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Fishing for DX with a Five Band Portable Antenna

A telescopic fiberglass fishing pole supports five quarter-wave vertical monopoles for 10, 12, 15, 17, and 20 meters.

Barry L. Strickland, AB4QL

I enjoy getting out to the countryside with my portable rig and operating QRP on the five bands between 10 and 20 meters. While my Elecraft K1 was an easy choice, my antenna design evolved over time as the result of numerous experiments. The configuration I finally arrived at is five quarter-wave vertical monopoles in parallel and driven against 16 radials laid on the ground (see Figure 1). Having one tuned element per band means that I can switch between bands without the need for an antenna tuner. While a single portable vertical element is a trivial construction challenge, a portable antenna with five vertical elements proved to be a different case. First we'll look at the problems I had to overcome, as well as the mechanical aspects of this antenna, and then we'll look at the antenna's electrical characteristics.

Design and Construction Challenges

The design challenges of this antenna were grouped into three categories: support of the antenna elements, prevention of coupling between the tuned elements, and construction techniques to enable its rapid setup and dismantling. Figure 2 summarizes the various mechanical aspects of the antenna that will be discussed below.

Support

To support the antenna, I use a Shakespeare® Wonderpole fishing rod (model TSP16). The Wonderpole is a specialty pole designed for crappie and bream fishing. It is made of fiberglass and has five telescopic sections that extend from 45 inches in the collapsed state to 16 feet for this model. There is a wide variety of fishing poles available, ranging from stiff, short, and heavy surf rods, to lightweight and flexible fly rods. A crappie pole is a bit heavier than a fly rod and stiffer in the "spine," which makes it more suited to our use for antenna support. The Wonderpole is very light, which makes it ideal for portable operation, but it requires some additional support to keep it upright.

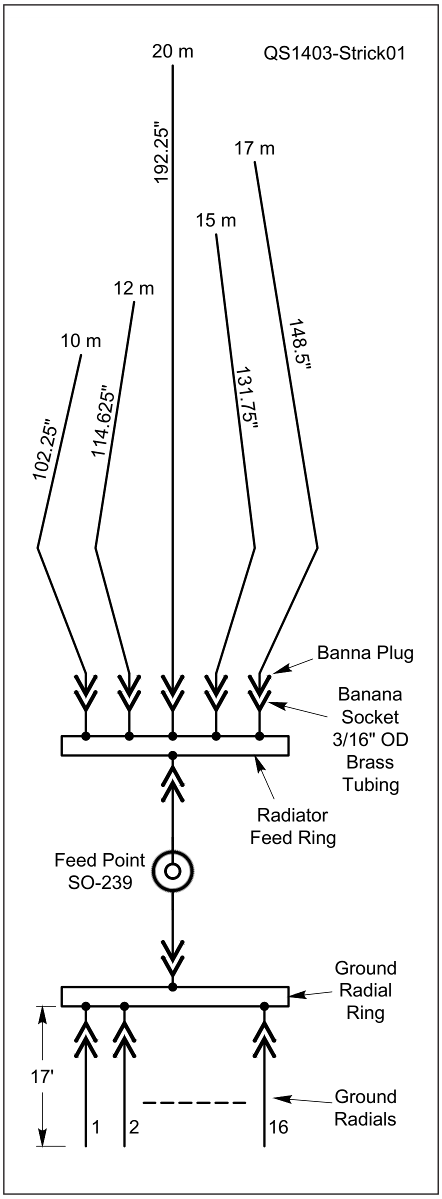

Figure 1 — Schematic of the five band portable vertical antenna. The element lengths are those arrived at after tuning. In general, begin tuning with elements that are several inches too long and shorten them gradually in repeated round robin fashion (due to inter-element coupling) to obtain the minimum SWR for the band portion of interest.

If the ground is not too rocky at the location where I want to set up, I drive either a wood or metal stake into the ground, taking care to keep it vertical. I then slip a length of ¾ inch PVC pipe over the stake and then slide the pole over the PVC pipe. The PVC pipe should slide about 10 inches into the pole and form a tight friction fit. If either the stake or PCV fits are too loose, they can be shimmed with tape for a snug fit.

As a backup for rocky ground or an extremely windy day, I made a three point guy ring (see Figure 3A). The material is not critical — you can use ⅛ inch acrylic or Lexan plastic or even a piece of scrap circuit board. I attached 10 foot string guy lines to anchor points on the ring using miniature carabiner clips similar to those used on key rings. The guy lines are tied to plastic bags filled with a few pounds of rocks collected at the operating site.

Coupling Prevention and Radiator Support

The problem I faced with the five resonant quarter-wave radiators was how to support them more or less vertically while minimizing the coupling among them. My solution was to run the longest element — the 20 meter radiator — up the pole, letting it spiral around the pole a half dozen times before reaching the top. The other four radiators are held away from the pole by 18 inch spreader arms spaced at 90° intervals and emanating from a PVC hub that slides onto the Wonderpole from the top and stops about 44 inches from the bottom.

I made the spreader arms from ¼ inch diameter fiberglass rods that are sold in home improvement stores for use as reflective driveway markers. The antenna wire is secured at the end of each arm with a wire guide made from ¼ inch inside diameter

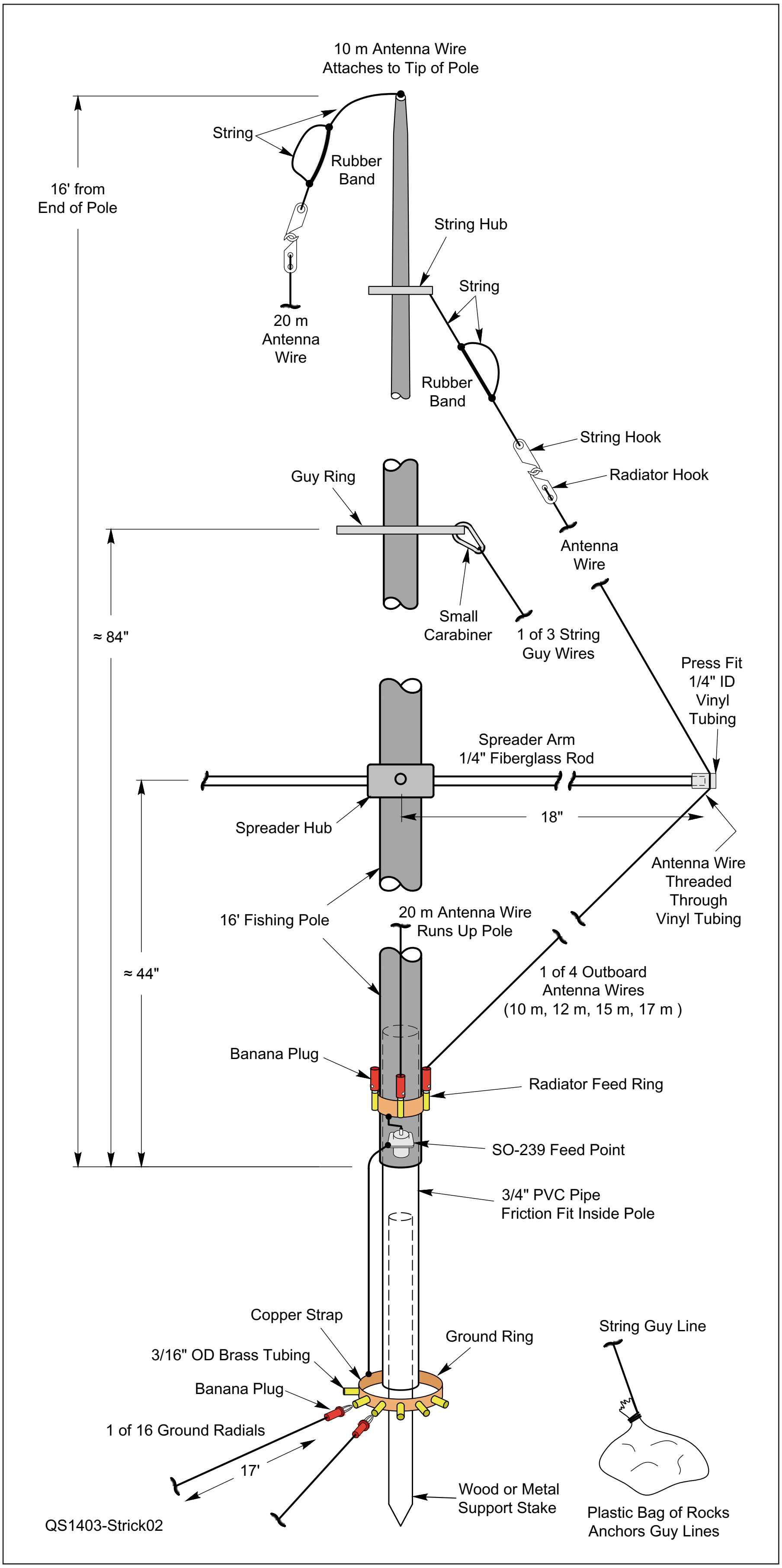

Figure 2 — Mechanical details of the five band vertical antenna.

vinyl tubing that pressed onto the end of the spreader arm. Holes big enough to let the antenna wire (#20 AWG stranded insulated) slide through easily are drilled in the ends of the guides. The wire guides remain on the antenna wire for storage after dismantling.

While I was at the home improvement store looking for spreader arm material, I found the ideal item for the spreader hub — a ¾ × 2 inch PVC bushing. The spreader arms are inserted into four ¼ inch diameter holes drilled just under the flat part of the bushing (see Figure 4). Note that there are two walls to drill through for each hole. There is an inner shoulder on the ¾ inch bushing that should be filed away with a round file so that the hub can slide down the pole until it is about 44 inches from the bottom end. If you want, some of the excess hub material can be cut off. However, if you choose to use a power tool like a band saw, be extremely careful and use a jig or clamp to hold the work; do not use your fingers.

The four shorter radiators are supported by strings attached to a string hub that slides onto the pole and is held in place by friction (see Figure 3B). There is a 17⁄64 inch diameter hole in the center of the hub that limits its travel down the pole. At the free end of each string, a string hook (see Figure 3C) engages a radiator hook (see Figure 3D) that is attached to the end of each radiator. The radiator hook is held to the radiator line by the friction of the line passing through two holes in the hook. A small amount of tension is applied to each radiator by a rubber band tied into its supporting string. Thin plastic is adequate for the hooks — I cut mine from old credit cards.

The 20 meter radiator, which runs up the pole, is secured by a similar string and hook (see Figure 3E) assembly that is tied to the small ring at the tip of the pole.

At the bottom of each radiator is a banana plug that plugs into one of five sockets soldered to a radiator feed ring that is clamped to the bottom of the pole (see Figure 5). The sockets are fashioned from ¾ inch lengths of 3⁄16 inch outside diameter brass tubing commonly sold at hobby shops. It can be easily cut by rolling it back and

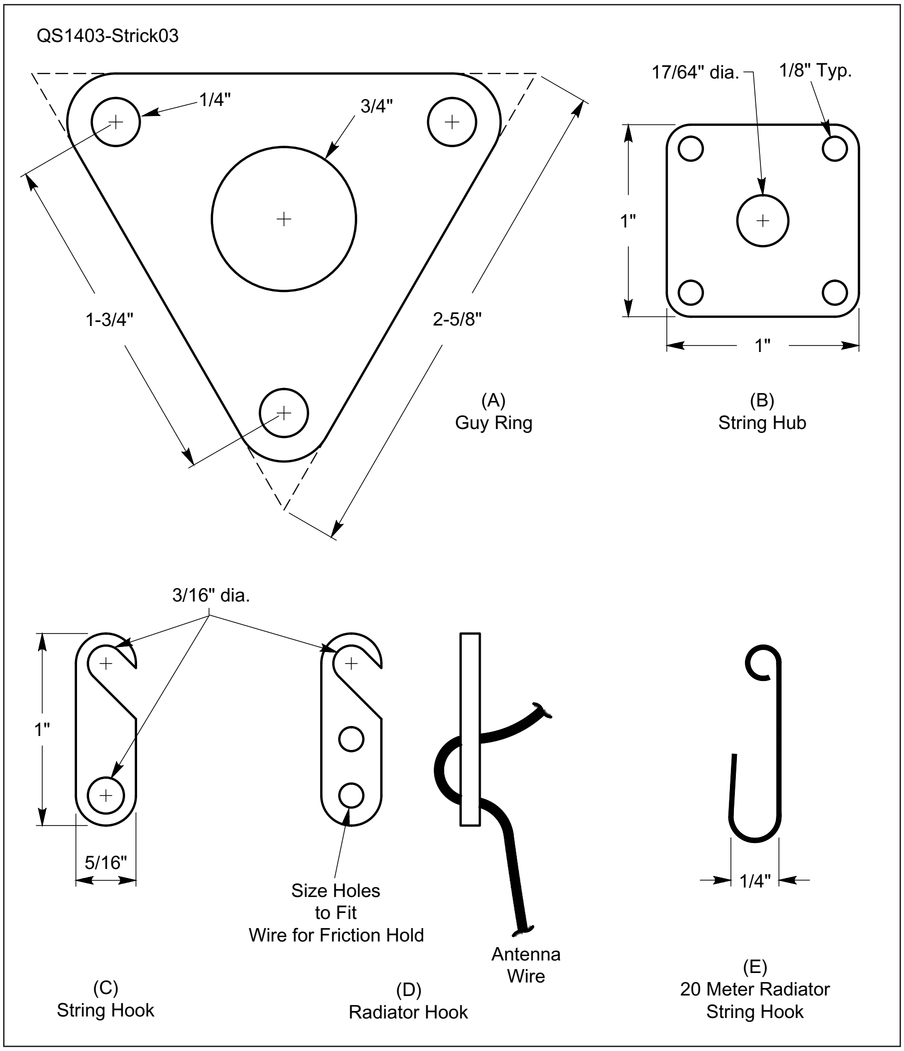

Figure 3 — Detailed drawings of pieces used for supporting the pole and radiators: at (A) optional guy ring for pole when setting up over rocky soil or during windy conditions; at (B) string hub to support the four outboard radiators; at (C) radiator hook that holds wire fed through pair of holes; at (D) string hook that engages radiator hook to support outboard radiator wire; at (E) 20 meter radiator string hook is fashioned from paper clip in order to pass through string hub center hole.

Figure 4 — Drilling hole through PVC bushing to form the hub for the spreader arms. Excess material on the spreader hub was later cut off to reduce its size.

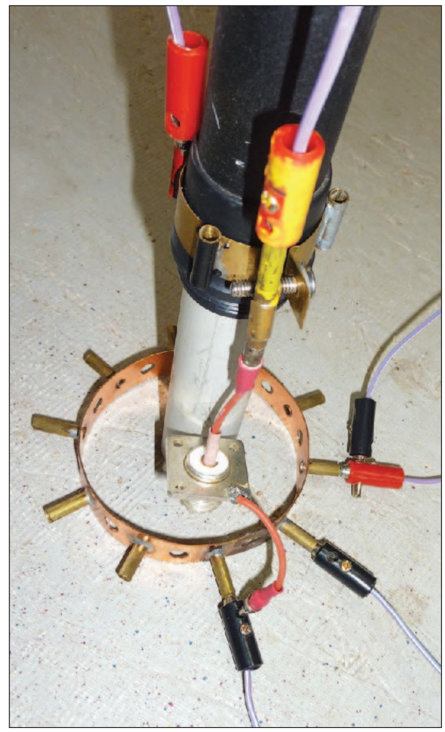

Figure 5 — Bottom of antenna showing radiator feed ring clamped to end of five section telescopic fiberglass fishing pole that slides onto ¾ inch PVC pipe sleeve that slips over supporting stake driven into ground. The center conductor of the SO-239 feed point plugs into the bottom of the feed ring and the shell is connected to the ground ring. Connections are doubled up by using banana plugs with an auxiliary socket. Ground and feeder ring banana sockets are shop-fashioned from 3⁄16 inch OD brass tubing.

forth under a sharp knife. The feed ring is fashioned from 0.016 × 0.5 inch brass sheet typically sold alongside the brass tubing used for the sockets. One of the sockets is made double length to accommodate the banana plug from the center conductor of the SO-239 feed point.

The shell of the SO-239 feed point is connected via a short wire to a banana plug that connects to a ground ring made from a 3¼ inch diameter loop of copper plumbing strap with 10 brass tubing banana sockets soldered into existing holes in the strap that were enlarged to 3⁄16 inches to fit the brass tubing (see Figure 5). Although there are only 10 sockets, the ground ring can accommodate the 16 ground radials and feed point ground by using the auxiliary socket on the side of the banana jacks, which permits connections to be doubled up.

Rapid Setup

The antenna sets up without the need for tools — all electrical connections are made with banana plugs and all mechanical connections use hooks or friction fit. The complete package is shown in Figure 6.

To deploy the antenna, I first extend the telescopic sections of the Wonderpole, which are held by friction. Adding a slight twist as they lock into place makes them extra secure. Next, I slide the radiator feed ring, spreader hub, guy ring (if needed), and string hub onto the pole. I then insert the four spreader arms into holes on the spreader hub. Now the radiator wires can be connected.

First I plug the 20 meter radiator, which is the longest, into one of the banana jacks on the radiator feed ring and route the wire up the pole with five or six evenly spaced turns around the pole. At the top, I hook the radiator hook, which is at the end of the wire, onto the string hook, whose attachment string is already tied to the eyelet at the tip of the pole.

Next, I install the four outboard radiators by first plugging each one into the radiator feed ring, then slipping its captive wire guide over the tip of a spreader arm and finally hooking its radiator end hook to the appropriate string hook, whose attachment string is tied to the string hub. Each string hook and its respective radiator hook is color coded to speed the setup (note that the upper face of the string hub is also marked so that the setup order is always the same). Before erecting the pole, I lay out the ground radials.

The 16 ground radials are deployed as follows: first, I pick a spot to erect the antenna and then drive the support stake into the ground. I then slide the ¾ inch PVC pipe sleeve over the support stake and slide the ground ring over the pipe sleeve. The ground radials are individually coiled for storage and secured with a hook-and-loop fastening strap. I remove the hook-and-loop fastening and throw the coil out from the antenna mount and then connect its banana plug to the ground ring. Afterwards, I pull all the radials taut and arrange them in an evenly spaced radial pattern.

Finally, I pick up the pole, slide it over the pipe sleeve and then connect the center conductor of the SO-239 to the radiator feed ring and its shell to the ground ring. All that's left is to connect my K1 to the SO-239 feed point and start calling CQ (see Figure 7).

Electrical Aspects

In this section we'll look at how to tune the antenna, problems with modeling due to radials laid on the ground, some performance anecdotes, and finally a note on safety.

Tuning

The design of the antenna was driven by the desire to minimize coupling among the five radiators. While the inter-element coupling was indeed reduced, it was not totally eliminated, which led me to adopt the following tuning method: First, find an area away from buildings and overhead power lines then set up the antenna and distribute the 16 ground radials in an even pattern. Next, attach an antenna analyzer to the feed point and begin tuning with the 10 meter radiator.

Figure 6 — Entire antenna kit laid out. At the top: sharpened support stake that is driven into the ground; ¾ inch PVC pipe sleeve that slides over support stake; 16 foot, five-section telescopic Shakespeare® Wonderpole. Under the Wonderpole from left to right: backup red guy ring with three guy line sets comprised of miniature carabiner, 10 feet of guy string, and plastic bag to hold rocks to anchor guy string; bag of rubber bands; color-coded radiator support strings; copper ground ring; SO-239 feed point; radiator feed ring; electrical tape to back up tired Wonderpole friction joints; five radiator lines with captive wire guides on the four outboard lines. At the center and bottom: four spreader arms that fit into the white PVC spreader hub; 16 sets of ground radials, each secured with a hook-and-loop strap.

Figure 7 — AB4QL operating CW QRP from one of his favorite remote locations in Mentone City Park on Lookout Mountain in northeastern Alabama. The antenna's low radiation angle and clear views of the horizon from sites like this have brought in numerous international QRP contacts.

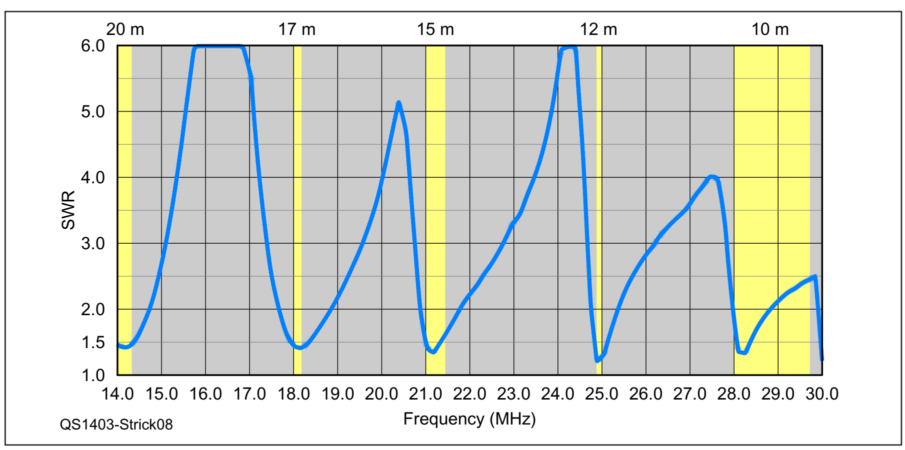

Figure 8 — SWR plot from 14 to 30 MHz from RigExpert AA-54 antenna analyzer. Yellow highlighted regions are for amateur bands: 20 meters, 17 meters, 15 meters, 12 meters, and 10 meters respectively.

Modeling a Ground Mounted Monopole Can be Tricky

The author mentions that he had difficulty modeling his ground mounted monopole to determine the radiation patterns. This is often a problem for *EZNEC* users, but it doesn't have to be, as we'll discuss. The first problem is that the usual amateur versions of *EZNEC* make use of the *NEC-2* calculating engine that does not allow modeling buried or on-ground radials. The professional version (*EZNEC PRO/4 V.5.0*) that does support the *NEC-4* calculating engine is quite expensive to start with ($650) and then it also requires a special license for the use of *NEC-4* ($300 for an academic or non-commercial license). This version supports the modeling of buried (but not on-ground or zero height) wires and has many other features, including the modeling of antennas with up to 20,000 segments as compared with 500 for *EZNEC V.5.0* ($89) or 1500 for *EZNEC+ V.5.0* ($139).[A]

There are Some Solutions to This Problem

There is a simple technique, but as is often the case in real life, the results are not terribly satisfactory. By just modeling the monopole itself, with the bottom at zero height, we have a kind of model. If we select the GROUND TYPE (on the main *EZNEC* menu) as PERFECT, we get the elevation pattern shown in blue in Figure A. If we select the REAL/HIGH ACCURACY GROUND TYPE, we get the pattern shown in red. If we select REAL/MININEC GROUND TYPE, we get the pattern shown in black.

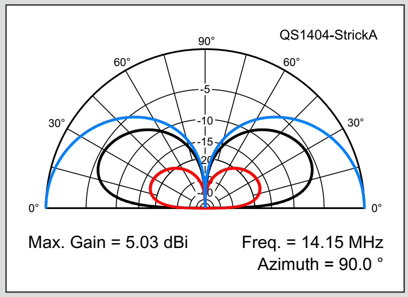

Figure A — *EZNEC V.5.0* elevation plots of the same 20 meter ¼ wave ground mounted monopole using the three different *EZNEC* ground models. The blue plot is with the *perfect* ground model, the red shows the results with the *real/high accuracy* model and the black shows the *real/MININEC* model results. For each of the real ground models, the conductivity was 0.005 S/M and the relative dielectric constant was 13. These are the default values representing "typical" ground, but can be changed if local information is available.

As is clearly indicated, we can get whatever results we want by selecting the appropriate model — but which represents reality?

What Do the Different Answers Really Mean?

My belief is that the *perfect* ground model is likely a reasonable representation of the performance of the monopole over seawater, an important case (see the contest results of Team Vertical as they operate from the water's edge of Pacific islands), but not one that most amateurs enjoy. We can get a calibration by running the author's 16 radial configuration, modeling the radials an inch or so underground using *EZNEC PRO*. The resulting elevation plot is shown in Figure B.

We note that the *EZNEC PRO* buried radial model elevation pattern looks strikingly similar to the pattern of the simple model over the *MININEC* ground model. This may be useful for an antenna with a substantial ground system such as this one, however, it does not indicate anything about the actual ground that is being used, a key element in the efficiency of antennas of this sort.

A Solution is at Hand

Anyone who has an interest in this topic would do well to read about the excellent experimental work con-

[A]The different versions of *EZNEC* antenna modeling software are available from developer Roy Lewallen, W7EL, at **www.eznec.com**. The models used in the sidebar are available on the *QST* in Depth web page at **www.arrl.org/qst-in-depth**.

Rather than making a single trim adjustment, only cut off about half the length needed to bring the radiator to resonance. Then move to the 12 meter radiator and perform the same partial trimming adjustment. Proceed in round robin fashion until all radiators show minimum SWR in the band portions that interest you. Remember, it's much easier to cut off a bit more wire than to add some back, so take your time. The SWR plot from 14 to 30 MHz made with my RigExpert AA-54 is shown in Figure 8.

Modeling

Modeling with *EZNEC* proved to be problematic due to the radials that were laid on the ground. *QST* Contributing Editor Joel Hallas, W1ZR, was prevailed upon to explore this problem using the professional version of *EZNEC* and his findings are shown in the sidebar, "Modeling a Ground Mounted Monopole Can be Tricky."

Performance

I'm aware that some folks may criticize a vertical antenna as noisy due to its omnidirectional pattern. This might be true in a suburban setting in proximity to plasma TVs, light dimmers, leaky power line transformers, and who knows what else in the way of electrical noise generators. However, away from cities, this is not the case, and in fact, the vertical's omnidirectional pattern gives me the freedom to operate in any direction without the need to worry about the fortuitous placement of trees that would enable me to string a horizontal antenna.

This antenna has been a good performer. Running CW QRP at 5 W or less from remote locations such as Mentone City Park on Lookout Mountain in northeastern Alabama, I have made contacts on all five bands with Europe, Asia, South and Central America, Hawaii, Alaska, and all over the continental United States. However, I'm still looking forward to the day when I receive a "G'day, mate!" from a VK down under. I'm sure it will come in time.

Safety

My principal safety concern, operating at 5 W or less, is not to set up too close to a mountain precipice. However, others, perhaps using this antenna in the backyard, should be aware that on 10 meters if the

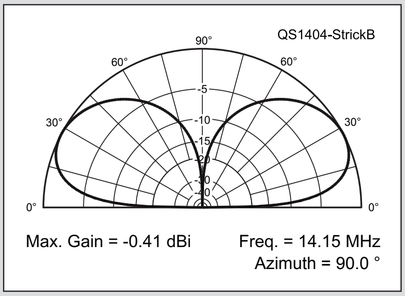

Figure B — *EZNEC PRO/4 V.5.0* elevation plot of the author's 20 meter ¼ wave ground mounted monopole with 16 radials (buried 0.1 feet deep). This analysis used the high accuracy ground model, the only one usable for buried wires.

ducted by Rudy Severns, N6LF.[B] One of Rudy's conclusions was that radials on the ground will act very much like radials under the ground. I took the buried radial model and changed all heights so that the radials were 0.05 feet above ground, eliminating the buried radial issue. Just as Rudy predicted, the results were virtually identical to those of the buried model using *NEC-4*. This was the case for each of the real ground models, and with both *NEC-2* and *NEC-4* calculating engines. In my opinion, this is probably the best *NEC-2* approximation of a buried ground system, since it takes into account the actual ground radial configuration.

[B]R. Severns, N6LF, "An Experimental Look at Ground Systems for HF Verticals," *QST*, Mar 2010, pp 30 – 33.

A simpler technique that I frequently use makes use of another result of Rudy's work. Rudy noted that four resonant elevated radials provided performance similar to up to 60 buried radials. Instead of modeling all 60 radials (a busy trig project to get all the coordinates), I just model an antenna with four ¼ wave elevated radials a foot or two off the ground. For this case, with the radials 1 foot above ground, the gain is exactly the same as that of the more complicated models. The additional height of the antenna does reduce the main elevation lobe by 1°, which is not a major discrepancy, in my opinion.

Some Observations on the Design

In the process of performing these modeling experiments, I did note a few results worth mentioning, because they may affect the way the antenna works in the field. First, while radials right above ground tend to act like buried radials and are not terribly length sensitive, elevated radials do need to be resonant to work properly. Depending on the nature of the ground and how tightly the radials are secured, this antenna may work better if the radials are cut so that there are two opposite each other cut for each band. I would hedge my bets and leave four at 17 feet and then have the others cut to resonance as noted — especially if the radials are loosely laid on rocky ground. This change could be made in the field if the tuning is not what is expected.

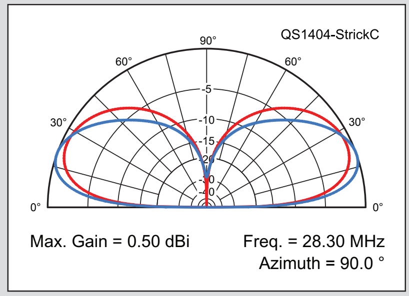

Figure C — *EZNEC V.5.0* elevation plots of the ¼ wave ground mounted monopole on 10 meters. The blue plot shows the pattern with the 20 meter wire in place and not connected. In that configuration, the SWR is about 5:1. The red plot shows the effect of removing, or detuning, the 20 meter wire returning the SWR to 1.5:1 with a normal ¼ wave pattern.

One more item I noted was interaction between the 10 meter monopole and the 20 meter wire, the only pair of harmonically related bands. If the 10 meter wire is driven, the ungrounded 20 meter wire — a ½ wave on 10 — actually improves the 10 meter pattern by increasing the gain and lowering the peak of the elevation lobe (see Figure C). The problem is that the Z goes to around 220 Ω, for about a 5:1 SWR. With a short length of coax and an antenna tuner, it will be a plus. To go back to the regular ¼ wave monopole pattern and SWR, fold some of the 20 meter wire back while using the 10 meter wire. — *Joel R. Hallas, W1ZR,* QST *Contributing Editor*

peak envelope power (PEP) to the antenna exceeds 50 W, the FCC requires that an RF environmental evaluation be performed. More about antenna evaluation can be found on the ARRL website and in Ed Hare's, W1RFI, book on RF exposure.[1, 2]

I look forward to discussions with other amateurs who are building this antenna.

[1]**www.arrl.org/fcc-rf-exposure-regulations-the-station-evaluation**

[2]Ed Hare, W1RFI, *RF Exposure and You*, (Newington 1998, 2004). Available from your ARRL dealer, or from the ARRL Store, ARRL order no. 6621. Telephone toll-free in the US 888-277-5289, or 860-594-0355, fax 860-594-0303; **www.arrl.org/shop/**; **pubsales@arrl.org**.

Photos by the author.

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