Medium-Gain 2 Meter Yagi

Editor's note: Section and figure references in this article are from the 2013 edition of the ARRL Handbook. This material was originally contributed to the Handbook *by the late L.B. Cebik, W4RNL.*

This project was designed and built by L. B. Cebik, W4RNL (SK). Practical Yagis for 2 meters abound. What makes this one a bit different is the selection of materials. The elements, of course, are high-grade aluminum. However, the boom is PVC and there are only two #6 nut-bolt sets and two #8 sheet metal screws in the entire antenna. The remaining fasteners are all hitch-pin clips. The result is a very durable six-element Yagi that you can disassemble with fair ease for transport.

THE BASIC ANTENNA DESIGN

The 6-element Yagi presented here is a derivative of the *optimized wide-band antenna* (OWA) designs developed for HF use by NW3Z and WA3FET. **Fig 21.115** shows the general outline. The reflector and first director largely set the impedance. The next 2 directors contribute to setting the operating bandwidth. The final director (Dir. 4) sets the gain. This account is over-simplified, since every element plays a role in every facet of Yagi performance. However, the notes give some idea of which elements are most sensitive in adjusting the performance figures.

Designed using *NEC-4*, the antenna uses 6 elements on a 56-inch boom. **Table 21.21** gives the specific dimensions for the version described in these notes. The parasitic elements are all 3⁄16-inch aluminum rods. For ease of construction, the driver is ½-inch aluminum tubing. Do not alter the element diameters without referring to a source, such as RSGB's *The VHF/UHF DX Book*, edited by Ian White, G3SEK, (Chapter 7), for information on how to recalculate element lengths.

The driver is the simplest element to readjust. Table 21.21 shows an alternative driver using 3⁄16-inch diameter material. Of all the elements, the driver is perhaps the only one for which you may extrapolate reasonable lengths for other diameters from the two lengths and diameters shown. However, the parasitic elements may require more work than merely substituting one diameter and length for another. The lower portion of the table shows the design adjusted for ⅛-inch elements throughout. Not all element lengths change by the same amount using any single formula.

The OWA design provides about 10.2 dBi of free-space gain with better than 20 dB front-to-back (or front-to-rear) ratio across the entire 2 meter band. Azimuth (or E-plane) patterns show solid performance across the entire band. This applies not only to forward gain but rejection from the rear.

One significant feature of the OWA design is its direct 50-Ω feed point impedance that requires no matching network. Of course, a choke balun to suppress any currents on the feed line is desirable, and a simple ferrite bead balun (see the **Transmission Lines** and **Station Accessories** chapters) works well in this application. The SWR, shown in **Fig 21.116**, is very flat across the band and never reaches 1.3:1. The SWR and the pattern consistency together create a very useful utility antenna for 2 meters, whether installed vertically or horizontally. The only remaining question is how to effectively build the beam in the average home shop.

THE BEAM MATERIALS

The boom is Schedule 40, ½-inch nominal PVC. Insulated booms are good for test antennas, since they do not require recalculating the element lengths due to the effects of a metal boom.

White PVC stands up for a decade of ex-

Table 21.21
2 Meter OWA Yagi Dimensions

Element	*Element Length (in)*	*Spacing from Reflector (in)*	*Element Diameter (in)*
Version described here:			
Refl.	40.52	——	0.1875
Driver	39.70	10.13	0.5
Alt. Driver	*39.96*	*10.13*	*0.1875*
Dir. 1	37.36	14.32	0.1875
Dir. 2	36.32	25.93	0.1875
Dir. 3	36.32	37.28	0.1875
Dir. 4	34.96	54.22	0.1875
Version using 1/8-inch diameter elements throughout:			
Refl.	40.80	——	0.125
Driver	40.10	10.20	0.125
Dir. 1	37.63	14.27	0.125
Dir. 2	36.56	25.95	0.125
Dir. 3	36.56	37.39	0.125
Dir. 4	35.20	54.44	0.125

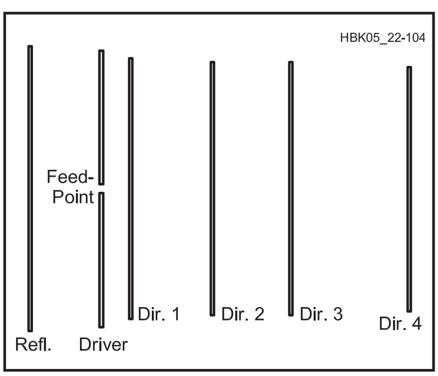


Fig 21.115 — The general outline of the 2 meter 6-element OWA Yagi. Dimensions are given in Table 21.21.

Table 21.22
Parts List for the 2 Meter OWA Yagi

Qty	*Item*
17'	0.1875" (3⁄16") 6061-T6 aluminum rod (Source: Texas Towers)
3.5'	0.5" (½") 6063-T832 aluminum tubing (Source: Texas Towers)
7'	Schedule 40, ½" PVC pipe (Source: local hardware store)
3	Schedule 40, ½" PVC Tee connectors (Source: local hardware store)
2	Schedule 40, ½" PVC L connectors (Source: local hardware store)
—	Miscellaneous male/female threaded pipe diameter transition fittings (Source: local hardware store)
1	Support mast
10	Stainless steel hitch-pin clips (hairpin cotter pins), 3⁄16" to ¼" shaft range, 0.04" "wire" diameter (McMasters-Carr part number 9239A024, or local hardware store)
2	Stainless steel #6 nut/bolt/lock-washer sets, bolt length 1" (Source: local hardware store)
2	Stainless steel #8 sheet metal screws (Source: local hardware store)
1	BNC connector (Source: local electronics outlet)
2"	1⁄16" thick aluminum L-stock, 1" per side (Source: local hardware store)
1	VHF bead-balun choke (Source: Wireman, Inc.)

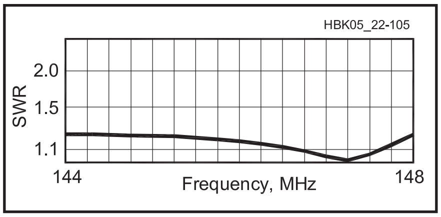


Fig 21.116 — SWR curve as modeled using *NEC-4* for the 2-m 6-element OWA Yagi.

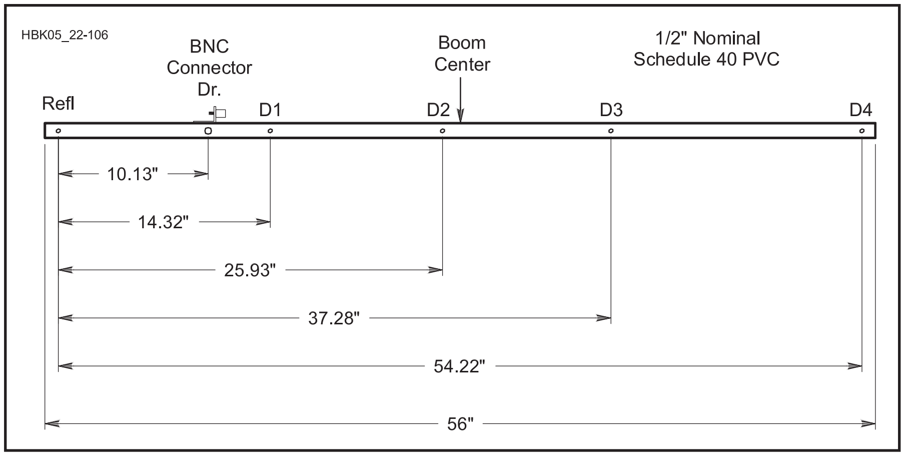


Fig 21.117 — Layout of elements along the PVC boom for the 2 meter 6-element OWA Yagi, showing placement of the BNC connector and the boom center.

posure in Tennessee, but apparently does not do as well in every part of the US. You may wish to use the gray electrical conduit version. If you use any other material for your boom, be sure that it is UV-protected. You'll find a parts list in **Table 21.22**. Sources for the parts are given in the table. However, you are encouraged to develop your own sources for antenna materials.

Fig 21.117 shows the element layout along the 56-inch boom. Centering the first element hole 1 inch from the rear end of the boom results in a succession of holes for the 3⁄16-inch pass-through parasitic elements. Only the driver requires special treatment. We shall use a 3⁄8-inch hole to carry a short length of fiberglass rod that will support the two sides of the driver element. Note that the antenna uses a BNC connector, mounted on a small plate that we shall meet along the way.

The boom is actually a more complex structure than initially meets the eye. You need a support for the elements, and a means of connecting the boom to the mast. If you break the boom in the middle to install a Tee connector for the mast junction, you come very close to the 2nd director. **Fig 21.118** shows how to avoid the predicament.

Before drilling the boom, assemble it from common Schedule 40 ½-inch fittings and insert the lengths of PVC pipe. Fig 21.118 shows the dimensions for the center section of the boom assembly. However, PVC dimensions are always *nominal*, that is, meeting certain minimum size standards. So you may have to adjust the lengths of the linking pieces slightly to come up with a straight and true boom assembly.

Use scrap lumber to help keep everything aligned while cementing the pieces together. A 1×4 and a 1×6 nailed together along the edges produce a very good platform with a right-angle. Start with the two upper Tees and the Ls below each one. Dry-fit scrap PVC into the openings except for the short link that joins the fitting. Cement these in place and align them using the dry-fit pieces as guides to keep everything parallel. Next, cement the two short (2¾-inch) links into the third Tee. Then, cement one link into its L, using the dry-fit tube in the upper Tee as an alignment guide.

Before proceeding further, carefully mea-

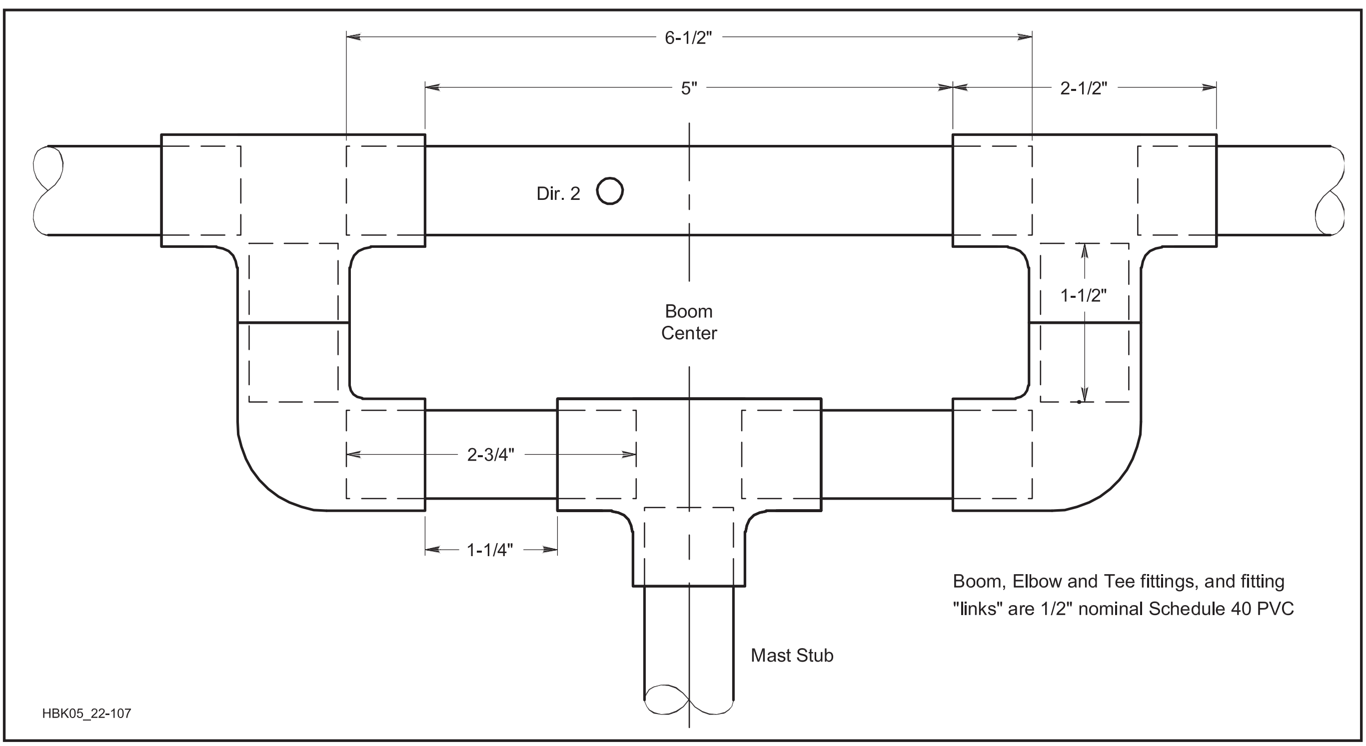
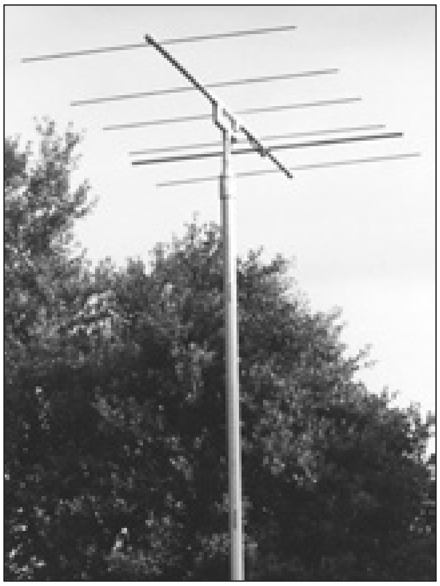


Fig 21.118 — Details of a parallel PVC pipe structure for the Yagi boom and mount.



(A)

(B)

Fig 21.119 — The completed Yagi is shown at A. A close-up view of the parallel PVC boom and mount, the sequence of threaded fittings, and the hitch-pin clips used to secure parasitic elements is shown at B.

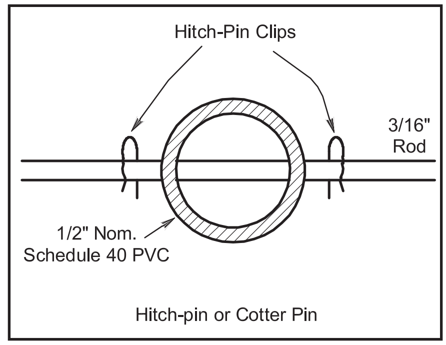


Fig 21.120 — The parasitic element mounting system, showing the placement of the hitch-pin clips and the shape of the clips.

sure the required length of PVC for the boom section between Tees. How well you measure here will determine whether the boom will be straight or whether it will bow up or down. Now, cement both the L and the Tee at the same time, pressing the cemented sections into the 2-board jig to assure alignment.

The final step in the process is to add the 23-inch boom end pieces to the open ends of the upper Tees. For the brief period in which the PVC cement is wet, it is possible to misalign the tubing. Dry-fit end caps on the boom ends and do the cement work using the 2-board jig. By pressing the assembly into the right angle of the boards, you can assure that you have a very true boom. When you've put the PVC cement back onto its shelf, your boom should be ready to drill.

Consider the boom-to-mast connection. The lower Tee in Fig 21.118 receives a short length of ½-inch nominal Schedule 40 PVC. This material has an outside diameter of about ⅞-inch, not a useful size for joining to a mast. However, PVC fittings have a handy series of threaded couplers that allow you to screw-fit a series of ever-larger sizes until you reach a more useful size. As **Fig 21.119B** shows, enough of these fittings will finish off with a 1¼-inch threaded female side and a 1¼-inch cement-coupling side. To this fitting, cement a length of 1¼-inch tubing that slides over a length of common TV mast. For a tight fit, wrap the TV mast with several layers of electrical tape in two places — one near the upper end of the PVC pipe section and the other close to where the PVC pipe ends. You may then use stainless steel through-bolts or set-screws to prevent the PVC assembly from turning.

BOOM AND ELEMENTS

Before installing the elements, you need to drill the holes in the boom. The two-board jig comes in handy once more. The key goals in the drilling process are to: A) precisely position the holes; B) create holes that are a fairly tight fit for the rod elements; and C) keep the elements aligned in a flat plane. For this purpose, a drill press is almost a necessity for all but those with the truest eyes.

Use the jig and a couple of clamps to hold the boom assembly in place. Because the assembly has two parallel sections, laying it flat will present the drill press with the correct angle for drilling through the PVC in one stroke. Drill the holes at pre-marked positions, remembering that the driver hole is ⅜ inch while all the others are 3⁄16 inch. Clean the holes, but do not enlarge them in the process.

By now you should have the rod and tube stock in hand. For antenna elements, don't rely on questionable materials that are designed for other applications. Rather, obtain 6063-T832 tubing and 6061-T6 rods from mail order sources, such as Texas Towers, McMasters-Carr, and others. These materials are often not available at local hardware depots.

Cut the parasitic elements to length and smooth their ends with a fine file or sandpaper. Find the center of each element and carefully mark a position about 1⁄16 in. outside where the element will emerge from each side of the boom. You'll drill small holes in these locations. You may wish to very lightly file a flatted area where the hole is to go to prevent the drill bit from slipping as you start the hole.

Drill 1⁄16-inch holes at each marked location all the way through the rod. De-burr the exit ends so that the rod will pass through the boom hole. These holes are the locations for hitch-pin clips. **Fig 21.120** shows the outline of a typical hitch-pin clip, which is also called a hairpin cotter pin in some catalogs and stores. Obtain stainless steel pins whose bodies just fit tightly over the rod when installed. Initially, install 1 pin per parasitic element. Slide the element through the correct boom hole and install the second pin. Although the upper part of the drawing shows a bit of room between the boom and pin, this space is for clarity. Install the pins as close to each side of the boom as you can.

Pins designed for a 3⁄16-inch rod are small enough that they add nothing significant to the element, and antenna tests showed that they did not move the performance curve of the antenna. Yet, they have held securely through a series of shock tests given to the prototype. These pins — in various sizes — offer the home builder a handy fastener that is applicable to many types of portable or field antennas. Although you may wish to use better fasteners when making permanent metal-to-metal connections, for joining sections of Field Day and similar antennas, the hitch-pin clips perform the mechanical function, while clean tubing sections themselves provide adequate electrical contact for a limited period of use.

THE DRIVER AND FEED LINE CONNECTOR

The final construction step is perhaps the one requiring the most attention to detail, as shown in **Fig 21.121**. The driver and feed point assembly consists of a 4- to 6-inch length of ⅜-inch fiberglass or other non-

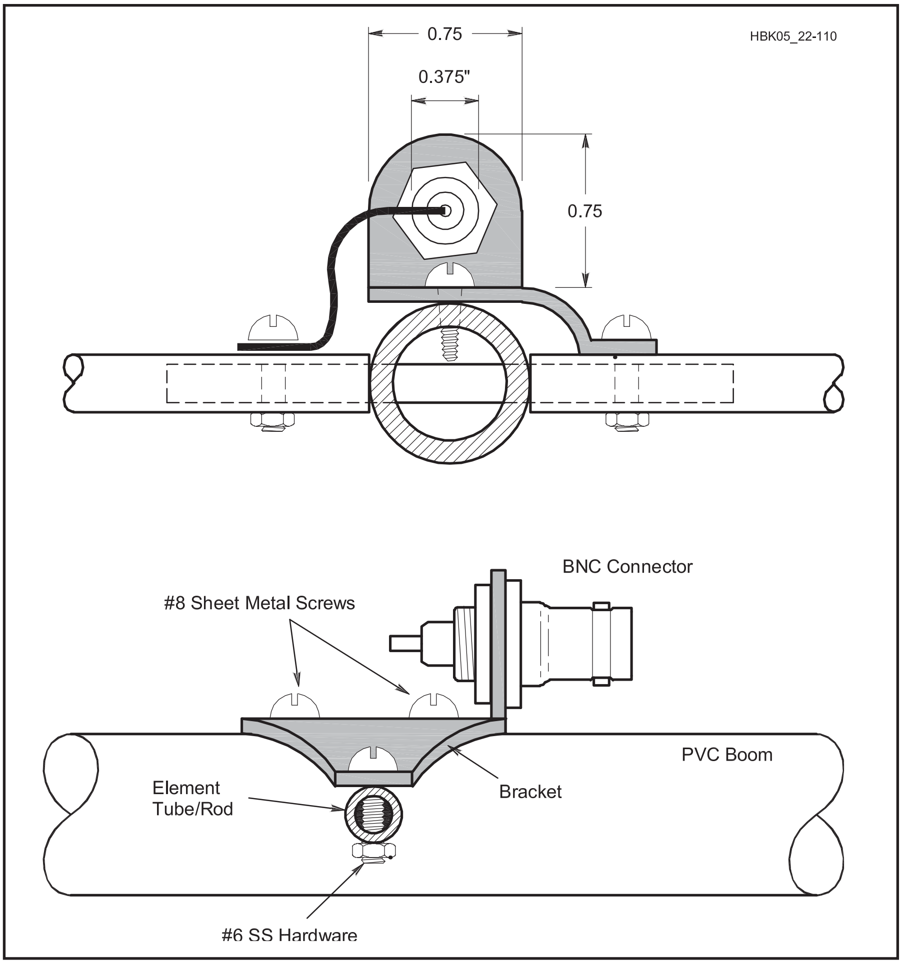


Fig 21.121 — Details of the feed point of the Yagi, showing the BNC connector, mounting plate, and connections to the ½-inch driver element halves placed over a central ⅜-inch fiberglass rod.

conductive rod, two sections of the driver element made from ½-inch aluminum tubing, a BNC connector, a home-made mounting plate, two sets of stainless steel #6 nuts, bolts, and lock-washers, and two stainless steel #8 sheet metal screws. Consult both the upper and lower portions of the figure, since some detail has been omitted from each one to show other detail more clearly.

First, trial fit the driver tubing and the fiberglass rod, marking where the rod exits the boom. Now pre-drill 9/64-inch holes through the tubing and the fiberglass rod. Do not use larger hardware, since the resulting hole will weaken the rod, possibly to the breaking point. If you use an alternative plastic material, observe the same caution and be certain that the rod remains strong after drilling. Do not use wooden dowels for this application, since they do not have sufficient strength. Position the holes about 1/4 to 3/8 inch from the tubing end where it presses against the boom. One hole will receive a solder lug and the other will connect to an extension of the BNC mounting plate.

Second, install the fiberglass rod through the boom. You can leave it loose, since the elements will press against the boom and hold it in place. Alternatively, you may glue it in place with a two-part epoxy. Slide the driver element tubes over the rod and test the holes for alignment by placing the #6 bolts in them.

Next, cut and shape the BNC mounting plate from 1/16-inch thick aluminum. The fitting is made from a scrap of L-stock 1 inch on a side. Before cutting the stock, drill the 3/8-inch hole needed for the BNC connector. Then cut the vertical portion. The horizontal portion requires a curved tab that reaches the bolt on one side of the boom. Use a bench vise to bend the tab in a curve and then flatten it for the bolt-hole. It takes several tries to get the shape and tab exact, so be patient. When the squared-edge piece finds its perfect shape, use a disk sander and round the vertical piece to follow the connector shape. Taper the tap edges to minimize excess material. The last step is to drill the mounting holes that receive the #8 sheet metal screws.

Mounting the assembly involves loosely attaching both the #6 and #8 hardware and alternately tightening up all pieces. Be certain that the side of the BNC connector that receives the coax points toward the mast. Next, mount the BNC connector. The shield side is already connected to one side of the driver. Mount the other side of the driver, placing a solder lug under the bolt head. Connect a short wire as directly as possible from the solder lug to the center pin of the BNC connector. After initial testing, you may coat all exposed connections with Plasti-Dip for weather protection.

TUNE-UP

Testing and tuning the antenna is a simple process if you build carefully. The only significant test that you can perform is to ensure that the SWR curve comes close to the one shown in Fig 21.116. If the SWR is high at 148 MHz but very low at 144 MHz, then you will need to shorten the driver ends by a small amount — no more than 1/8 inch per end at a time. Shaving the ends with a disk sander is most effective.

Using the antenna with vertical polarization will require good spacing from any support structure with metal vertical portions. One of the easiest ways to devise such a mounting is to create a PVC structure hat turns the entire boom by 90°. If you feel the need for added support, you can create can angular brace by placing 45° connectors in both the vertical and horizontal supports and running a length of PVC between them.

As an alternative, you can let the rear part of the boom be slightly long. To this end you can cement PVC fixtures — including the screw-thread series to enlarge the support pipe size. Create a smooth junction that you attach with a through-bolt instead of cement. By drilling one side of the connection with two sets of holes, 90° apart, you can change the antenna from horizontal polarization to vertical and back in short order.

The six-element OWA Yagi for 2 meters performs well. It serves as a good utility antenna with more gain and directivity than the usual three-element general-use Yagi. When vertically polarized, the added gain confirms the wisdom of using a longer boom and more elements. With a length under five feet, the antenna is still compact. The ability to disassemble the parts simplifies moving the antenna to various portable sites.