real ground in an ad. There's nothing wrong with this approach, provided that performance over ground is advertised *in addition to* that in free space.

Some additional conditions arise for computations done over ground. First, the ground model used must be the "Sommerfeld/Norton" ground model in *NEC-4*, with "typical" ground constants of 5 mS/m for ground conductivity and a dielectric constant of 13. Further, the terrain surrounding the antenna is assumed to be flat. These restrictions preclude the use of the simple "perfect-ground" or "*MININEC*-ground" models, which both can inflate performance claims considerably.

Some antennas are optimally tuned to operate over specific ground conditions. For example, I used *NEC-2* to design the 75/80-meter quad at N6BV for a specific height above ground, 115 feet.[5] If I changed the model conditions to free space, the carefully optimized F/R would degrade from 20 dB down to about 10 dB. If for some reason I wanted to advertise this quad in *QST*, I would have to submit two files to the ARRL Lab for validation. One would be optimized in free space and the other optimized over real ground.

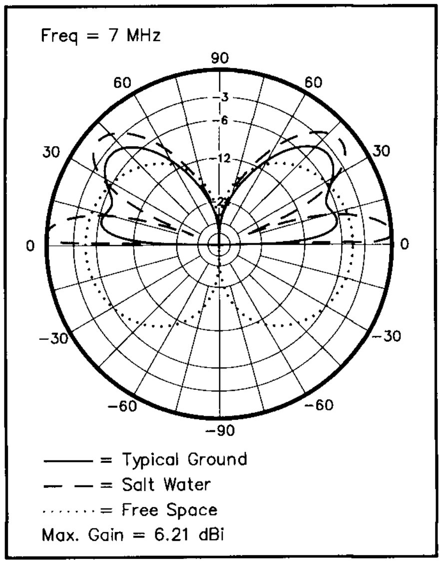

Figure 2—Comparison of elevation-plane patterns for 7-MHz ground-plane antenna, whose radial tips are located a half-wave above three ground models: free space (dotted line), "typical" ground (solid line) and salt water (dashed line). It's pretty obvious that the performance of a vertically polarized antenna is best over salt water, particularly at low elevation angles!

Other Types of Ground

In addition to free-space gain (and gain over typical ground), the manufacturer may also want to show performance characteristics for specific types of ground. For example, a manufacturer of verticals may want to show the gain over salt water. He may do so, provided that he also shows gain in free space and gain over typical ground (with conductivity of 5 mS/m and dielectric constant of 13).

Figure 2 shows a comparison of elevation patterns for a 7-MHz ground-plane antenna whose radial tips are a half-wave above ground (at 33 feet) for three ground conditions: in free space, over "typical ground" and over salt water. Note that the two patterns computed over ground cannot have elevation angles less than 0° because the ground blocks these angles, while the free-space elevation pattern can go below 0° because there is no ground in free space.

You can see that a vertical antenna mounted over salt water has a decided advantage compared to the same antenna located over typical earth. At a 5° elevation angle, the saltwater vertical has an advantage of about 8 dB over its landlubber brother. Here in New England, with our very poor, rocky soil, the advantage to the saltwater vertical is even larger.

Incidentally, we don't expect many manufacturers of non-gain antennas, such as dipoles or verticals, to specify gain, F/R or F/B in their ads. After all, the gain for a vertical over typical ground is often less than 0 dBi, and this doesn't show that well in an ad!

Modeling Losses

NEC-based programs can accurately model losses in several ways. The resistive loss in wires or tubing, often referred to as "copper losses" can be modeled, and discrete losses in traps or loading coils or stubs can be modeled as networks.

If the ARRL Lab finds that the feed-point impedance of an antenna model is suspiciously low, where losses in the matching network might become large, then they will ask the advertiser to submit a sample of his product for inspection. By the way, this is true for all products, not only antennas—all must undergo scrutiny before being allowed to advertise in ARRL publications.

Modeling Files on the Web

The ARRL encourages advertisers to allow us to post the modeling files they send for ad-acceptance validation to a special area on the ARRL Web site, at **http://www.arrl.org/antmodels/**. Knowledgeable users can download the files and explore the antenna designs using their own software. A number of prominent manufacturers have indicated their willingness to post their files publicly.

The files are available in one of three different formats: *NEC-4* ASCII files, *YO* ASCII files, and *EZNEC Pro* binary files. The *EZNEC Pro* files are meant to be run using the *NEC-4* core code. Many *NEC-4* files can be run satisfactorily using *NEC-2* software, but some will not. The files that will not run properly in *NEC-2* based software (such as *EZNEC* or native *NEC-2*) will often include internal comments to this effect or will give error messages when the operator attempts to run them. Note also that Yagis having more than 17 elements or ones with multiple element-tapering schedules will not run in *YA*, although they will run in *YO*.

Final Comments

Although several wags have claimed that the new ad-acceptance policy must surely be designed to increase advertising revenue, that is *not* the reason the policy was changed! The desired effect is to improve the quality and quantity of antenna-related information available to help our members make rational purchasing decisions.

Notes

[1]The full ARRL ad-acceptance policy may be found on the ARRL Web site, at **http://www.arrl.org/ads/#Policy.**

[2]As of February 1998, the latest version of *NEC* is *NEC-4.1*. This program is subject to export restrictions by the US government and is available to authorized US individuals or companies in the US from: Jerry Burke, Lawrence Livermore National Laboratory (LLNL), PO Box 808, L-154, Livermore, CA 94550.

[3]The *YO* (Yagi Optimizer) program is available from: Brian Beezley, K6STI, 3532 Linda Vista Dr, San Marcos, CA 92069, tel: 619-599-4962, e-mail **k6sti@n2.net**.

[4]*The ARRL Antenna Book*, 18th Edition (Newington: ARRL, 1997), pp 11-2 to 11-9.

[5]R. Dean Straw, "The N6BV 75/80-Meter Quad," *The ARRL Antenna Compendium, Vol 5* (Newington: ARRL, 1996), pp 45-50.

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