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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.*

Rotatable Dipole Inverted-U Antenna

This simple rotatable dipole was designed and built by L. B. Cebik, W4RNL (SK), for use during the ARRL Field Day. For this and other portable operations we look for three antenna characteristics: simplicity, small size, and light weight. Complex assemblies increase the number of things that can go wrong. Large antennas are difficult to transport and sometimes do not fit the space available. Heavy antennas require heavy support structures, so the overall weight seems to increase exponentially with every added pound of antenna.

Today, a number of light-weight collapsible masts are available. When properly guyed, some will support antennas in the 5-10 pound range. Most are suitable for 10 meter tubular dipoles and allow the user to hand-rotate the antenna. Extend the range of the antenna to cover 20-10 meters, and you put these 20-30-foot masts to even better use. The inverted-U meets this need.

THE BASIC IDEA OF THE INVERTED-U

A dipole's highest current occurs within the first half of the distance from the feed point to the outer tips. Therefore, very little performance is lost if the outer end sections are bent. The W4RNL inverted-U starts with a 10 meter tubular dipole. You add extensions for 12, 15, 17 or 20 meters to cover those bands.

You only need enough space to erect a 10 meter rotatable dipole. The extensions hang down. **Fig 21.31** shows the relative proportions of the antenna on all bands from 10 to 20 meters. The 20 meter extensions are the length of half the 10 meter dipole. Therefore, safety dictates an antenna height of at least 20 feet to keep the tips above 10 feet high. At any power level, the ends of a dipole have high RF voltages, and we must keep them out of contact with human body parts.

Not much signal strength is lost by drooping up to half the overall element length straight down. What is lost in bidirectional gain shows up in decreased side-nulls. **Fig 21.32** shows the free-space E-plane (azimuth) patterns of the inverted-U with a 10 meter horizontal section. There is an undetectable decrease in gain between the 10 meter and 15 meter versions. The 20 meter version shows a little over a half-dB gain decrease and a signal increase off the antenna ends.

The real limitation of an inverted-U is a function of the height of the antenna above ground. With the feed point at 20 ft above ground, we obtain the elevation patterns shown in **Fig 21.33**. The 10 meter pattern is typical for a dipole that is about ⅝ λ above ground. On 15, the antenna is only 0.45 λ high, with a resulting increase in the overall elevation angle of the signal and a reduction in gain. At 20 meters, the angle grows still higher, and the signal strength diminishes as the antenna height drops to under 0.3 λ. Nevertheless, the signal is certainly usable. A full-size dipole at 20 meters would show only a little more gain, and the elevation angle would be similar to that of the invert U, despite the difference in antenna shape. If we raise the inverted-U to 40 feet, the 20 meter performance would be very similar to that shown by the 10 meter elevation plot in Fig 21.29.

The feed point impedance of the inverted-U remains well within acceptable limits for virtually all equipment, even at 20 feet above ground. Also, the SWR curves are very broad, reducing the criticalness of finding exact dimensions, even for special field conditions.

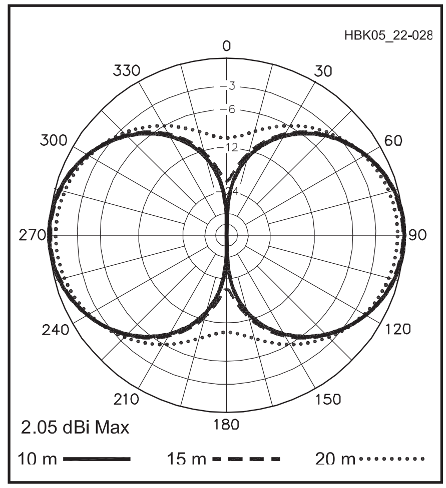

Fig 21.32 — Free-space E-plane (azimuth) patterns of the inverted-U for 10, 15, and 20 meters, showing the pattern changes with increasingly longer vertical end sections.

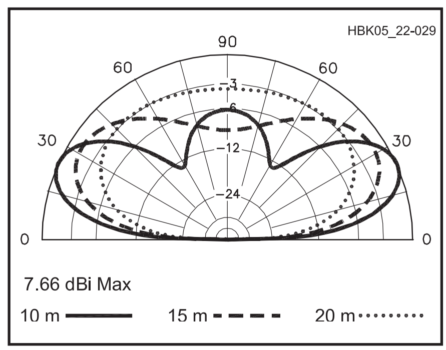

Fig 21.33 — Elevation patterns of the inverted-U for 10, 15, and 20 meters, with the antenna feed point 20 ft above average ground. Much of the decreased gain and higher elevation angle of the pattern at the lowest frequencies is due to its ever-lower height as a fraction of a wavelength.

BUILDING AN INVERTED-U

Approach the construction of an inverted-U in 3 steps: 1) the tubing arrangement, 2) the center hub and feed point assembly, and 3) the drooping extensions. A parts list appears in **Table 21.2**.

The Aluminum Tubing Dipole for 10 Meters

The aluminum tubing dipole consists of three longer sections of tubing and a short section mounted permanently to the feed point plate, as shown in **Fig 21.34**. Let's consider each half of the element separately. Counting from the center of the plate — the feed point — the element extends five inches

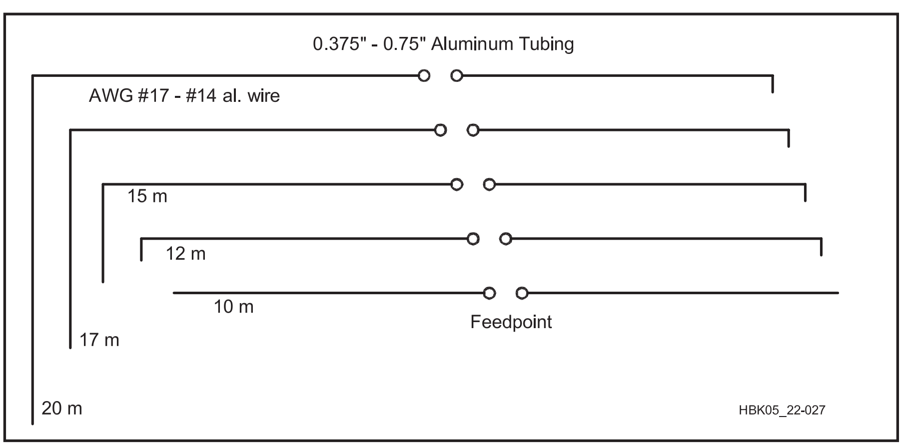

Fig 21.31 — The general outline of the inverted-U field dipole for 20 through 10 meters. Note that the vertical end extension wires apply to both ends of the main 10 meter dipole, which is constant for all bands.

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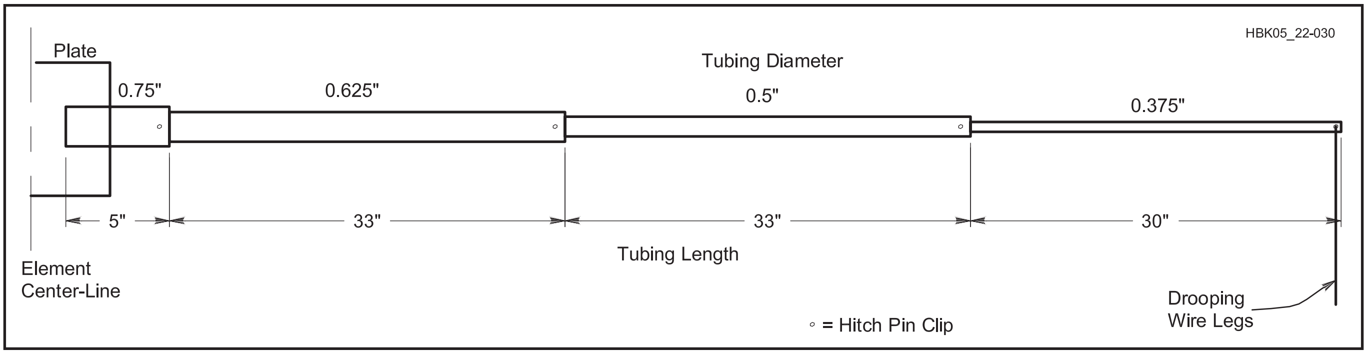

Fig 21.34 — The general tubing layout for the inverted-U for each half element. The opposite side of the dipole is a mirror image of the one shown.

Table 21.2
Parts List for the Inverted-U

Amount	*Item*	*Comments*
6'	0.375" OD aluminum tubing	2 - 3' pieces
6'	0.5" OD aluminum tubing	2 - 3' pieces
6'	0.625" OD aluminum tubing	2 - 3' pieces
10"	0.75" OD aluminum tubing	2 - 5" pieces
4"	0.5" nominal (⅝" OD) CPVC	
50'	Aluminum wire AWG #17	
8	Hitch pin clips	Sized to fit tubing junctions.
1	4" by 4" by ¼" Lexan plate	Other materials suitable.
2	SS U-bolts	Sized to fit support mast
2	Sets SS #8/10 1.5" bolt, nut, washers	SS = stainless steel
2	Sets SS #8 1" bolt, nut, washers	
2	Sets SS #8 0.5" bolt, nut, washers	
1	Coax connector bracket, 1⁄16" aluminum	See text for dimensions and shape
1	Female coax connector	
2	Solder lugs, #8 holes	
2	Short pieces copper wire	From coax connector to solder lugs

Note: 6063-T832 aluminum tubing is preferred and can be obtained from such outlets as Texas Towers (**www.texastowers.com**). Lexan (polycarbonate) is available from such sources as McMasters-Carr (**www.mcmasters.com**), as are the hitch pin clips (if not locally available). Other items should be available from local home centers and radio parts stores.

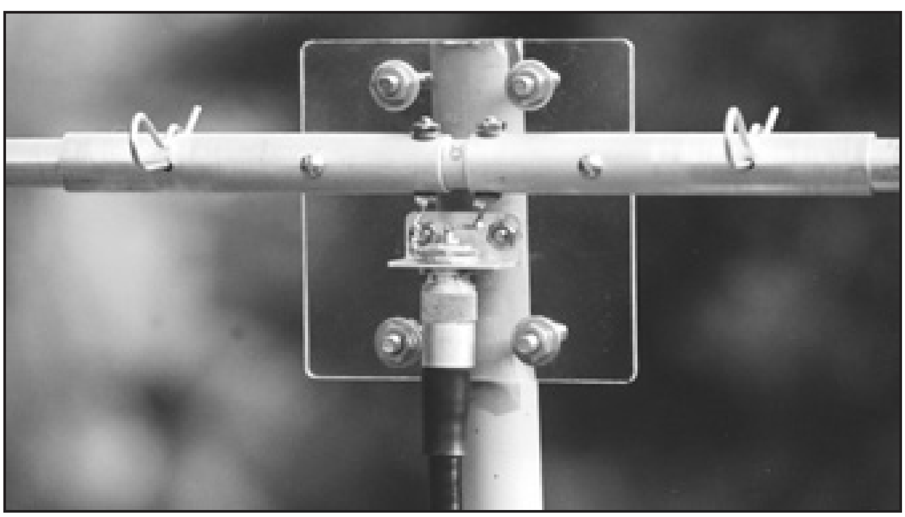

Fig 21.35 — A close-up of the element mounting plate assembly, including the hitch pin clips used to secure the next section of tubing.

using ¾-inch aluminum tubing. Then we have two 33-inch exposed tubing sections, with an additional three inches of tubing overlap per section. These sections are ⅝- and ½-inch diameter, respectively. The outer section is 30 inches long exposed (with at least a three-inch overlap) and consists of ⅜-inch diameter tubing.

Since the ⅝- and ½-inch sections are 36 inches long, you can make the outer ⅜-inch section the same overall length and use more overlap, or you can cut the tubing to 33 inches and use the 3-inch overlap. Three inches of overlap is sufficient to ensure a strong junction, and it minimizes excess weight. However, when not in use, the three outer tubing sections will nest inside each other for storage, and a 36-inch length for the outer section is a bit more convenient to un-nest for assembly. Keep the end hitch pin on the ⅜ inch tubing as an easy way of pulling it into final position. You may use the readily available 6063-T832 aluminum tubing that nests well and has a long history of antenna service.

The only construction operation that you need to perform on the tubing is to drill a hole at about the center of each junction to pass a hitch pin clip. Obtain hitch pin clips (also called hairpin cotter pin clips in some literature) that fit snugly over the tubing. One size will generally handle about two or three tubing sizes. This antenna uses 3⁄32 (pin diameter) by 2⅝-inch long clips for the ¾- to ⅝-inch and the ⅝- to ½-inch junctions, with 3⁄32 by 1⅝-inch pins for the ½- to ⅜-inch junction and for the final hitch pin clip at the outer end of the antenna. Drill the ⅛-inch diameter holes for the clips with the adjacent tubes in position relative to each other. Tape the junction temporarily for the drilling. Carefully de-burr the holes so that the tubing slides easily when nested.

The hitch pin clip junctions, shown in **Fig 21.35**, hold the element sections in position. Actual electrical contact between sections is made by the overlapping portions of the tube. Due to the effects of weather, junctions of this type are not suitable for a

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permanent installation, but are completely satisfactory for short-term use. Good electrical contact requires clean, dry aluminum surfaces, so do not use any type of lubricant to assist the nesting and un-nesting of the tubes. Instead, clean both the inner and outer surfaces of the tubes before and after each use.

Hitch pin clips are fairly large and harder to lose in the grass of a field site than most nuts and bolts. To avoid losing the clips, attach a short colorful ribbon to the loop end of each clip.

Each half element is 101 inches long, for a total 10 meter dipole element length of 202 inches (16 ft 10 inches). Length is not critical within about one inch, so you may pre-assemble the dipole using the listed dimensions. However, if you wish a more precisely tuned element, tape the outer section in position and test the dipole on your mast at the height that you will use. Adjust the length of the outer tubing segments equally at both ends for the best SWR curve on the lower 1 MHz of the 10 meter band. Even though the impedance will be above 50 Ω throughout the band, you should easily obtain an SWR curve under 2:1 that covers the entire band segment.

The Center Hub: Mounting and Feed Point Assembly

Construct the plate for mounting the element and the mast from a 4 × 4 × ¼-inch-thick scrap of polycarbonate (trade name Lexan), as shown in **Fig 21.36**. You may use other materials so long as they will handle the element weight and stand up to field conditions.

At the top and bottom of the plate are holes for the U-bolts that fit around the mast. Since masts may vary in diameter at the top, size your U-bolts and their holes to suit the mast.

The element center, consisting of two five-inch lengths of ¾-inch aluminum tubing, is just above the centerline of the plate (to allow room for the coax fitting below). ½-inch nominal CPVC has an outside diameter of about ⅝ inch and makes a snug fit inside the ¾-inch tubing. The CPVC aligns the two aluminum tubes in a straight line and allows for a small (about ½ inch) gap between them. When centered between the two tubes, the CPVC is the same width as the plate. A pair of 1.5-inch #8 or #10 stainless steel bolts — with washers and a nut — secures the element to the plate.

Note in the sketch that you may insert the ⅝-inch tube as far into the ¾-inch tube as it will go and be assured of a three-inch overlap. Drill all hitch pin clip holes perpendicular to the plate. Although this alignment is not critical to the junctions of the tubes, it is important to the outer ends of the tubes when you use the antenna below 10 meters.

Mount a single-hole female UHF connector on a bracket made from a scrap of 1⁄16-inch-thick L-stock that is 1 inch on a side. Drill the UHF mounting hole first, before cutting the L-stock to length and trimming part of the mounting side. Then drill two holes for ½-inch long #8 stainless steel bolts about 1 inch apart, for a total length of L-stock of about 1.5 inches. The reason for the wide strip is to place the bolt heads for the bracket outside the area where the mast will meet the plate on the back side. Note in Fig 21.36 that the bracket nuts are on the bracket-side of the main plate, while the heads face the mast. The bracket-to-plate mounting edge of the bracket needs to be only about ¾ inch wide, so you may trim that side of the L-stock accordingly.

With the element center sections and the bracket in place, drill two holes for one-inch long #8 stainless steel bolts at right angles to the mounting bolts and as close as feasible to the edges of the tubing at the gap. These bolts have solder lugs attached for short leads to the coax fitting. Solder lugs do not come in stainless steel, so you should check these junctions before and after each use for any corrosion that may require replacement.

With all hardware in place, the hub unit is about 4 × 10 × 1 inch (plus U-bolts). It will remain a single unit from this point onward, so that your only field assembly requirements will be to extend tubing sections and install hitch pin clips. You are now ready to perform the initial 10 meter resonance tests on your field mast.

The Drooping Extensions for 12-20 Meters

The drooping end sections consist of aluminum wire. Copper is usable, but aluminum is lighter and quite satisfactory for this application. **Table 21.3** lists the approximate lengths of each extension *below* the element. Add three to five inches of wire — less for 12 meters, more for 20 meters — to each length listed.

Common #17 AWG aluminum electric fencing wire works well. Fence wire is stiffer than most wires of similar diameter, and it is cheap. Stiffness is the more important property, since you do not want the lower ends of the wire to wave excessively in the breeze,

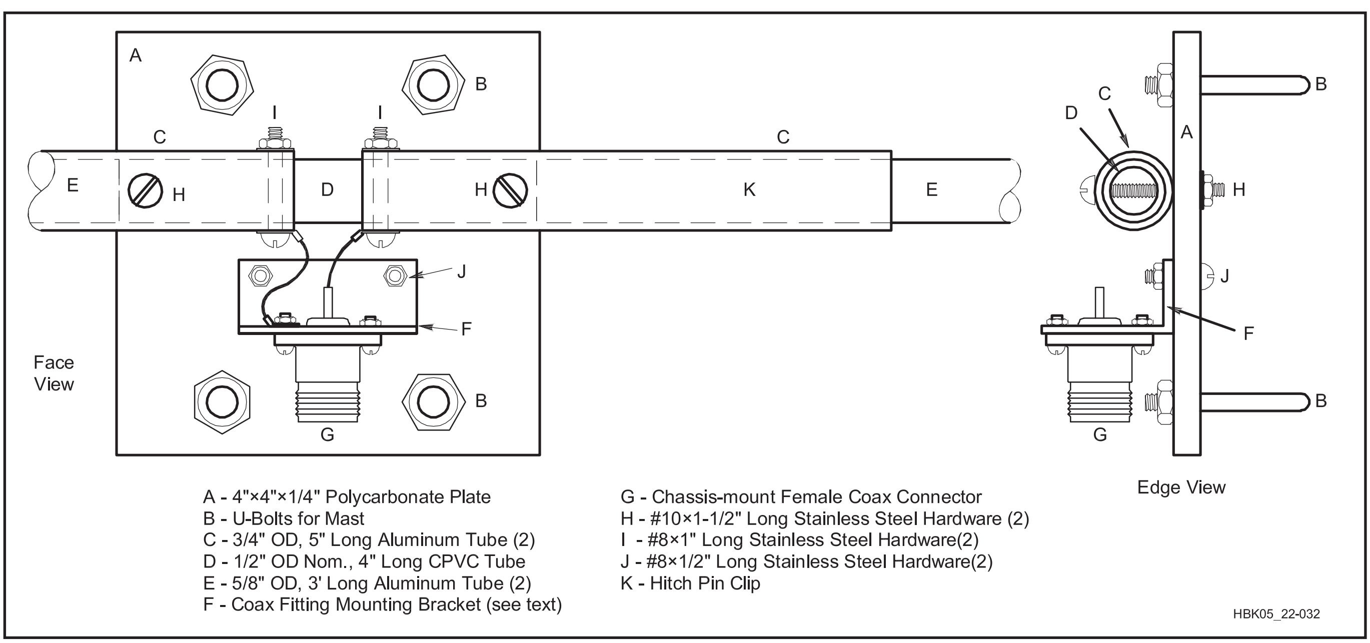

Fig 21.36 — The element and feed point mounting plate, with details of the construction used in the prototype.

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Table 21.3
Inverted-U Drooping Wire Lengths

Band (meters)	*Wire Length (inches)*
10	n/a
12	15.9
15	37.4
17	62.0
20	108.0

Note: The wire length for the drooping ends is measured from the end of the tubular dipole to the tip for #17 AWG wire. Little change in length occurs as a function of the change in wire size. However, a few inches of additional wire length is required for attachment to the element.

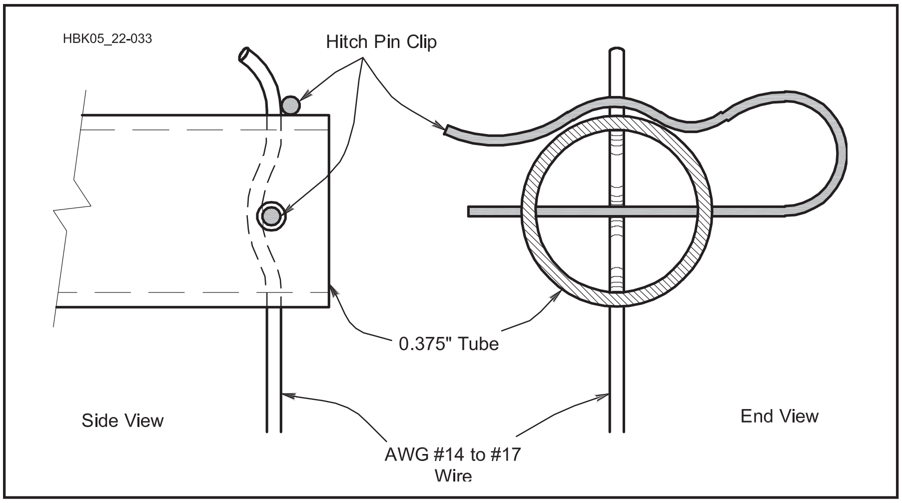

Fig 21.37 — A simple method of clamping the end wires to the ⅜-inch tube end using a hitch pin clip.

potentially changing the feed point properties of the antenna while it is in use.

When stored, the lengths of wire extensions for 12 and 15 meters can be laid out without any bends. However, the longer extensions for 17 and 20 meters will require some coiling or folding to fit the same space as the tubing when nested. Fold or coil the wire around any kind of small spindle that has at least a two-inch diameter (larger is better). This measure prevents the wire from crimping and eventually breaking. Murphy dictates that a wire will break in the middle of an operating session. So carry some spare wire for replacement ends. All together, the ends require about 50 ft of wire.

Fig 21.37 shows the simple mounting scheme for the end wires. Push the straight wires through a pair of holes aligned vertically to the earth and bend the top portion slightly. To clamp the wire, insert a hitch pin clip though holes parallel to the ground, pushing the wire slightly to one side to reach the far hole in the tube. The double bend holds the wire securely (for a short-term field operation), but allows the wire to be pulled out when the session is over or to change bands.

Add a few inches to the lengths given in Table 21.3 as an initial guide for each band. Test the lengths and prune the wires until you obtain a smooth SWR curve below 2:1 at the ends of each band. Since an inverted-U antenna is full length, the SWR curves will be rather broad and suffer none of the narrow bandwidths associated with inductively loaded elements. **Fig 21.38** shows typical SWR curves for each band to guide your expectations.

You should not require much, if any, adjustment once you have found satisfactory lengths for each band. So you can mark the wire when you finish your initial test adjustments. However, leave enough excess so that you can adjust the lengths in the field.

Do not be too finicky about your SWR curves. An initial test and possibly one adjustment should be all that you need to arrive at an SWR value that is satisfactory for your equipment. Spending half of your operating time adjusting the elements for as near to a 1:1 SWR curve as possible will rob you of valuable contacts without changing your signal strength is any manner that is detectable.

Changing bands is a simple matter. Remove the ends for the band you are using and install the ends for the new band. An SWR check and possibly one more adjustment of the end lengths will put you back on the air.

FINAL NOTES

The inverted-U dipole with interchangeable end pieces provides a compact field antenna. All of the parts fit in a 3-ft long bag. A draw-string bag works very well. **Fig 21.39** shows the parts in their travel form. When assembled and mounted at least 20 feet up (higher is even better), the antenna will compete with just about any other dipole mounted at the same height. But the inverted-U is lighter than most dipoles at frequencies lower than 10 meters. It also rotates easily by hand — assuming that you can rotate the mast by hand. Being able to broadside the dipole to your target station gives the inverted-U a strong advantage over a fixed wire dipole.

With a dipole having drooping ends, safety is very important. Do not use the antenna unless the wire ends for 20 meters are higher than any person can touch when the antenna is in use. Even with QRP power levels, the RF voltage on the wire ends can be dangerous. With the antenna at 20 feet at its center, the ends should be at least 10 feet above ground.

Equally important is the maintenance that you give the antenna before and after each use. Be sure that the aluminum tubing is clean — both inside and out — when you nest and un-nest the sections. Grit can freeze the sections together, and dirty tubing can prevent good electrical continuity. Carry a few extra hitch pin clips in the package to be sure you have spares in case you lose one.

Scaling Up the Inverted-U

To inverted-U's rotatable dipole can be scaled up by as much as a factor of three with correspondingly heavier mounting plate and tubing diameters. This results in a rotatable dipole that can be used as low as 30 meters with excellent performance. A full-sized dipole is a very efficient antenna and will hold its own with two-element Yagis at comparable heights.

Suitable tubing and mounting hardware can be obtained by scavenging pieces from old tri-band HF Yagis that have been damaged or taken out of service. Metal boom-to-mast plates can be used if the antenna elements are insulated by enclosing them in a piece of exterior plastic electrical conduit whose inside diameter is a close match to the element's outside diameter. Cut a ¼-inch slot along the length of the conduit so that it can be compressed around the element by the U-bolt or muffler clamp.

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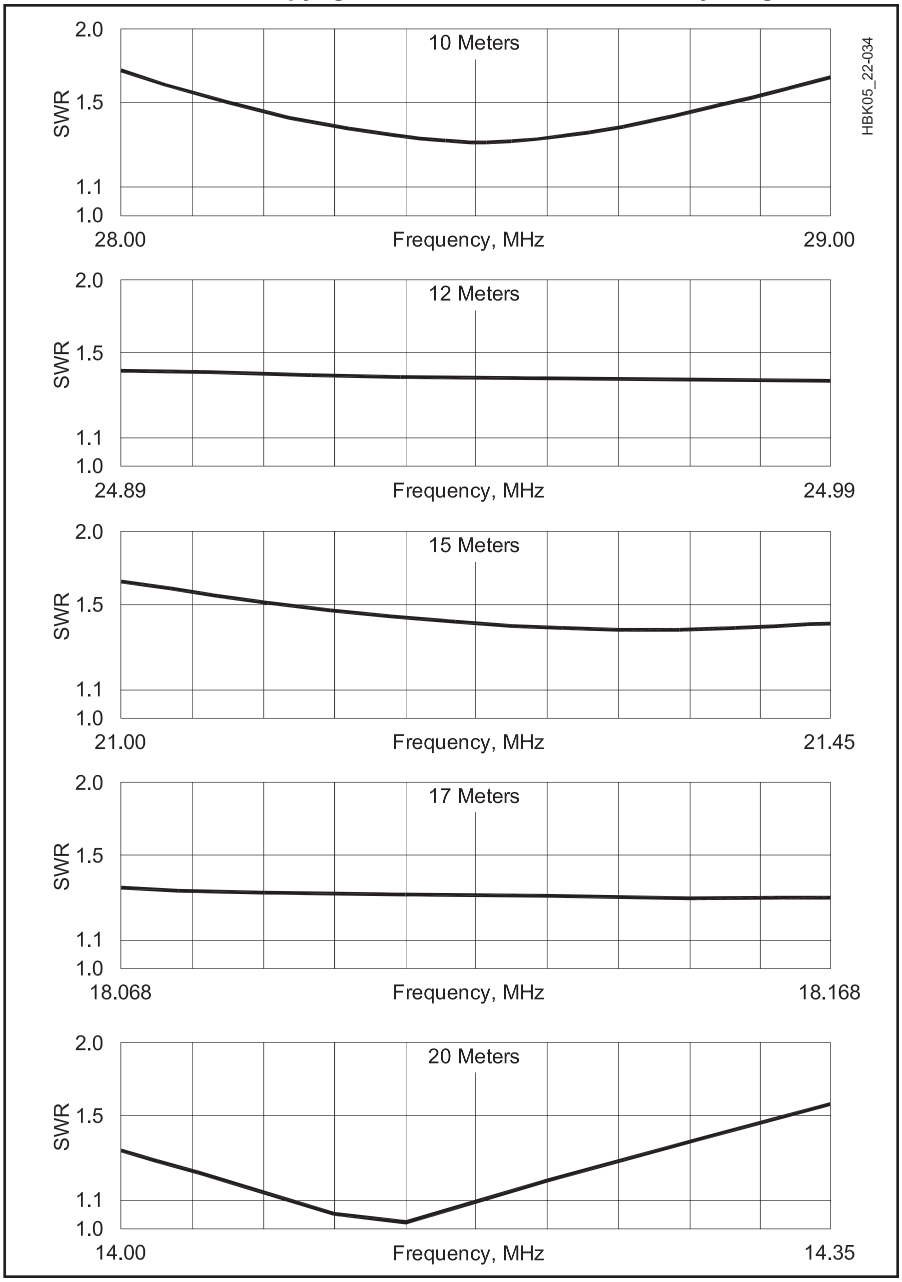

Fig 21.38 — Typical 50-Ω SWR curves for the inverted-U antenna at a feed point height of 20 ft.

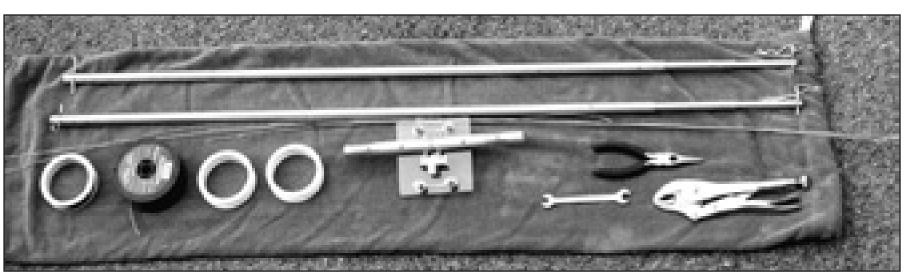

Fig 21.39 — The entire inverted-U antenna parts collection in semi-nested form, with its carrying bag. The tools stored with the antenna include a wrench to tighten the U-bolts for the mast-to-plate mount and a pair of pliers to help remove end wires from the tubing. The pliers have a wire-cutting feature to help replace a broken end wire. A pair of locking pliers makes a good removable handle for turning the mast. The combination of the locking and regular pliers helps to uncoil the wire extensions for any band; give them a couple of sharp tugs to straighten the wire.