



A Yagi Case Study Part 3: Construction Options



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In the first episode of this "Tale of 3 Yagis," we explored the design options for a 3-element 2-meter Yagi with intended field use and restricted to a 30" boom or smaller. Our options included high-gain, high-front-back, and wide-band versions of the antenna. Each option provided design dimensions for round-tubing elements ranging from 0.125" up to 0.5" in diameter. In the second episode, we examined some of the element materials other than round tubing that we may use for the Yagis. As well, we looked at the process of correlating these materials to the dimensions in the first part of this exercise on antenna options.

In this final portion of the exercise, we shall explore some of the construction options involved in building the small 3-element Yagi--whatever the selected design and element material. Our perspective will not be commercial construction, but rather what we can accomplish within a typical home shop.

Part 3: Building 3-Element Yagis for Different Uses

A commercial antenna designer might begin with a set of operating or use specifications and then select materials and construction methods that will achieve those goals. However, the average home antenna-builder often begins from a different position. He or she has some materials, some shop abilities and limitations, and some uses for the final product. The next step is usually reaching a physical design that combines these starting points into one antenna. Therefore, let's examine a few building options for both permanent (long-term) installations and for field antennas.

Long-term construction techniques: Utility antennas on 2 meters can make good use of 1/2" to 1" nominal PVC pipe as the boom material. The elements are light enough that you can place a Tee fitting off center (to avoid the driver position) and still have a stable mounting. Indeed, you may even extend the boom rearward so that the boom-to-mast assembly is behind the reflector. This system is especially suitable for vertically oriented Yagis to suppress interactions between the mast and the array. The non-conductive boom also means that you may use the dimensions in Part 1 as a direct guide to construction without adjustment for the use of a metallic boom.

The typical white PVC is variable around the U.S. with respect to its UV resistance. If the white plumbing PVC in your area is UV susceptible, then the gray electrical conduit version is usable and tends to be more uniformly UV resistant. Other alternatives include fiberglass and other resin-based non-conductive tubular materials.

For long-term installations, I recommend round elements, either aluminum tubes or rods. All of the designs that appear in Part 1 use split drivers to minimize the number of mechanical connections on the driver assembly. The low-impedance drivers are either resonant (the high-gain version) for use with a 35-37-Ohm 1/4-wavelength matching section, or they are designed for about 25 Ohms of capacitive reactance for use with a beta or hairpin match (the maximum front-to-back ratio version). The very wide-band design requires direct connection to a 50-Ohm coaxial cable (the very wide-band version). In each case, the design places the antenna connections at the split-driver terminals.

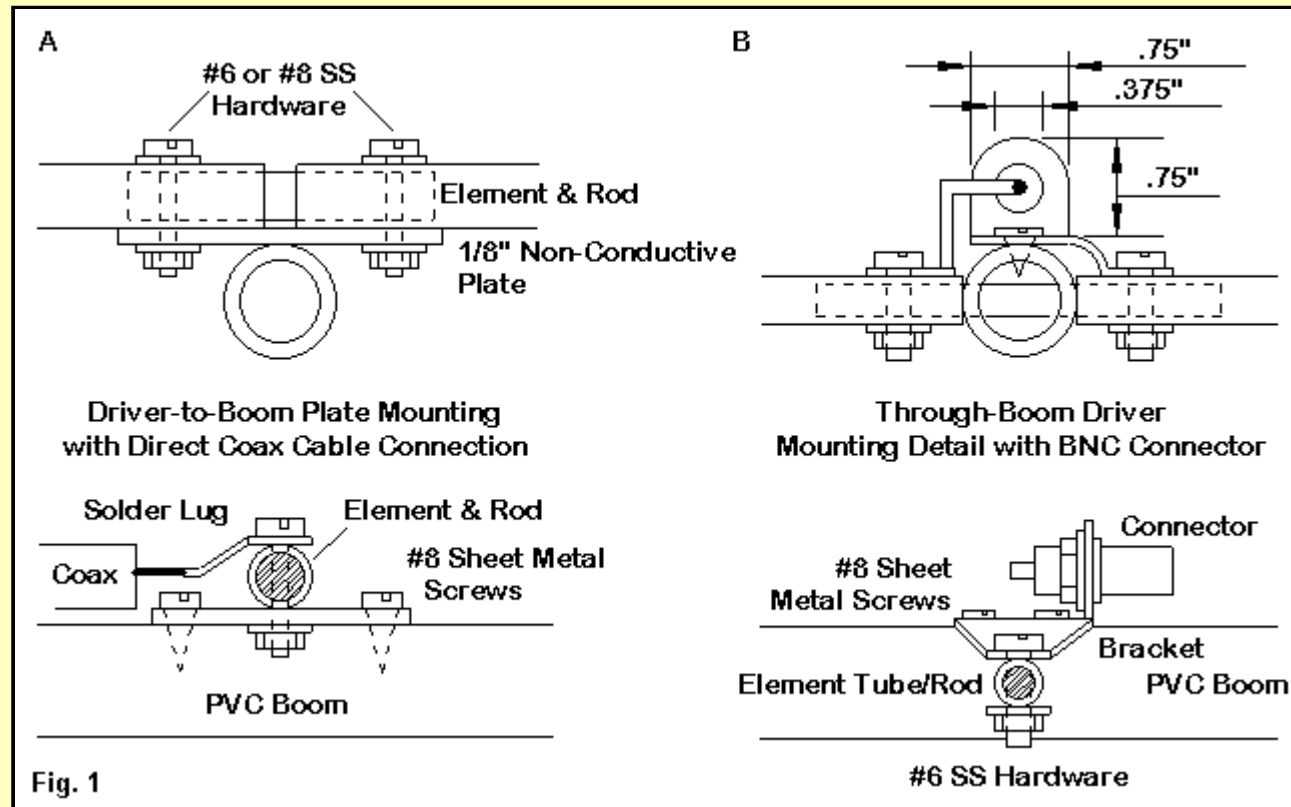
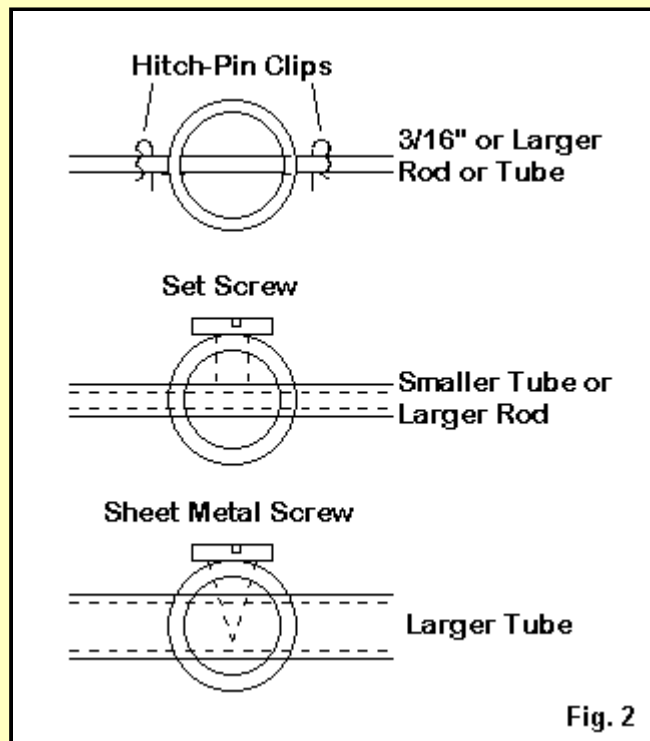


Fig. 1 gives us several alternatives for assembling the driver to the boom. Although the graphic shows alternatives A and B, we actually have 4 major combinations, plus any number of adaptations you may create based on local materials. Alternative A uses a small plate (Plexiglas, polycarbonate, or acrylic) with the drive tube anchored to it. A non-conductive insert (fiberglass, CPVC, or similar) aligns the two halves of the driver and strengthens the tube against crushing during bolt tightening. Even if the parasitic elements pass through the boom, the very slight misalignment of elements relative to their ideal plane will create no operational difficulties.

Alternative A also shows a direct connection to coaxial cable without the use of a connector. This technique allows you to use a length of cable of your choosing to dress the lead to the boom and as much farther as you choose during antenna assembly. The open end of the coax, with its implicit ring connectors for attachment to the driver terminals, requires sealing. Plasti-Dip and similar products have proven reliable in this service and are less bulky than coax sealant and tape. Indeed, over the years, I have come to prefer this system over the alternative shown in B.

If you prefer a connector, alternative B shows a simple mounting bracket that not only holds the connector, but also extends to one side of the element. 1" by 1/16" L-stock will handle either the BNC connector shown in the sketch or a standard UHF connector. Do all drilling before trimming the L-stock to final size for easier handling while creating the required holes. The sketch also shows the bracket with rounded upper edges. The easiest way to arrive at this shape is to use a disk sander. (Do not use a grinder designed for steel.) Clearly, you may adapt the connector bracket for use with the plate assembly in alternative A. Likewise, you may use direct coaxial cable connections to each side of the driver that passes through the boom.

The through-boom driver shown in the sketch uses 1/2" tubing with a 3/8" fiberglass or similar rod or tube that actually passes through the boom PVC pipe. There is a limit for minimum effective insulating rod size to support the driver, since a hardware hole will pass through both the element and the rod. However, you may use this larger driver with any of the dimension sets in Part 1, using thinner material for parasitic element diameters. The "fat" driver will require a reduction in length to bring the beam to its proper SWR curve, but it will not otherwise affect performance.



There is no good reason why the parasitic elements for a simple 3-element Yagi should not pass through the PVC boom. There are three (or more) different suitable systems for holding the elements in place. See Fig. 2. The top option works well with rods and tubes at least 3/16" in diameter. It uses minimum-size hitch-pin clips on either side of the boom to secure the element. Some builders use C- or E-clips, relying upon their spring action to hold the element in place against the boom. However, all such hardware should be non-corroding. The middle sketch shows the use of a setscrew. If you under-drill the hole, most stainless steel bolts (#6 to #10, depending on the element diameter and the boom diameter) will self-tap the material for a firm seating. You may install a nut below the setscrew head and tighten it to the boom after securing the element. For larger tube sizes, you may use the final option, a sheet metal screw that penetrates both the PVC boom and a hole at the center of the element.

Both the hitch-pin mount and the setscrew mount benefit from a small bit of filing. The hitch-pin clips require holes through the round rods or tubes. A small jeweler's file can create a flat spot no great than about 3/32" diameter without weakening the element. The flat spot eases the drilling if you do not have a drill press. A similar flat spot at the element center gives a setscrew a good surface for the bite necessary to secure the element.

The techniques suggested here have resulted in numerous solid Yagis up to 6 elements, with boom lengths up to 5' or more. (The longer the boom, the less suitable that rear mounting becomes.) All of the designs in Part 1 use under 30" of boom for the elements and are suitable for the hardware-store materials noted along the way. The one place not to use hardware-store materials is in the elements themselves. High-grade 6063 or 6061 aluminum tubing or rod is the best element choice for a long-term installation.

Construction of field-antennas: Antennas for the field call for some special notes. Of course, you may take an antenna built according to the preceding suggestions into the field. However, that antenna has a permanent size, about 40" by 30". Hence, it is a bit ungainly for transport in an auto trunk or other confined space. One of the hallmarks of a good field antenna is that it stores compactly for transport and is ready for use with minimal field assembly. The ideal situation is one that requires no tools to transform the transport package into a working antenna.

You can achieve this goal in a variety of ways. There are as many ways to successfully build a good field antenna as there are alternative materials for antenna elements. To demonstrate what is possible (in local talks for clubs and other functions), I created a hybrid Yagi using separate techniques for each of the 3 elements. The design uses the very wide-band design as its basis, although there is no reason not to use any of the other versions. Since you will likely use a single material best suited to your operating goals, your own field antenna will pick the design that is also most apt to those goals.

My hybrid begins with a length of 1/2" nominal PVC pipe. The actual outer diameter of this pipe is a little over 7/8". I placed a Tee fitting just behind the driver position. The fitting is aligned for horizontal mounting of the antenna on a boom, using PVC screw fittings to increase the boom diameter until it matches the mast on which the antenna will sit. For many field uses, you need not cement the fitting in place. Press fitting the Tee will provide a secure and durable connection between the boom sections for most field operations. You may use a sheet-metal screw to secure the un-cemented side of the Tee, but that requires a screwdriver. The forward end of the boom also has a cap to keep out bugs and debris.

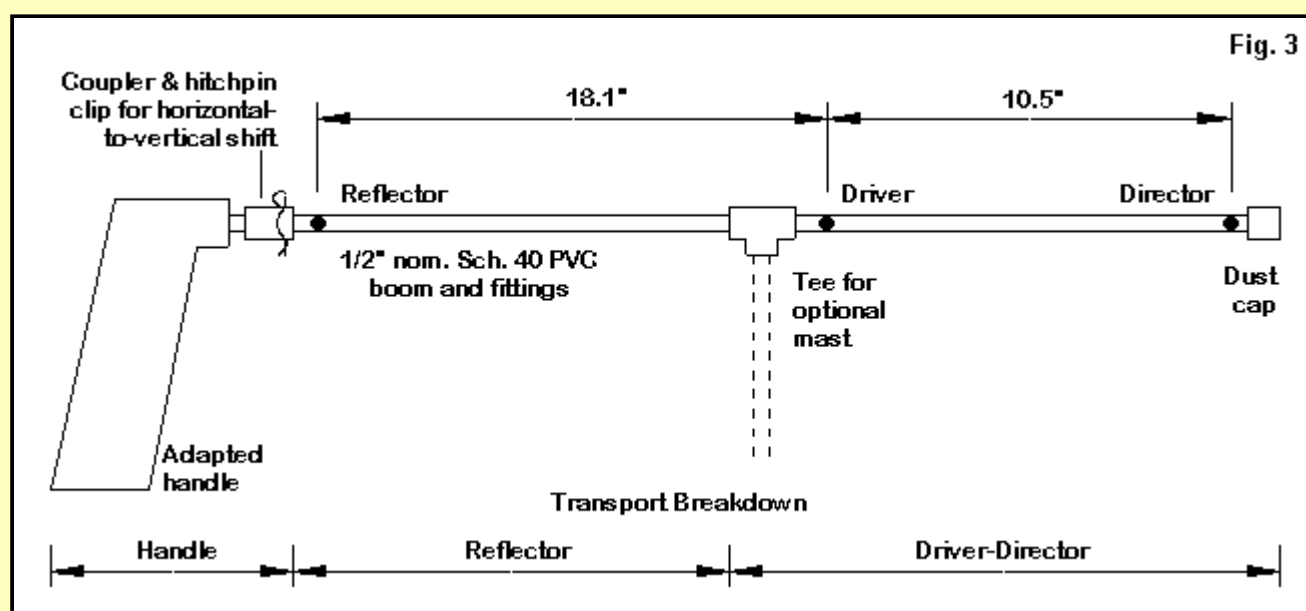


Fig. 3 shows the general arrangement of the boom, along with the special rear section. At the rear end of the boom, there is an in-line coupler. It attaches to the forward boom sections with a large hitch-pin clip. I drilled the end of the boom with two holes at 90-degree angles. Hence, I can

change the orientation of the antenna from horizontal to vertical and back again simply by removing the hitch-pin clip, twisting the boom, and re-installing the clip. You can use the same system with a rear boom-to-mast attachment system rather than the funny handle shown in the sketch.



Most fox-hunting antennas that I have seen use rubber hand-grips in line with the antenna. These grips are most suitable to point Yagis at satellites, but are not ergonomically suitable for aiming the antenna straight ahead. Therefore, I took the pistol grip handle from a defunct electric weed cutter and replaced the steel tube with a short length of PVC. Since the in-line coupler bears the lever-force of the entire antenna ahead of it, I cemented the coupler to the handle-end pipe. **Fig. 4** reveals that I left the trigger in place, since it is smooth, while the bare opening without it has sharper, less comfortable edges. You can store the entire antenna as a 3' long storage unit that is only about 4" wide, plus the handle. Alternatively, you can remove the handle and break the boom at the Tee for even more compact storage. **Fig. 4** shows the pieces in full storage mode.

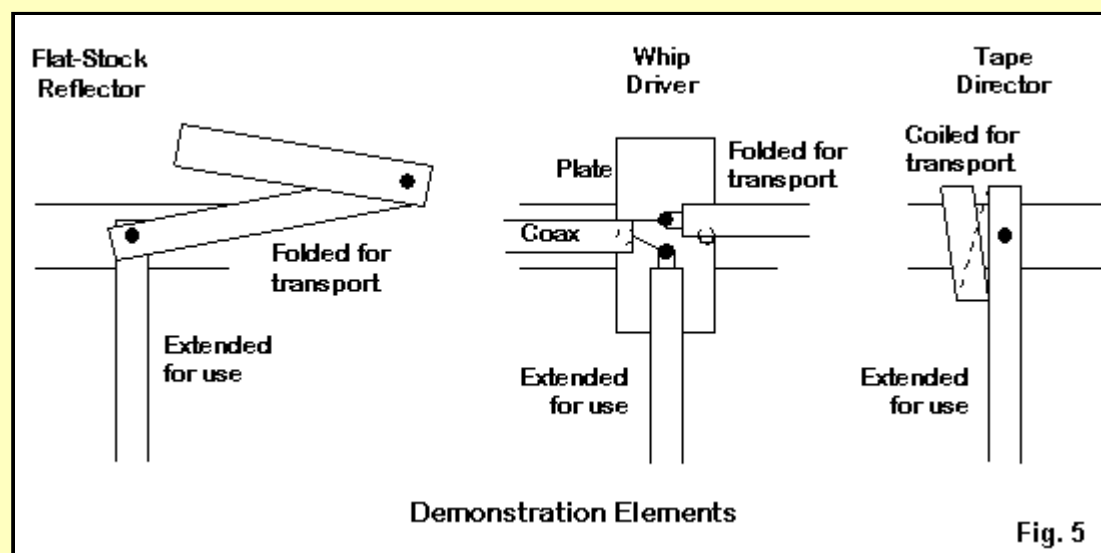
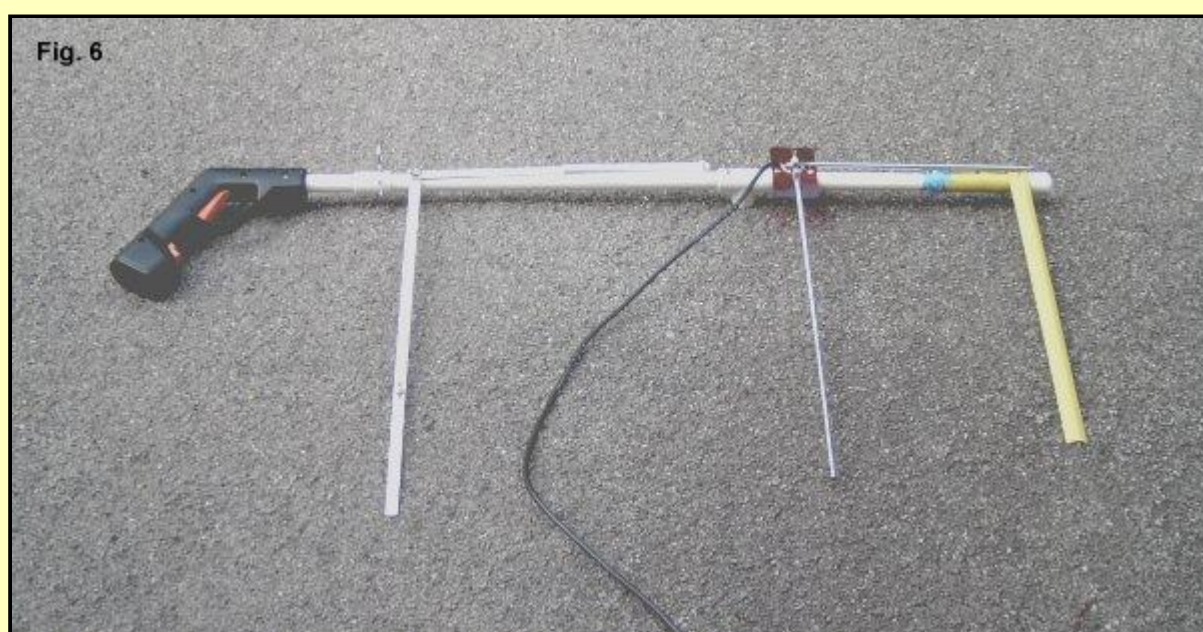


Fig. 5 show the elements, each half-ready for use and half-stored for transport. The photo in **Fig. 6** also shows the demonstration elements. The driver uses collapsible whips taken from TV rabbit ears. The reflector uses flat stock, and the director uses a length of steel measuring tape.



The 1/2"-wide flat-stock reflector would not store well if we used a full half-element length each side of the boom. Instead, I used #8 bolts and wing nuts for the outer section so that it could fold back on itself and fit entirely behind the driver during storage. For the reflector, I used a #10 wing nut and bolt that passes entirely through the boom to secure the reflector in place for both use and transport. 1/16"-stock seemed a bit flimsy initially, but has held up well during use.

The driver whips retract for storage and extend for use. Setting them requires a tape measure or other measuring strip to get the correct length each side of center. (I wrote the measurement on the boom.) #8 hardware secures the position of the driver. I ground shallow grooves with a rotary tool in the small Plexiglas plate so that the driver stays in either the use or storage position once I tighten the wing nuts. The feedpoint bolts also hold the length of coax that I have devoted to the antenna.

The director uses a length of steel measuring tape. A single sheet metal screw is usable as an element-to-boom fastener, although I placed a few thin washers between the tape and the boom to maintain the tape curvature. The tape does not require re-positioning for storage. Instead, wrap the tape around the boom and secure it with a piece of duct tape or similar. In fact, you can use sections of cardboard tubing from a roll of paper towels to slide over the coiled elements. In either case, guard your face when opening the element, since it will spring to position very rapidly.

Does the hybrid field antenna work? Since I selected materials for the director and reflector that are very close equivalents to 1/2"-diameter round elements. I used the spacing for the very wide-band design for those elements. Then, I simply adjusted the driver length to give the 50-Ohm impedance curve for that design. I used the two fattest sections of the whip, and the resulting length was not much longer than the value shown in the Part-1 tables, about 19.25" each side of center.

For field use, especially if you plan to use the antenna in a hand-held activity like fox hunting, you will need to determine the correct driver length for a normal use position well in advance of going into the field. You may also discover that for different orientations and heights above ground, the required driver lengths may differ.

If you prefer the design security of using tubular elements, Fig. 10 shows one method of achieving a compact storage package and a full-size array of the type that you choose. You may construct the boom in the same manner as for the alternative element materials, using the 3-piece break down for transport. However, the element positions will have stubs protruding about 1.5" on each side of the boom. The reflector and director stubs will be 3/8"-diameter aluminum tubes, while the driver stub will be a length of 3/8"-diameter fiberglass or other non-conductive rod or tube. Secure each stub through the boom with a sheet metal screw as a permanent mounting.

Table 1. Aluminum 6061-T6 rod and 6063-T832 tube weights.

Type	Outside Diameter	Weight/12"
Rod	0.125"	0.015 lbs
Rod	0.1875	0.032
Rod	0.25	0.058
Tube	0.375	0.044
Tube	0.50	0.095
Tube	0.625	0.104
Tube	0.75	0.127
Tube	0.875	0.150
Tube	1.00	0.202

Although you may believe in thinner rods for field use, 1/2" 6063-T832 tubing weighs very little more than 3/16" solid rod. **Table 1** provides some comparative weight of rods and tubes used in common amateur antenna construction. The material is drawn from the web site maintained by Texas Towers. It applies to aluminum tubing with a wall thickness of 0.058". Alternative materials with thicker or thinner walls will, of course, change the weight per foot. For the project at hand, the elements are between 3.0' and 3.3', so totaling the element weight is easy math.

In most cases, the boom will outweigh the sum of the elements and their hardware by a good margin. So using larger materials adds little to the antenna weight, but allows the use of nuts and bolts as fasteners. The half-elements use 1/2" diameter tubes, none of which will be longer than about 20". You may attach the reflector and director outer element halves to the stubs with #6 or #8 nuts and bolts or with hitch-pin clips. (Do not exceed #8 size hardware, or the necessary hole may weaken the stub.) The driver uses nuts and bolts, plus solder lugs, to attach the element halves and to form connection points for the coax cable and any matching device (such as a hairpin).

The advantages of using aluminum tubes as elements for the field antenna include general strength. Overgrown fox-hunting field sites that can snag the elements may still test the antenna's sturdiness. However, use of the antenna at an emergency or Field-Day site for FM or similar applications is unlikely to encounter such tests. The disadvantages include the need for small hardware to assemble the antenna. If you opt for this type of field antenna, be sure that the transport package includes both extra hardware to replace pieces lost in the grass and tools for assembly. A dedicated screwdriver and nut-driver are essential.

In the end, the decisions concerning the methods of construction will rest upon your intended uses, the availability of materials, and your own assessment of your construction skills. However, somewhere in this collection of ideas--and other ideas that you develop--will be a Yagi that you can build yourself.

Conclusion

The hybrid demonstration antenna is simply a potpourri of ideas that you can adapt to both field and long-term antennas for 2 meters. In fact, we have surveyed a wide variety of factors that go into a home-brew utility Yagi for this band.

- 1. We examined three different Yagi designs: a high-gain version, a maximum front-to-back ratio model, and a very wide-band unit.
- 2. We also saw 2 ways of matching a 25-Ohm driver impedance to a 50-Ohm coax line using a 1/4-wavelength matching section with a resonant driver and a potential hairpin match with a driver that is capacitively reactive.
- 3. We explored a variety of alternative materials that builders of field antennas use instead of rods and tubes, and we measured them at 146 MHz to find their nearest round equivalents.
- 4. Finally, we explored various ideas for constructing both long-term and field antennas using common materials from hardware outlets.

Now, you have no excuse for not building your own 3-element 2-meter Yagi, whatever your operating goals. In fact, I would expect you to have some building ideas that yield an antenna better than any of the samples that you have seen in these notes. Those ideas increase the number of options we have. The greater the number of options, the closer that we can match our antenna to the job for which we need it.

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