

The FoxFinder Antenna

Find the fox with an easy-to-carry (read "lightweight"), high performance 2 meter antenna.

For several years, our local club has been the unofficial sponsor of a hidden 2 meter fox box transmitter. Finding this hidden transmitter has proven to be an exciting and challenging activity. In addition to developing skill in the art of radio direction finding (RDF) and locating, it is an activity that can be shared with other family members, young and old— licensed or not—with a chance to get out in the fresh air and enjoy nature as one stumbles around in the woods and fields looking for a strange little box with a whip antenna on it.

Our group enjoys hiding the fox in the deepest thicket of brush and woods imaginable. Even when the fox box is not in the midst of a thicket, it seems that the route I choose to take to the fox passes through at least two briar patches, poison

ivy, a swamp, and a stream I can't ford. With all this tramping around in the woods, I decided I needed a lightweight, rugged replacement for the 3-element Yagi antenna I was using. That antenna was strong, with thick, tubular elements. It functioned well, but it was heavier than I thought it needed to be. The rigid elements were always catching on things and bending or working loose from the boom. So, I thought I could build something better and, besides, I like to design and build antennas.

Requirements

I began to list some of the things I wanted in the antenna. Low weight was at the top of the list. Since the antenna is held from the rear and pointed as an extension of the arm (this can

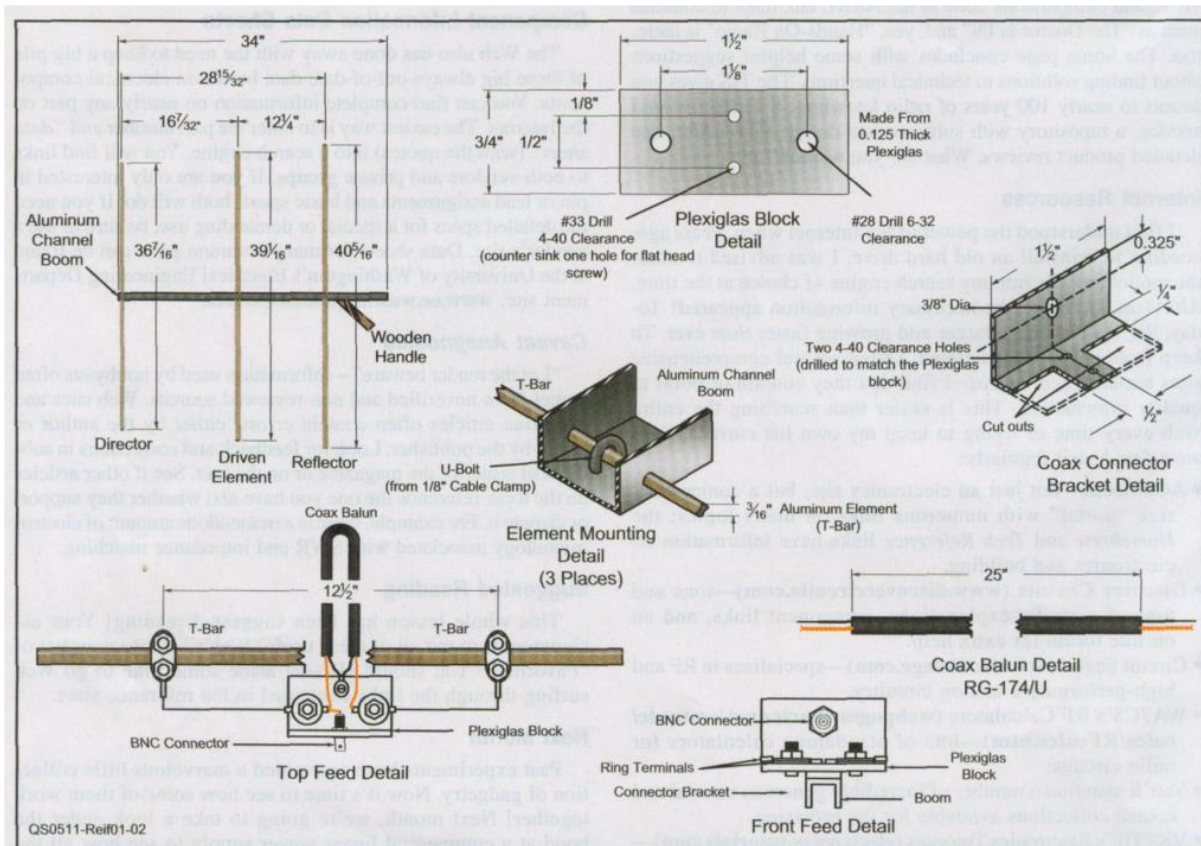


Figure 1—Constructional details for the 3 element FoxFinder antenna. A thorough study of these drawings, including Figures 2 and 5 should enable easy construction.

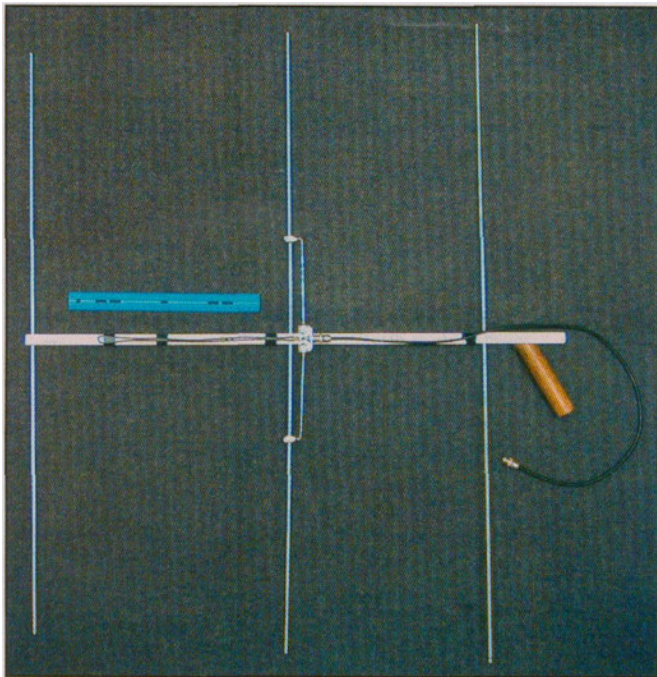


Figure 2—The assembled antenna. This example is made of aluminum. Copper or brass elements can also be used, although weight will increase. The wood handle was fashioned from an old axe handle; a dowel can be substituted.

get heavy after an hour or so of hunting!), I decided to make the antenna as light as possible. The antenna's mechanical design needs to be rugged, but with a difference. Rigid elements are not the best solution. I considered alternatives, using flexible elements. Electrical performance is also important. I decided that a 3 or 4 element Yagi would be ideal. I wanted decent gain with a good pattern, as the antenna pattern is significant in fox hunting. If you can't tell the front from the back of the antenna, you are left with two directions to walk. A good front-to-back ratio is another requirement. I also use the antenna with my FoxFinder receiver.¹ The greater the antenna gain, the farther the useful range from the fox is, so I wanted all the gain I could get in a 3 or 4 element antenna.

Initially, ease of construction was not on the list, as I had a decent assortment of tools available. The antenna I originally designed and built used 1/8 inch aluminum elements, mounted on Plexiglas blocks. The matching arrangement used aluminum blocks that were drilled and tapped. That antenna was used for several years and was featured on the April 2001 *QST* cover. I received many requests for information about the antenna, but I decided that, although a sound design and good performer, it was not necessarily easy to duplicate. Some of the parts used required ordering through a wholesaler or bulk supplier. A new design was therefore developed that maintained the original goals while being simpler to build with easier to obtain parts.

The Design

The design presented here is the result of that effort. It satisfies all of the original design goals and it is easier to build than the original (with normal hand tools). The materials required are a length of small aluminum channel for the boom, three lengths of 1/8 inch aluminum rod, a small piece of Plexiglas, some 12 gauge solid copper wire, assorted hardware, connectors, some coaxial cable and a suitable piece of wood for the handle. The constructional details are shown in Figure 1.

¹Notes appear on page 70.

Before I built the original antenna I did a computer analysis. I have used computers to analyze antennas for some years using many different analysis programs. I have written some; others are available in both the public and private domain. If you are interested in modeling antennas, see the series of articles by L. B. Cebik, W4RNL.² I started modeling a 4 element antenna; finally settling on a 3-element design. I decided that three elements were adequate, as the desire was to keep the length of the antenna short to make it easier to hold and maneuver.

I chose to optimize the design for good performance over the entire 2 meter band. Although local fox hunting is likely on one frequency: a real hunt may be anywhere in the band.¹ Also, a broadband design is less likely to be effected by manufacturing tolerances and nearby objects. The assembled antenna is shown in Figure 2. The final design is the result of revisiting the computer and developing a shorter boom length to reduce the weight and turning moment. This was done partly to compensate for the heavier elements used in the new antenna. The 1/8 inch diameter elements were adequate, but 3/16 inch material is more readily available.⁴ Figure 3 shows the antenna pattern from the computer analysis and Figure 4 is a plot of the actual measured SWR data on the antenna.

I chose a light aluminum 3-sided channel for the boom, as opposed to the more common round tubing. It is low in weight and the strength is adequate and it does allow for a certain amount of twist, but this is unimportant for this application. A warning, however—that twist could lead to mechanical oscillation in the wind if the antenna is used in a permanent installation. The flat surface of the channel gives a solid surface to mount the elements on. This has stood up to the rugged use the antenna has received.

The elements are made out of 3/16 inch aluminum rod. The alloy is 6061-T6. This is strong and springy. A solid rod is "springier" than a hollow tube. The element configuration (solid versus hollow) was chosen specifically for the springy characteristic that was desired for the elements. Type 6063-T6 alloy is similar and could also be used. The softer alloys are not

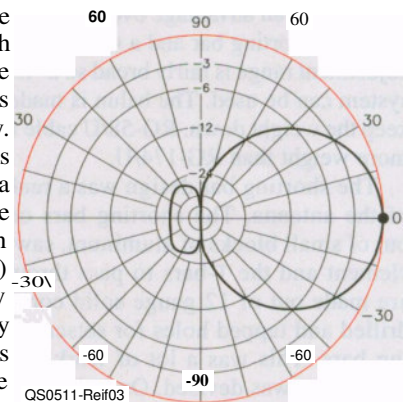


Figure 3—An azimuth pattern of the antenna. The modeled gain of the antenna is 8 dBi and that appears to be correct in practical use.

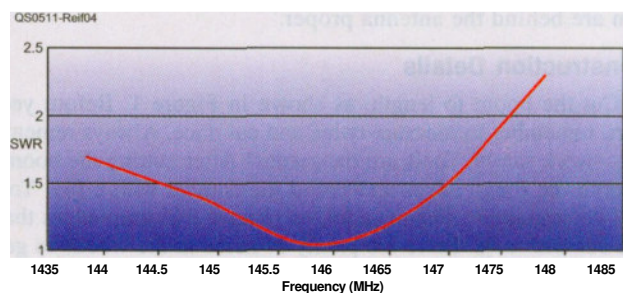


Figure 4—The measured SWR of the FoxFinder antenna.

likely to be successful, as they will not stand up to stress when the elements get tangled in the bushes. I considered other materials; stainless steel could be a good choice. This would be better than aluminum with regard to its elasticity, but I happened to have the aluminum on hand and it is easier to obtain [although the greater loss of stainless, about 30 times worse than aluminum, would result in lower gain.—*EdJ*].

I considered using steel measure tape for the elements. The thought was that those would bend away and then snap back into place. Round elements, however, will deflect in any direction, compared to a steel tape. I didn't try elements made out of steel tape, but I know that others have used them. I chose to mount the elements off center on the boom (as detailed in Figure 1). This unique method of element mounting is simple, and it allows them to be easily removed. The elements are mounted by drilling a clearance hole in the two sides of the aluminum channel. The holes are offset from the centerline of the boom, so the element, when slid into the hole, is in contact with the surface between the two sides of the channel. A small U-bolt (removed from an VB inch cable clamp) is used to clamp the element in place against the Oat surface. Offsetting the element in the boom avoids bending the element by over tightening the U-bolt. I originally considered a split driven element, but this could weaken the element at the point of maximum stress.

I was not able to come up with a method of matching that seemed attractive. In the end, I chose the T match. A gamma match requires a short second element, a shorting bar between the driven element, the gamma element, and a capacitor to tune out the reactance of the gamma section. Computer analysis of the T match indicated that an acceptable SWR was possible over the full 2 meter band without any reactance canceling capacitors. This seemed like an advantage over the Gamma match. It does require a second shorting bar and a 4:1 balun transformer. The T match adjustment range is fairly broad so a "no adjustment needed" feed system can be used. The balun is made out of miniature coax to keep the weight down. RG-58/U cable is usable, but adds slightly more weight than RG-174/U.

The shorting bar design was a real hang-up in the redesign of the antenna. The shorting bars originally had been made out of small blocks of aluminum, sawed out and drilled for the element and the T-bars to pass through. Note that the T-bars are made out of 12 gauge solid copper wire. I originally had drilled and tapped holes for setscrews in the aluminum shorting bars. This was a lot of work for such an antenna, so an alternative was devised. One-eighth inch cable clamps are enlarged with a file so they fit over the Vi6 inch elements. These are used to connect to the driven element. A solder lug is then connected to the end of the T bar and mounted under a nut on the cable clamps. See Figure 5 for the details.

One of the unique features of the antenna is the pistol grip handle. I mounted the handle so that the antenna is normally in the vertical mode when the handle is held. This has made it much easier to use the antenna for extended periods of time. I extended the boom past the reflector element so the hand and arm are behind the antenna proper.

Construction Details

Cut the boom to length, as shown in Figure 1. Before you start, remember to measure twice and cut once. Always remember—work safely. Tools are dangerous! After cutting the boom, smooth the rough edges and round the corners with a file. You will be around the antenna a lot, so remove the sharp edges that can cut and snag. There are plenty of items in the woods to get scratched on; the antenna doesn't need to be one of them.

Carefully mark and center-punch the centers of the element mounting holes. The element spacing dimensions are given in

Table 1

Parts List—FoxFinder 2 Meter Antenna

1	Boom, 34" aluminum channel; 1/2 x 1/16" thick; Crown Bolt Inc (Home Depot).
3	Elements, 3/16" aluminum rod, 6061 or 6063 alloy lengths: 36 7/16", 39 1/16", 40 5/16"; (Texas Towers).
5	Cable clamps, for 1/8" cable (Ace Hardware).
1	Aluminum angle bracket, 3/4"x3/4" aluminum angle stock 1/16" (or 0.0501/2") Crown Bolt Inc (Home Depot).
1	Plexiglas block 3/32" or 1/8" acrylic safety glazing scraps (Ace Hardware).
1	Coaxial connector, BNC, chassis female UG-1094/U.
1	27" length RG-174/U coaxial cable (balun).
4	Crimp lugs, to clear #8 screw.
3	Solder lugs, to clear #6 screws.
1 foot	12 gauge solid copper wire (for T match).
1	Dowel (wood), 1 1/4" x6" long (handle).
3	6-32 x 3/8" machine screws, binder head.
6	Nuts, 6-32.
1	6-32x 3/8" machine screw, flathead.
2	#6 wood screws, 1 1/2" to 1 3/4" long.

Figure 1. The director is set-in 3/8 inch from the front end of the boom. The center of the hole is 0.145 inch (about ⁹/₆₄ inch) from the flat surface of the channel. See Figure 4 for details of the element-to-boom mounting. Study this and Figure 1 carefully before proceeding. A drill press is preferred, but a hand drill and care can get the holes true enough. Be sure to line up the drill before drilling. Hold the boom to the work surface with a C clamp or ask someone to hold it while you drill. Again, work safely and protect everyone's eyes with safety glasses when drilling. I suggest starting with a small drill and then finishing up with the #12 or Vu> inch drill. The holes for the U-bolt that secures the elements are drilled next. These holes are drilled with a #19 drill, 0.340 (11/32) inch apart, centered on the element. This dimension can vary slightly, depending on the U-bolt style. Repeat for the driven element and the reflector using the spacing dimensions on the drawing. Now set the boom aside.

Next, cut the elements to length. Once again, refer to Figure 1 for the element lengths. Use a fine tooth hacksaw to cut the elements. Then file the ends, even and smooth. Again, the element ends are possible points of injury. A slight chamfer to the end of the elements is desirable. It will also aid in sliding the element into the boom. I file one end flat and smooth, then cut the second end and file it. If you obtain the 3/16, inch rod for the elements in 6 foot lengths, you will need three lengths and will only be able to get one element out of each length. Measure twice and cut once.

After the elements are cut, you are ready to make the Plexiglas block. The block is made out of material sold for unbreakable window glass replacement and is available at most hardware stores. Only a small scrap is needed for the center insulator. Cutting the block with a scroll saw is easy, but a hacksaw and vise also work fine. The easiest way to do this is to cut a strip and then saw the block out of the strip. Note that the block mounts on top of the coax connector bracket. This offsets the block by the bracket material thickness. This must be accounted for when the bracket and block mounting holes are drilled. There is also a close fit between the Plexiglas block and the coax connector nut. The mounting hole in the Plexiglas block closest to the coax connector must be countersunk for a flat head screw to provide clearance for the BNC nut. If thicker material is used, there will probably be an interference problem between the block and the nut that secures the BNC coax connector to the bracket. Filing

the Plexiglas to provide clearance is acceptable.

The T-match bars are made out of 12 gauge solid copper wire. I used scraps of house wire (insulation removed), polished with steel wool, straightened by rolling between two wooden blocks, then cut to length. The lugs used on the T-bars are crimp lugs with the plastic insulation sleeve removed. The lug size is for #8 screws. This fits the bolt on the cable clamp and is a bit sloppy, but is an acceptable fit on the #6 screws on the Plexiglas block. The 12 gauge solid wire is soldered—not crimped—into the lugs. Trim the wires and solder per Figure 1 at assembly. The exact position of the shorting bars and wires is not critical to the match. You may ask: "Why not solder the T-bars to the driven element?" The driven element is aluminum and normal solders won't work. I've tried several special solders but have never been satisfied with the results. The driven element could be made of copper or brass. These materials will accept solder, but copper is generally not stiff enough and brass would add weight to the antenna.

The slots in the cable clamp castings must be enlarged to fit over the elements. File the slots wider to fit over the element. Mount the casting in a vise and widen the slot with a file until the element fits all the way into the bottom of the slot. The cable clamps I used are made out of ferrous alloy and will rust if exposed to moisture for an extended time. In widening the slot in the metal casting you will be exposing the iron to the air and in time this surface will rust if the antenna is left outside, unprotected. After assembly, a squirt with some spray paint on these surfaces may help prevent the rust.

One more part to make before starting assembly is the bracket for the coax connector. I chose a BNC for the antenna connector because it matches both my handheld radios and the FoxFinder used with this antenna. A different coax connector could be substituted and the bracket modified, as required. Cut the notches for the T-bar mounting bolts with a hacksaw; then drill the hole for the coax connector. Note the offset dimensions, so the connector nut will clear the Plexiglas block. The two mounting holes are drilled last. These are drilled to align with the holes in the Plexiglas block. Again, note that the coax connector bracket mounts against the flat surface of the boom. The plastic block mounts on top (see Figures 1 and 5). This arrangement mounts the connector bracket against the boom. The metal-to-metal contact is desirable from both a mechanical and an electrical consideration, but it could create a clearance problem between the BNC connector mounting nut and the plastic block. If thicker material is used for the plastic block it will have to be filed away to clear the nut. If the materials specified are used and the dimensions given are followed, it should fit together as shown.

Assembly

Now that all the pieces are made you are ready to start assembly of the antenna. First, slide an element through the boom and secure it with the U-bolt from a cable clamp. Discard the cast clamp. After all the elements are mounted, cut off the excess of the U-bolt extending past the nut with a hacksaw. This is to eliminate the bolts snagging items. Remove any burrs with a file. I installed the driven element last.

Mount the coax connector bracket and the Plexiglas block. I suggest using a 6-32 flat head screw for the mounting screw farthest from the driven element, so the screw head won't interfere with the coax connector mounting nut. Locate the bracket and block on the boom so that the center-to-center spacing between the driven element (center element) and the center of the holes in the Plexiglas block for the T-bar wires is $\frac{1}{16}$ inch. Face the bracket so, when mounted, the coax connector is facing the rear of the antenna. The T-bar wires are on

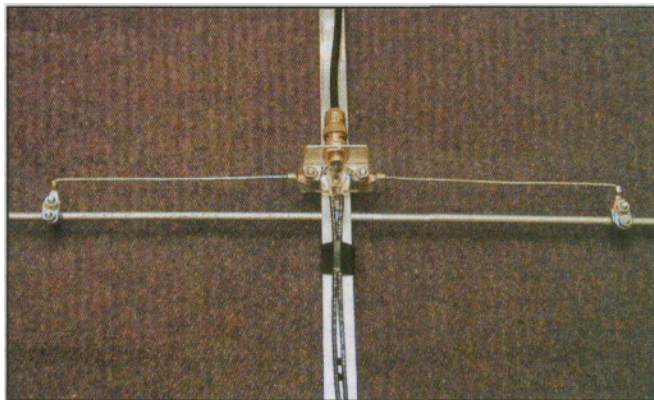


Figure 5—A close-up of the T match driven element feed system. Note the balun and the Plexiglas feed block; both are described in the text.

the reflector side of the driven element. See Figures 1 and 5. Mark the holes on the boom and drill with a #28 (or $\frac{1}{16}$ inch) drill. When the block and bracket are mounted on the boom, the holes in the Plexiglas block should be $\frac{1}{16}$ inch behind the center of the driven element. This establishes the spacing for the T-bar wires.

The Plexiglas block mounts on top of the connector bracket. Mount the block and bracket with a flat head screw. The screw closest to the driven element will be added as the balun is attached. Install the coax connector in the bracket. The nut should just clear the surface of the Plexiglas block, as discussed earlier. The T-match shorting bars (cable clamps with enlarged slots) are slid on the driven element and positioned as shown in Figure 5. The T-bars are then mounted on the Plexiglas block with 6-32 bolts and nuts. The bolt head is on the lower side and the nut is on the connector side. The other end of the T-bar is connected to the shorting bars (Figure 5). Reposition the shorting bars as required to match up with the lugs on the T-bar wires. Secure the four nuts on the T-match shorting bars.

Assemble the 4:1 coaxial balun transformer from a length of RG-174/U coax. RG-58/U may be used in place of the RG-174/U coax. Carefully remove the jacket from one end of the cable for about $\frac{1}{2}$ inch. Push the braid back on the center conductor to loosen it. Then, with a pointed object pull the center conductor through a hole in the braid at the point where the jacket starts. Now pull the braid tight again. Strip about $\frac{1}{4}$ inch of insulation from the center conductor. Measure 26 inches from the start of the cable jacket and cut off the cable. Mark the jacket 25 inches from the start of the jacket at the other end and carefully remove the jacket from the mark to the end. Carefully separate the center conductor and braid, as on the other end. Cut the length of the center conductor to match the length at the opposite end and remove about $\frac{1}{8}$ inch of the center conductor insulation, as before. Twist the two braids together and thread the braid through the wire hole in a #6 solder lug and solder. Be careful not to overheat and melt the insulation on the coax.

Leaving about $\frac{1}{16}$ inch of braid between the lug and the cable will reduce the chances of melting the cable. If you are using RG-58AJ coax, you may want to thin out the braid on the coax to allow the two braids to fit into the hole in the solder lug. Now solder two #6 solder lugs onto the ends of the center conductors of the coax. The shield solder lug mounts with the coax bracket and Plexiglas block mounting screw closest to the driven element. The two center conductor solder lugs mount to the two T-bar mounting bolts in the Plexiglas block. Use two additional #6 nuts to secure. The coax balun is routed along the boom between the driven element and the director and tape secures the coax to the boom. Now connect a short wire from the center pin

of the BNC coax connector to one of the center conductor lugs. Either one will do. See Figures 1 and 5.

The handle goes on last. This may be the best idea in the antenna! It evokes the most comment. One person asked where I got the handle. I replied that the short answer was from the wood box next to the wood stove in my workshop. It was about one fire short of being ashes when I rescued it. It was originally a handle on an axe or a splitting maul and is slightly oval in shape and fits my hand well. I cut it off at an angle that seemed to fit my hand and my wrist by holding it out at arm's length and observing the angle that the handle made with the horizontal. I drilled two holes in the boom for long #6 wood screws. I then drilled two matching pilot holes in the end of the handle and drove in the screws. A shorter screw was used in front, so it wouldn't come through the handle. Not having a suitable axe handle that you'd want to cut up, I would suggest a hardwood dowel. Choose one to fit your hand. I would guess that 1 1/4 inches is a good starting point, and it could be sanded or carved to fit. Stand back and admire your handiwork!

If you want, you can check the match; the SWR should be close to that indicated in Figure 4. I hope you enjoy using your antenna as much as I have mine. I have compared the antenna to other 3 and 4 element Yagis, and it works as well as any of them. It is also much lighter than any of them. It is this design goal that is so easy to appreciate at the end of a long foxhunt.

70 QST November 2005

I would like to thank Stan, KD1LE, for keeping after me to write about the antenna, his many comments on the text, and for building the beta test antenna. Also, thanks to Ralph, KD1SM, for his support and for taking the photos.

Notes

¹B. Reif, R. Swick, S. Pozerski, "The NVARC FoxFinder," *QST*, Apr 2001, pp 35-39. ²L. B. Cebik, "A Beginner's Guide to Modeling with NEC," *QST*, Nov 2000-Feb 2001, Parts 1-4, p 34, 40, 44, 31, respectively. ³As a result of the article (see Note 1), the author received many requests regarding radio direction finding (RDF) outside the 2 meter amateur band. "A source for 3/8" diameter rod in 6 foot lengths is Texas Towers, 1108 Summit Ave, Plano, TX 75074, tel 972-422-7306; www.texastowers.com.

All photos by Ralph Swick, KD1SM.

Rob Reif, W1XP, was first licensed in 1955 as KN9AQP. He holds an Amateur Extra class license and is an ARRL Life Member. After two years of active duty in the US Army, he joined GTE, Waltham, Massachusetts, in 1966, and for the next 30 years was involved in many areas of military communications, RF and antenna design. Bob earned a BSEE degree from Purdue University in 1993. Retiring in 1994, he now has more time to design and build equipment and antennas. Bob can be contacted at PO Box 363, Groton, MA 01450 or w1xp@arrrl.net.