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Chapter 16

VHF and UHF Mobile Antennas

VHF/UHF mobile antennas can be very efficient, if installed properly. This section presents the popular types of mobile antennas for VHF and UHF and discusses issues regarding mounting style and installation technique. The material was revised and updated from previous editions by Alan Applegate, KØBG.

16.1 ANTENNAS FOR VHF-UHF FM

Antennas for Hand-held Transceivers

For frequencies above 30 MHz, most mobile installations permit the use of a full-size antenna but for hand-held radios smaller, loaded antennas are used. Antennas designed for use with VHF/UHF handheld FM transceivers can also be considered mobile antennas, even "rubber ducky" antennas consisting of a spiral winding of flexible wire in a flexible enclosure.

Pictured in **Figure 16.1** is a telescoping full-size quarter-wave antenna for 2 meters and beside it a flexible "rubber ducky" antenna for the same band. The rubber ducky antenna is a helically wound radiator made of stiff copper wire enclosed in a protective covering. The inductance of the helical windings provides electrical loading for the antenna. This avoids the problems of a lengthier, cumbersome antenna attached to a handheld radio while sacrificing some efficiency and bandwidth compared to the full-size antenna. The rubber ducky, being compact and flexible, withstands the normal rigors of portable use much better than would a full-size antenna. For these antennas, survivability over long use outweighs electrical efficiency.

The use of a full-size antenna will greatly improve the performance of hand-held transceivers. By using a coax adapter, the transceiver can be connected directly to the feed line of mobile antennas such as those described in the following sections. This allows much more effective use of a hand-held transceiver in a vehicle. A mobile antenna can also be installed on top of a metal appliance at home for improved operation. For example, a mag mount antenna on top of a refrigerator or file cabinet is a popular way of improving local coverage of a hand-held radio.

Mobile Antennas

At VHF and UHF, mobile antennas are often full-size whips (meaning ¼- to ½-wavelength long) and simple collinear arrays that provide extra gain on the higher frequency

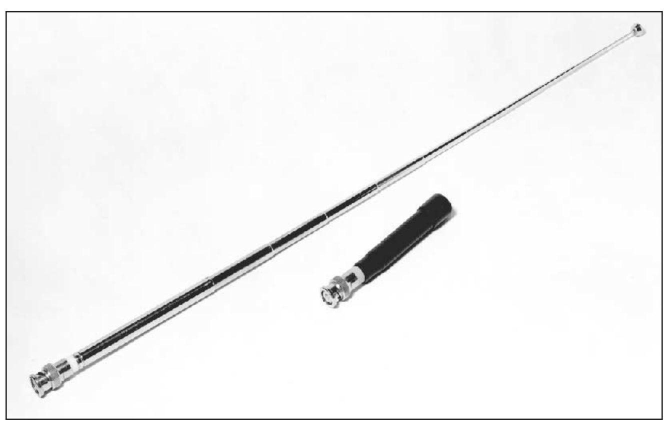


Figure 16.1 — A telescoping ¼-wavelength antenna and a "rubber ducky" antenna, both designed for use on 2 meters. The telescoping antenna is approximately 19 inches long when extended, while the rubber ducky antenna is only 3½ inches long. The rubber ducky is a helically wound radiator used because of its mechanical strength.

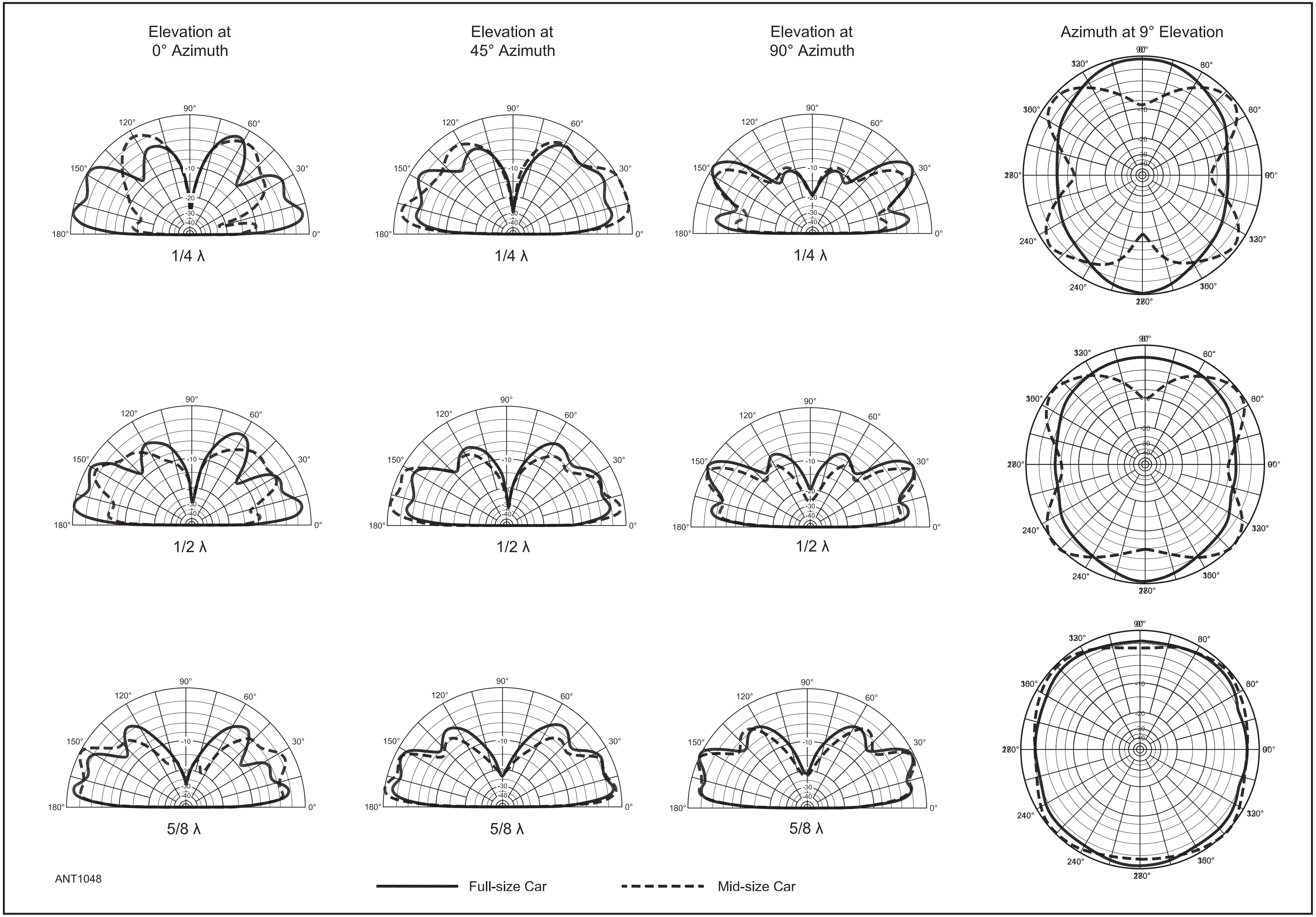


Figure 16.2 — Elevation and azimuth patterns showing the comparison for full and mid-sized cars for the three most popular VHF mobile antennas. (From "VHF Mobile Antenna Performance — The Other Half of the Story" by Dan Richardson, K6MHE.)

bands. There is always great debate about the best antenna for urban and/or suburban FM use. Which antenna to select depends on many factors — mounting style, mechanical characteristics, local terrain — and can't be based solely on advertised gain. Mobile antennas come in ¼-, ½-, ⅝-λ, and even in collinear styles where several elements are stacked atop one another.

It has been established that in general, ¼-λ vertical antennas for mobile repeater work are not as effective as ⅝-λ verticals. With a ⅝-λ antenna, more of the transmitted signal is directed at a low vertical angle, toward the horizon, offering a gain of about 1 dB over the ¼-λ vertical. However, in areas where the repeater is located nearby on a very high hill or a mountain top, the ¼-λ antenna will usually offer more reliable performance because it radiates more power at higher vertical angles.

Dan Richardson, K6MHE, has done extensive work on mobile VHF antennas, including modeling the various types, and how mounting location affects their radiation patterns. **Figure 16.2** shows representative azimuth patterns for roof mounted antennas. (The complete article is posted on his website **k6mhe.com/files/mobile_vhf_ant.pdf**.) The radiation patterns of antennas mounted on a trunk lid would be different from those depicted in the chart. Where — and how — the antenna is mounted would determine the actual pattern. Radiation pattern distortion aside, proper trunk lid mounting is a good alternative to roof mounting, especially when garage door clearance is an issue.

As can be seen from the patterns, there really isn't much difference between the radiation patterns of a ¼-, ½-, or ⅝-λ antenna. In fact, the vehicle in question and the antenna's mounting location affect the pattern more than the style! Since most mobile VHF and UHF operation is via FM repeaters, where the difference in height between the mobile and the repeater can be a major consideration, a ¼-λ antenna with more radiation at higher vertical angles can be a better choice.

Single-band whips are inexpensive and give excellent performance with proper mounting. If more gain and multiband use is required, the dual-band collinear that operates on both 2 meters and 70 cm is very popular. The Larsen NMO2/70BK shown in **Figure 16.3** is a typical example. Electrically it is a center-loaded ½-λ on 2 meters with gain identi-cal to a ¼-λ ground-plane. On 70 cm it is a 2-element collinear with a few dB

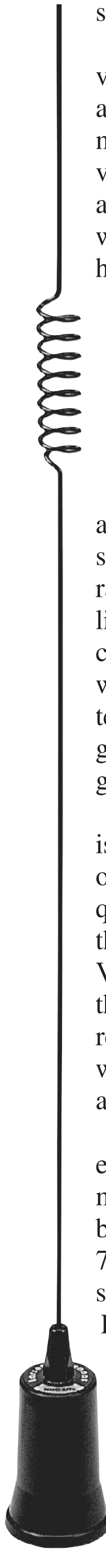


Figure 16.3 — A common style of dual-band VHF/UHF mobile whip antenna. (Larsen model NMO2/70BK)

Antenna Types for SSB and CW on VHF/UHF

Operating SSB and CW on 6 and 2 meters and 70 cm offers some exciting prospects for all license classes. While communications on the VHF bands are often considered line-of-site, propagation *beyond* line-of-site is common as discussed in the **Propagation of Radio Waves** chapter. This is especially true when using a "weak signal" mode such as SSB or CW, but there's a catch.

FM communications utilize vertically polarized antennas. Vertical polarization can be used for SSB but depending on the propagation path, signal strength via a vertically-polarized mobile antenna can have a 20+ dB disadvantage compared to a horizontally-polarized antenna.

Fortunately, horizontally-polarized antennas are of manageable size on the VHF bands, although they are not as simple to construct as vertically polarized whips. Dipoles and small beams present too much wind resistance to withstand the normal mobile environment. The usual solution is a loop antenna.

Figure 16.A shows an M² Antenna Systems (**www.m2inc.com**) horizontally polarized 6 meter loop called a *halo* (for circular versions) or *squalo* (if square as shown). Equivalent antennas for 2 meters and 70 cm are common. Although this particular design is square, they're still called loops and have a roughly omnidirectional pattern. The "Big Wheel" design is another option. Projects for both types of antennas are provided in the projects section.

Modern mobile SSB/CW transceivers usually output 100 W PEP on 6 meters and at least 50 W PEP on 2 meters and 70 cm. Under good band conditions, using horizontally-polarized antennas, *beyond* line-of-sight distances can exceed 200 miles even without any sky-wave or tropospheric scatter present!

Figure 16.A — A squalo (square halo) is a popular horizontally polarized VHF/UHF mobile antenna.

gain over a $\frac{1}{4}$-λ ground-plane. Other models are available which operate on three and even four bands. Antennas covering three or four bands are heavier and require sturdier mounting.

Six Meter FM Antennas

Technically, the 6 meter band is considered VHF but it often exhibits HF band properties while it also has an FM repeater sub band. Antennas for 6 meter FM operation look just like larger versions of those for 2 meters and they often use the same mounts. However, their ground plane requirements are more significant, similar to their HF cousins as discussed in the **Mobile and Maritime HF Antennas** chapter.

16.2 MOUNTS FOR WHIP ANTENNAS

VHF and UHF antennas are much smaller and lighter than HF antennas, making mounting quite a bit easier. Some permanent mounts require drilling holes in the vehicle, while others use a hood or trunk lid seam so screw holes don't show. Still others clamp around the outside of a trunk or door edge. For temporary installations, magnetic base mounts are available. For best performance, VHF and UHF antennas should be permanently affixed to the vehicle.

The roof of a vehicle is an inviting place to mount a VHF or UHF antenna as this maximizes performance, but a few precautions need to be followed. First, it is not uncommon for side air bags to be mounted within the headliner area with control wiring running through the roof support pillars. Further, the roof is supported by cross bracing to meet rollover standards. These braces must be avoided. A repair manual for the vehicle in question is a good resource in avoiding installation problems and finding the manufacturer's preferred routes for coaxial and control cables.

The type of mount is also a concern when roof mounting, as the mount must be securely waterproof. If you're unsure about drilling holes in your vehicle (see the sidebar "To Drill Or Not to Drill?"), use the services of a local two-way radio service or vehicle entertainment system installation company.

The center of the trunk lid is a second-best location but care must be taken to assure the antenna doesn't interfere with the opening of the trunk. With the trunk fully open, place the antenna at the desired mounting location to check clearance. Don't forget to include the height of the mount itself and account for vibration of the antenna and trunk lid. Whatever mount is used, care must be taken to assure clearance of the coax cable and control leads if present.

If the antenna's overall length is too great, overhead clearance becomes a problem. While lightly touching the garage door or carport top may be acceptable, if the antenna is long enough to drag the inner surface of the door or roof, you run the chance of catching the antenna between garage door panels or getting it stuck in a rafter. This will damage the antenna and often the vehicle. In these cases, you're much better off with a shorter $\frac{1}{4}$-λ antenna.

NMO — New Motorola Mount

The recommended antenna mount for VHF and UHF antennas is the NMO (from "New Motorola") as it is waterproof even when the antenna is removed. A permanent NMO mount (see **Figure 16.4**) usually requires a $\frac{3}{4}$-inch hole. Antennas with an NMO base have an integral O-ring or washer to seal the internal surfaces against water.

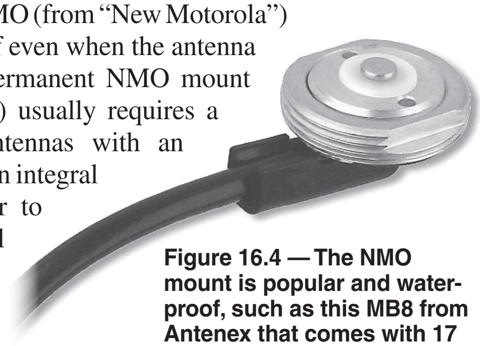


Figure 16.4 — The NMO mount is popular and waterproof, such as this MB8 from Antenex that comes with 17 feet of RG-58A coaxial cable.

SO-239 Mount

Some VHF antennas mounts have a modified SO-239 chassis coax connector with the mating PL-259 forming the base of the antenna. The standard connector type allows you to connect a coaxial cable to the antenna mount, if desired. Most SO-239 mounts *are not* waterproof, especially when the antenna is removed, and shouldn't be used for through-hole body mounting and should be capped when not in use.

Stud Mount

While popular at HF, the stud mount is less common at VHF and UHF. Larsen and other manufacturers offer mounts with a male $\frac{5}{16}$-24 stud. Detachable whips are then available for all VHF and UHF bands.

Angle Brackets

Angle brackets are generally attached by three or more sheet metal screws. Properly secured, they work well for

To Drill Or Not To Drill?

The decision to drill holes in sheet metal to mount antennas can be hotly debated. While no-hole mounts can be used satisfactorily, it is best to look at both sides of the issue.

One common reason given not to drill is if the vehicle in question is leased, but that doesn't preclude a drilled hole. If it did, there wouldn't be any leased commercial vehicles. What lease agreements specify is body damage such as from an accident or mistreatment. Properly installed NMO mounts, for example, are often acceptable.

Drilled holes and waterproof mounts also minimize common-mode current on the coaxial feed line that could interfere with or receive RFI from on-board computers and electrical devices. Aside from the hole itself, a permanent mount also minimizes damage to the finish.

Figure 16.5 — This angle bracket mounts to the vehicle body with three sheet metal screws and is drilled to accept a standard NMO mount.

lightweight antennas but routing coax through weather seals can be troublesome.

Angle brackets come in about a dozen different styles. The one shown in **Figure 16.5** is pre-drilled for an NMO mount. The brackets are often well-suited for installation along the hood and trunk seams.

Modern vehicles have very little clearance between the body structure and the various doors and hatches. Be sure to check clearance before you actually attach the bracket. Some vehicles may require specially bent or extended brackets as well.

Clip or Lip Mounts

There are a variety of mounts designed to clamp on the edge or "lip" of a trunk, hood, or hatch. Set screws are used to secure the mount to the lip and provide the requisite grounding of the mount. The set screws both secure the mount and make a connection to the sheet metal through the body paint. **Figure 16.6A** shows a typical "hatchback" style adjustable mount with an NMO base and **Figure 16.6B** is a close-up showing the set screws holding the mount to the vehicle body.

All modern vehicles are dipped in a zinc compound before final assembly and painting. When exposed to air, zinc rapidly oxidizes but in this case the oxidation is a good thing! When a piece of road debris nicks the paint down to the zinc layer, it quickly oxidizes, and protects the base metal underneath. Do not remove this zinc coating to bare metal! This removes the protective coating, allowing the underlying steel to rust and creates an intermittent connection.

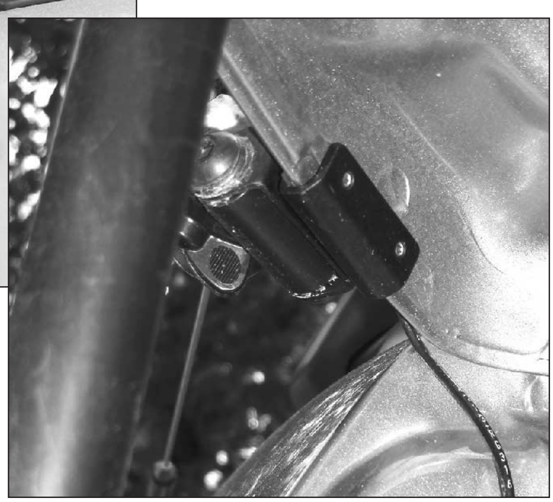
Be aware that the coax must often be bent sharply around the lip of the trunk. Because clearance is minimal many lip mounts come preassembled with about 10 feet of RG-174 sized coax (0.110 inch OD). While the loss per foot isn't much of a concern at HF, it becomes critical at UHF where the feed line loss is just over 4 dB! If coax loss is important in your installation, use a mount with RG-58 cable.

All lip mounts bring the coax cable into the trunk or passenger cabin through the weather seal, potentially allowing water to enter. Running the cable under the seal as in Figure 16.6 is often an option. Take care to dress the cables and seals to direct water toward a drain hole or other exit.

Glass Mounts

"Through-glass" or "on-glass" mounts such as the Larsen KG2/70CXPL use adhesive to hold the base of the antenna and cable fitting to opposite sides of a window, relying on metal foil surfaces to create a capacitor and pass VHF/UHF signals. The mount must be clear of window heating strips and cannot be used on tinted (passivated) glass that contains colloidal-sized metallic particles to provide protection from harmful UVA and UVB rays. Antenna performance is somewhat of a compromise because of the lack of a ground-plane but allows a permanent mount without holes, clamps, or magnets.

(A)



(B)

Figure 16.6 — (A) shows an adjustable lip mount made by Diamond. (B) is a close-up of the mount showing the set screws that hold the mount to the vehicle and make an electrical connection to the vehicle.

The outside surface of the coaxial feed line also becomes part of an on-glass antenna because there is no ground-plane, creating a path for common mode current. This allows the coax to both radiate and pick up noise in the vehicle interior.

Luggage Rack Mounts

The biggest issue with using luggage racks as an antenna mount is excessive ground loss. Most luggage racks consist of plastics, composites, and insulated metal beams electrically isolated from the vehicle's metal body. As such, they rarely provide a good ground-plane for the antenna and routing the feed line through door or window weather seals can create leaks. Like on-glass antenna mounts, luggage rack mounting is a compromise for when a permanent mount is not possible

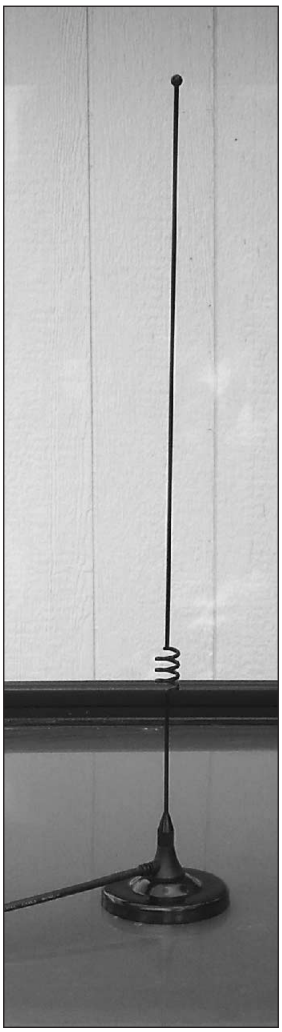


Figure 16.7 — A typical dual-band VHF/UHF mag mount with an integral antenna and feed line.

Magnet Mounts

Mag (magnet) mounts are very popular for VHF and UHF operation. They rely on capacitance to make their electrical connection to the vehicle ground plane, so common-mode current on the feed line shield can become a problem. Nevertheless, mag mounts do deliver acceptable performance at VHF and UHF.

Mag mounts are available with the antenna and feed line attached as in **Figure 16.7** or as the mount by itself. There are mag mounts for any of the popular antenna bases — NMO, stud mount, and SO-239. A spare dual-band mag mount, a set of VHF and UHF whips, and several coax connector adapters are a valuable addition to your emergency response capabilities.

Be wary of the fine grit that can work its way under the magnet and scratch the paint. If you do use a mag mount for long periods of time, remove it and clean the magnet surface occasionally. For temporary installations, a plastic sandwich bag around the magnet protects the finish against grit while still maintaining a solid attachment.

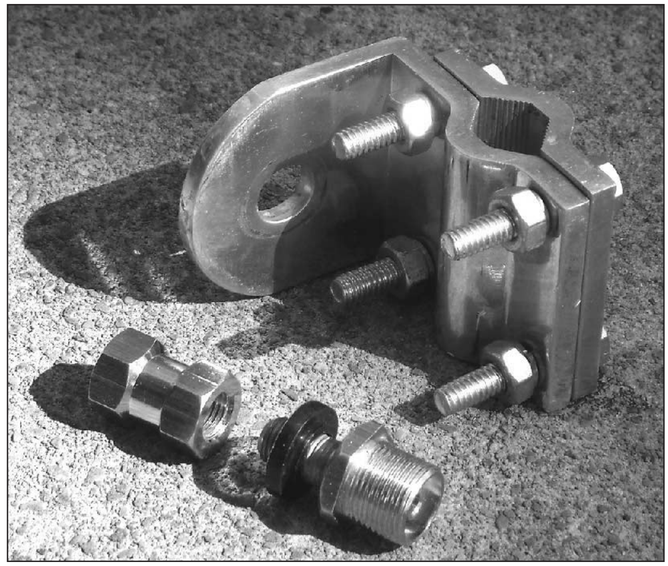


Figure 16.8 — The mirror-mount style of clamp-on bracket. This particular bracket is drilled for an SO-239 to ⅜-24 stud mount. The bracket can be mounted on vertical or horizontal struts.

Specialty Brackets and Adapters

Because there are so many variations in vehicles there are many different types of brackets for mounting antennas. One of the most common is the three-way mirror mount in **Figure 16.8** that is sold by many companies. This particular version is drilled to pass the shoulder insulator of the SO-239 to ⅜-24 threaded stud-mount adapter shown in the foreground. You can find a wide variety of brackets at hamfest flea markets, from vendors of antenna accessories, online from manufacturers and distributors, and at truck stops and CB shops.

The performance of the antenna depends on the size of what the bracket is attached to. Most mirrors mounts are just barely big enough to act as a counterpoise at UHF but if they are securely mounted to a metal vehicle body, performance will be acceptable. The radiation pattern of the antenna will rarely be omnidirectional due to the off-center antenna placement.

Adapters are also available that convert mounts such as the NMO to other types of bases and connectors, such as the various stud mounts and SO-239 connector. This allows your antenna mount to accommodate other types of antennas but generally increases the length of the antenna by an inch or so, lowering the antenna's resonant frequency. A few mount adapters should be included in your mobile equipment kit.

16.3 PROJECT: ¼-WAVELENGTH WHIPS FOR VHF AND UHF

The ¼-wavelength vertical whip is simple to make and can be made for nearly any type of mount. The preferred stainless steel wire or rod is available from two-way radio shops and CB antenna dealers. Cut the whip to length using a grinding wheel or score it with a file and break it — use eye protection! Any type of wire can be used in a pinch. Coat hangers, copper wire from home wiring cable, galvanized fence wire — all have been successfully used to replace broken or missing whips. Being able to repair or substitute for a broken antenna is a skill any amateur can learn for flexibility and resiliency during emergency situations.

Table 16.1
¼-Wavelength Whip Lengths

Frequency (MHz)	*Length (inches)*
53	53
146	19³⁄₁₆
222	12⅝
440	6
902	2⁷⁄₁₆

Table 16.1 shows the approximate lengths for ¼-λ whips in the VHF and UHF amateur bands based on a ³⁄₃₂-inch diameter whip. Thinner whips will be slightly longer and thicker whips slightly shorter. Be sure to include the antenna base in the total length of the antenna. If the base holds the whip with a set screw, cut the whip approximately 5% long and adjust for best SWR before making a final trim to length.

16.4 PROJECT: BICYCLE MOBILE ANTENNAS FOR VHF AND UHF

Operating while mobile from a bicycle is increasingly popular for recreation or during commuting to work. (The Bicycle Mobile Hams of America website, **www.bmha-hams.org**, has a lot of information about operating from your bike.) Being able to radiate an effective signal is straightforward but requires a slightly different approach to conventional mobile operation. For starters, most bicycles and accessories are not made of steel, so mag-mount antennas cannot be used. The frame of the bicycle is mostly oriented vertically so the conventional horizontal ground plane is not available. And of course, personal safety is of paramount importance on a bicycle. This project and the articles included on the book's CD-ROM provide some examples of effective antennas and mounting techniques you can use on your bike.

Unlike the conventional λ/4 ground-plane, the vertical dipole or J-pole do not use the bicycle frame as part of the antenna. While simple to construct, the main challenge is to support the antennas on the bicycle without adding a lot of weight. A common accessory provides the solution — a bicycle safety flag. Safety flags lift a high-visibility pennant on a slim fiberglass tube that mounts to the bike using a pressed-steel axle mount. Lightweight antennas can be attached to the fiberglass tube and a feed line run along the frame to the transceiver.

The J-pole shown here is a flexible "roll-up" design by Edison Fong, WB6IQN, originally published in March 2007 *QST* as the DBJ-2. **Figure 16.9** shows the initial 2 meter

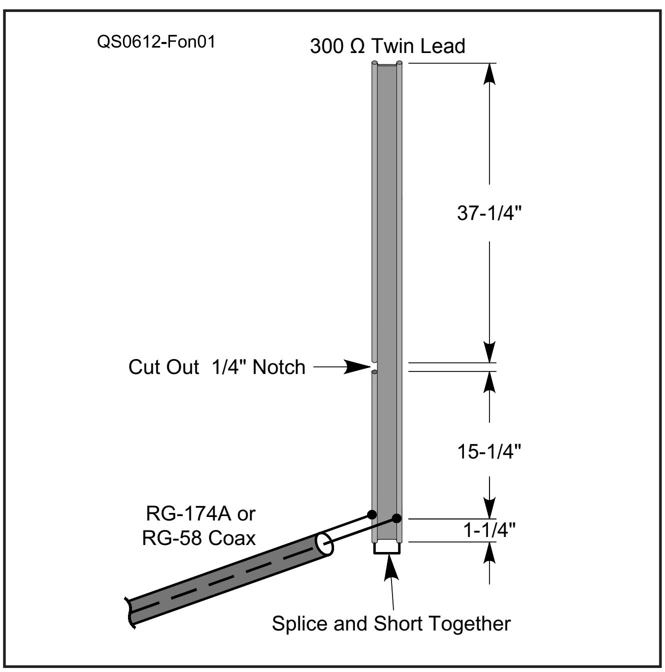


Figure 16.9 — A 2 meter flexible J-pole antenna. Any 50 Ω coaxial cable can be used. RG-58 or RG-8X is recommended for bicycle or other mobile use.

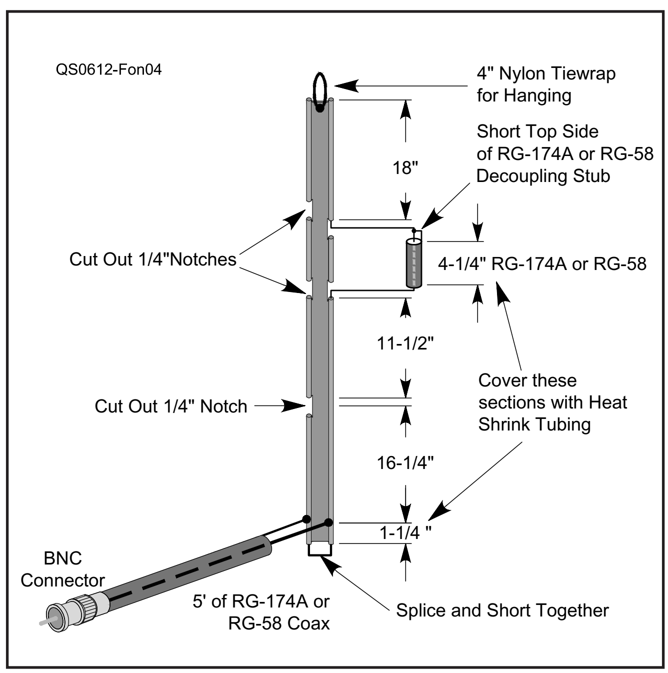


Figure 16.10 — The 2 meter/70 cm J-pole version. See the construction article on the CD-ROM for information about tuning the antenna and attaching the feed line.

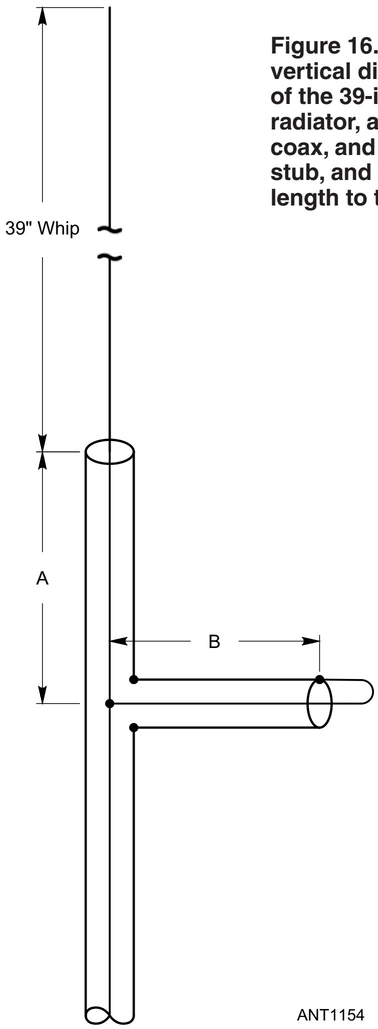


Figure 16.11 — The vertical dipole consists of the 39-inch vertical radiator, a λ/4 section of coax, and shorted tuning stub, and coax of any length to the transceiver.

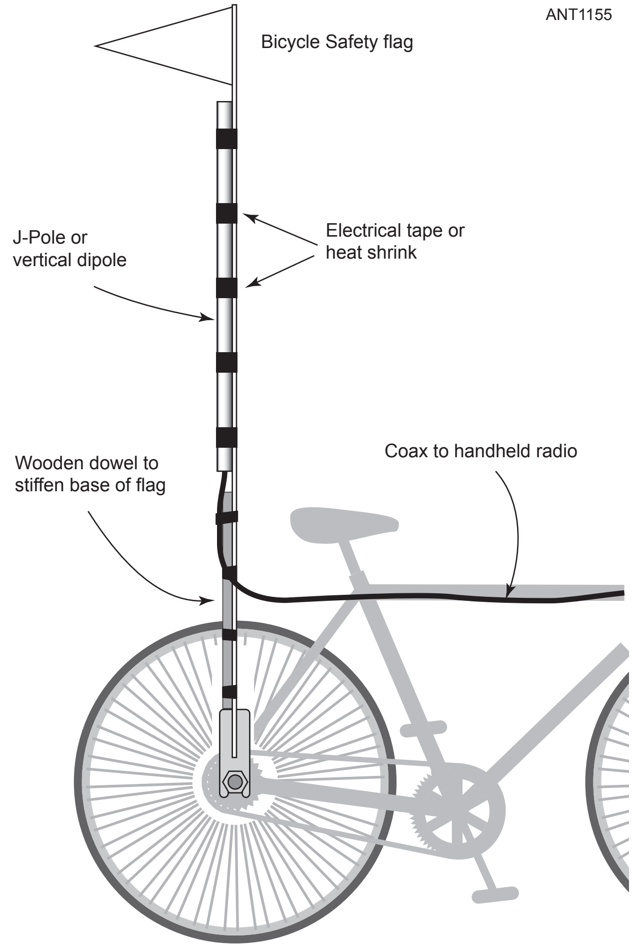


Figure 16.12 — Either the J-pole or vertical dipole can be attached to the fiberglass tube supporting a rear-axle mounted bicycle safety flag. Use tape or heat-shrink tubing to secure the antenna to the fiberglass. A wooden dowel can be used to stiffen the tube if necessary.

antenna design. RG-174A coax can be used as in the original design which was optimized for weight. Less lossy RG-58 or RG-8X coax would be a better choice if more weight is not a problem. The antenna in **Figure 16.10** works on both 2 meters and 70 cm. Both antennas are discussed in detail, including more construction and tuning details, in the article provided on this book's CD-ROM.

An alternate antenna shown in **Figure 16.11** is a vertical dipole based on the design by Charles Lofgren, W6JJZ, "The Bike 'n Hike Special" described in *QST's* Hints and Kinks. The antenna consists of a 39-inch radiating λ/2 whip of #14 or #16 AWG wire and an RG-58 coaxial tuning stub attached to the feed line ¼ λ below the radiating whip. The shorted stub adds some inductive reactance at a low impedance point in the feed line to raise the impedance to 50 Ω. From that point, any length of 50 Ω feed line to the transceiver can be used. (See the section "Matching Stubs" in the **Transmission Lines** chapter for information about how the shorted stub tunes the antenna system.)

The length of the stub depends on the velocity factor (VF) of the coaxial cable being used. Solid polyethylene dielectric coax has a VF of 0.66 (66%), while foam dielectric cable is typically 0.80 (80%). Check the velocity factor of your cable using an antenna analyzer or consult the table of coax characteristics in the chapter on **Transmission Lines**.

The stub should be 1.6 inches long for VF 66% cable and 2.0 inches long for VF 80% cable. Begin with the stub about ⅜ inch too long so that it can be trimmed to length after installation. Note that the length of the stub includes the short piece of center conductor that connects to the main feed line center conductor. Approximately ¼ inch is enough center conductor and braid to attach the stub to the main feed line. Leave approximately ½ inch of dielectric and a small bit of center conductor exposed on the other end to adjust the stub length.

To attach the stub to the coax feed line, remove about 1 inch of jacket from the main feed line. Using sharp wire cutters, cut through the braid without damaging the dielectric and push it toward the jacket. Use a sharp knife to expose a short section of the center conductor. Solder the stub's center conductor to the main feed line center conductor and insulate it with liquid electrical tape or heat-resistant glue. Slide the main feed line's braid back toward the stub attachment point. Solder the braid of the main feed line and stub. Weatherproof the stub attachment point with more liquid electrical tape and a wrap of good-quality electrical tape.

At the other end of the stub, twist the braid and center conductor of the stub together but don't solder them. Mount the antenna in the clear (at least several feet above the ground and away from any metallic objects). Use an SWR meter or antenna analyzer to adjust the length of the stub to give minimum SWR at the desired frequency. Since the stub is intentionally too long, adjustment consists of untwisting the braid and center conductor, removing a small amount of dielectric, twisting the braid and center conductor together again, and re-measuring. When the stub is at the desired length, solder the braid and center conductor together and seal the stub with heat shrink or tape.

Secure the completed antenna to the safety flag's fiberglass tube with heat shrink tubing or wraps of tape as shown in **Figure 16.12**. If the assembly needs additional support, a length of wooden dowel can be taped to the fiberglass for additional rigidity. If the assembly vibrates or rubs against the frame or a rack, a length of plastic hose can be used to protect the antenna.

16.5 PROJECT: BIG WHEEL FOR TWO METERS

The following section is an overview of the construction project, "A New Spin on the Big Wheel" by L. B. Cebik, W4RNL (SK), and Bob Cerreto, WA1FXT, in the March 2008 issue of *QST*. The complete article detailing the design's history, evolution, and critical elements is available on this book's CD-ROM with all construction details and drawings.

Most attempts to develop a horizontally polarized omnidirectional (HPOD) 2 meter antenna have sought to minimize the antenna's size. Shapes such as circles (halos), squares and rectangles usually result in the need for either hypercritical dimensions or difficult matching conditions — or both. By turning to more conventional full size structures using three dipoles, we can reduce the number of critical parameters and ease the process of replicating the antennas in a home workshop. In fact, we shall describe two versions of the same basic antenna. One is a triangle of three dipoles that folds into a flat package, suitable for easy transport to a hilltop. The other is a circle of three dipoles suitable for mobile operation that requires somewhat less space but needs greater precision in construction. Both antennas share a common feed system and display broadband characteristics that ease the builder's task.

The Three Dipole Design

The center and right outlines in **Figure 16.13** show the basic triangular and circular forms that emerged from the original design at left. Note that the current magnitude curves place the feed points of the dipoles at high current, relatively low impedance positions.

Both forms are very broadband in virtually every operating parameter once the builder gets the dimensions correct. The triangle, with a wider separation between the dipole end tips, is less critical with respect to dimensions, but requires more space. The circular version, with tighter coupling between dipole tips, requires more careful construction, but results in a more compact structure. In fact, for the same performance, the circular three-dipole antenna is smaller than the original big wheel.

The far-field performance of the three-dipole HPODs and the big wheel are virtually identical. Therefore, the data in **Figure 16.14** applies equally to all three designs. At a height of 20 feet above average ground, the three elements in all of the designs provide an average gain in the lowest lobe of about 7.2 dBi. The azimuth pattern is as close to

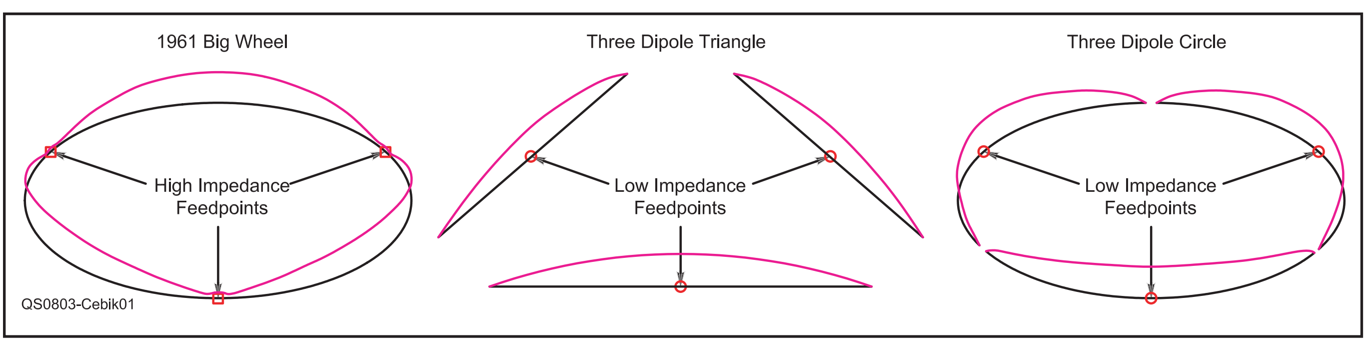


Figure 16.13 — Relative current magnitudes on three different three element HPOD antennas.

circular as is possible with fewer than four elements. The gain variation for the worst case was less than 0.3 dB.

The modeled SWR curve applies to both of the three-dipole models. Because the dipoles of the final designs present feed point impedance close to 50 Ω, we may use standard coaxial cable of virtually any length to reach the hub without changing the impedance significantly. Matched to a 50-Ω main feed point at the hub junction, the SWR curve is very flat and in the model shown in the graph, the SWR is acceptable (well under 2:1) for at least 8 MHz in the 2 meter range. Moreover, the circularity of the pattern and the gain are virtually constant across the entire 2 meter band. Even though the antenna is likely to see service only in the first MHz of the band, the broadband characteristics ease the difficulty of successfully building a version at home.

To obtain a 50-Ω main feed point impedance, the three-dipole arrays use a somewhat nonstandard arrangement at the hub. Both of our three-dipole designs use a series connection of the lines with the source. The resulting hub impedance is close to 150 Ω, and any stray reactances become very small portions of the impedance magnitude. Therefore, a simple λ/4 matching section can handle the impedance transformation to the 50-Ω region.

The Three-Dipole Triangle

Each dipole is broadside to a direction 120° from the adjacent dipoles. The goal is to find dimensions that will achieve this goal plus provide a workable feed point impedance at each dipole. The prototype constructed to test the basic model of this arrangement used ½-inch diameter aluminum tubing as a light but sturdy material. Each dipole used a 2-inch length of 0.375-inch diameter fiberglass rod as a center insulator. The dipole halves are held in place with #6

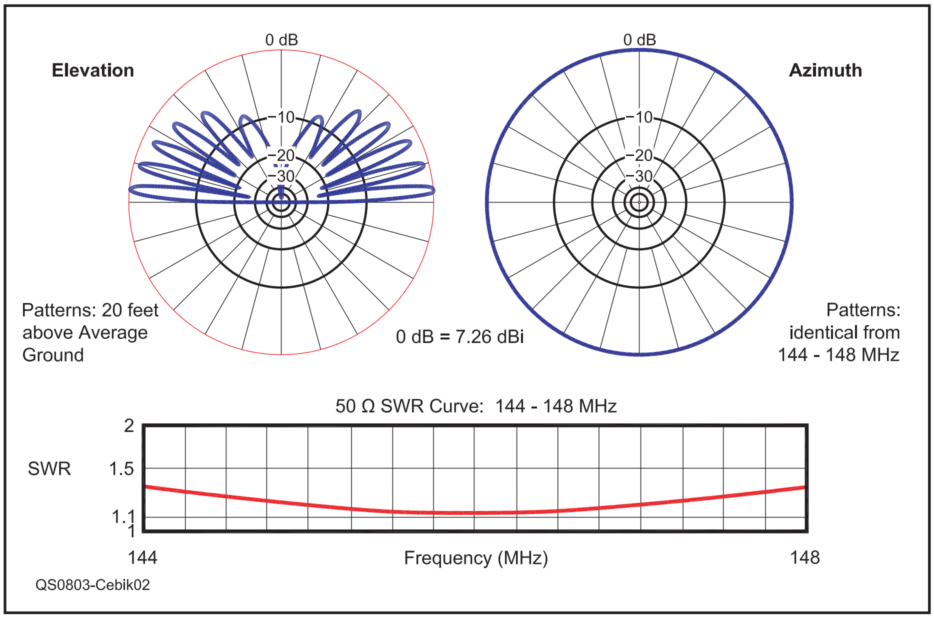


Figure 16.14 — Representative elevation and azimuth patterns and 50-Ω SWR curve for a three-dipole HPOD antenna using either a triangular or a circular shape at 20 feet above average ground. The patterns of the original big wheel are virtually identical in shape and strength.

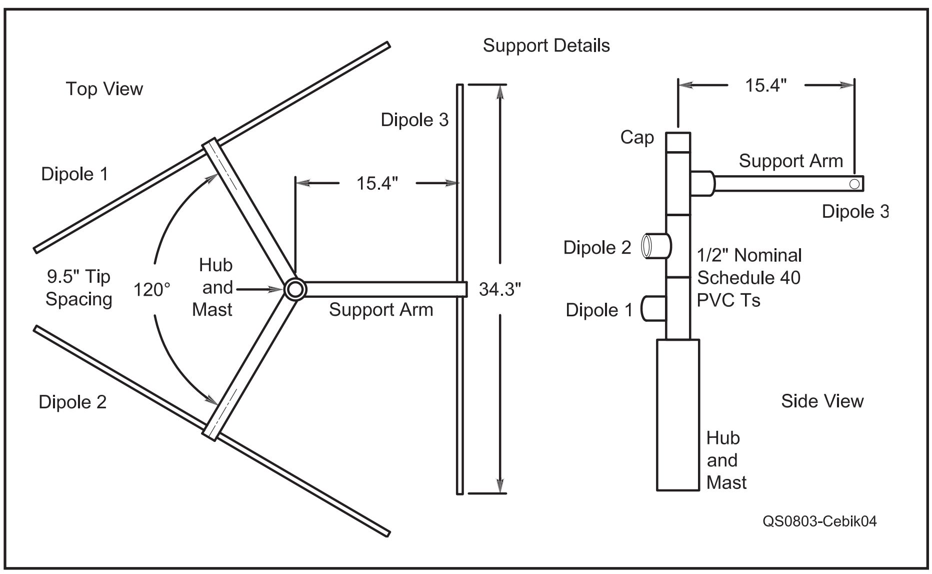


Figure 16.15 — Some details of the support structure used for the three-dipole 2 meter triangle.

Table 16.2
Dimensions for a Three-Dipole 2 Meter Triangle

Design Frequency (MHz)	*Element Diameter (inches)*	*Radius to Feed Point (inches)*	*Dipole Length (inches)*	*Tip-to-tip Spacing (inches)*
146	0.5	15.4	34.3	9.5
146	0.375	15.3	34.7	9.15
144.5	0.5	15.6	34.7	9.6
144.5	0.375	15.5	35.1	9.25

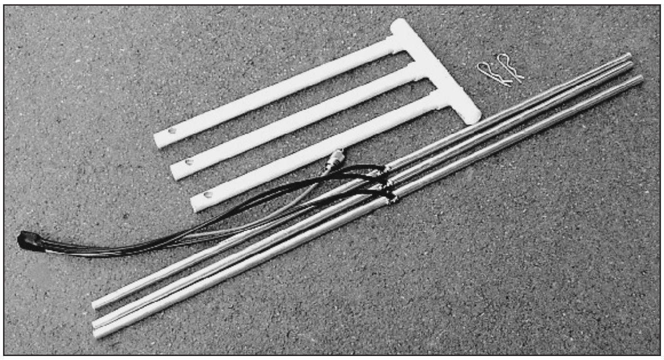


Figure 16.16 — The triangle HPOD disassembled for transport.

Figure 16.17 — The circular HPOD suitable for mobile use.

stainless steel sheet metal screws. The gap should be as small as is feasible, ⅛ to ¼ inch. These same screws fasten the ends of the coax cable to the element with a stainless steel washer to prevent electrolysis between the aluminum element and the copper wires. For ease of disassembly in portable operation, the prototype used lugs under the screws.

Table 16.2 lists some dimensions for both 0.5- and 0.375-inch aluminum tubing, perhaps the two most likely materials for this project. For the triangle, 146 MHz was used as the design frequency because the performance and the SWR do not significantly change across the band. This center-design frequency also provided a good view of the antenna's broadband properties. However, the table also lists dimensions that are usable if the builder wishes to place the performance center of the antenna at 144.5 MHz. The prototype used the half-inch-diameter material and the 146 MHz dimensions for that material.

Note the length of the dipole. It is about 3.3 inches shorter than an independent dipole composed of the same material. The resonant impedance (50 Ω) is lower than the usual value for a standard dipole of about 70 Ω. The three dipoles in the triangle do interact by virtue of both the proximity of their feed points and the closeness of their tips. The dimensions of the triangle are therefore quite critical to successful operation of the array as designed. However, in the triangular form, they are not finicky, and cutting errors of ⅛ to ¼ inch will not materially affect performance.

In fact, the relatively relaxed conditions for the triangle prompted the particular design that emerged. The prototype may be useful for field or hilltop service, since the support structure and the elements and their cable come apart and store in a flat package for transport. **Figure 16.15** provides a few of the support structure details and **Figure 16.16** shows the antenna disassembled for transport.

For a permanent installation or for mobile use, you may prefer a circle of three dipoles as shown in **Figure 16.17**. The circle has no loose dipole ends and is more compact than the triangle. Indeed, it is aesthetically more pleasing. However, such pleasure comes at a cost. The construction and adjustment of the elements are somewhat more critical, although completely manageable.

16.6 PROJECT: HALO FOR SIX METERS

The following section is based on the construction project, "A 6 Meter Halo" by Paul Danzer, N1II, in the September 2004 issue of *QST*. The complete article is available on this book's CD-ROM with all construction details and drawings. This inexpensive halo — the basic design was originally published in the 1975 *ARRL Handbook* — satisfies several key elements for an inexpensive 6 meter antenna: omnidirectional, horizontal polarization, no exotic components or materials, easy to adjust. With care, the construction should be robust enough for mobile use.

The halo is basically a half-wave dipole bent into a circle and fed with a gamma match. **Figure 16.18** shows the basic design and list of typical dimensions. The resonant frequency is quite sensitive to tip-to-tip spacing at the ends of the dipole but should initially be in the range of 50 to 52 MHz without requiring critical measurements or assembly.

Figure 16.19 is a photograph of the finished antenna, built from 20 feet of copper tubing and ¾-inch schedule 40 PVC pipe and fittings. The vertical support mast and horizontal supports are also PVC pipe. As the author notes, make sure the PVC fittings are aligned properly after the cement is applied as bonding takes place almost instantly and they can't be realigned.

Copper tubing can be formed into a circle by hand. The open ends of the halo and the gamma match are attached with ⅜-inch #8 or #10 sheet metal screws to PVC pipe stubs mounted in a PVC T fitting on the horizontal support. (See **Figure 16.20**.) The ends of the tubing are flattened with a vise or hammer and drilled for the screws. Tune the antenna first before permanently attaching the tubing ends to the support. Use short screws to avoid adding significant surface area after tuning is completed.

At the mounting point on the vertical mast, the center of the halo can be attached with a pair of copper tubing clamps as shown in **Figure 16.21** or the tubing simply flattened and attached with a sheet metal screw. (The latter technique may not be strong enough to withstand highway speed mobile use.)

The gamma shorting bar is made from a short piece of strap, braid, or heavy wire attached to a pair of copper tubing clamps at each end. The gamma capacitor is a fixed-value capacitor as shown in the photograph. To connect the feed line, the author used an SO-239 connector mounted on a bracket attached to the vertical support mast. (See Figure 16.21.) Solid wire, strap, or tinned braid may be used for the connection between the SO-239 and the main element of the antenna.

Use an anti-oxidation compound such as Noalox or

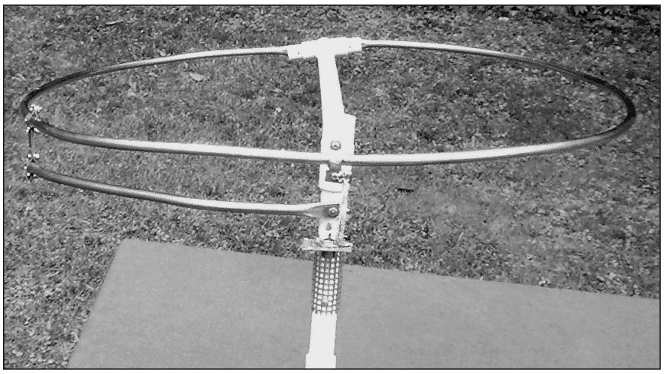


Figure 16.19 — The halo from the rear. A copper strap connects the matching section to the halo on the left.

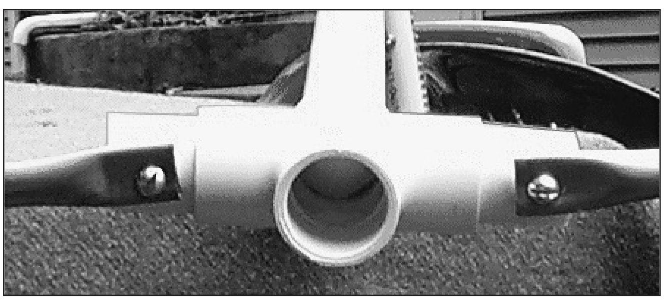


Figure 16.20 — The ends of the tubing are flattened and attached to the PVC pipe stubs with sheet metal screws.

Figure 16.21 — Details of the feed connection. The main element could be mounted using the flattened tube approach instead of with clamps as shown.

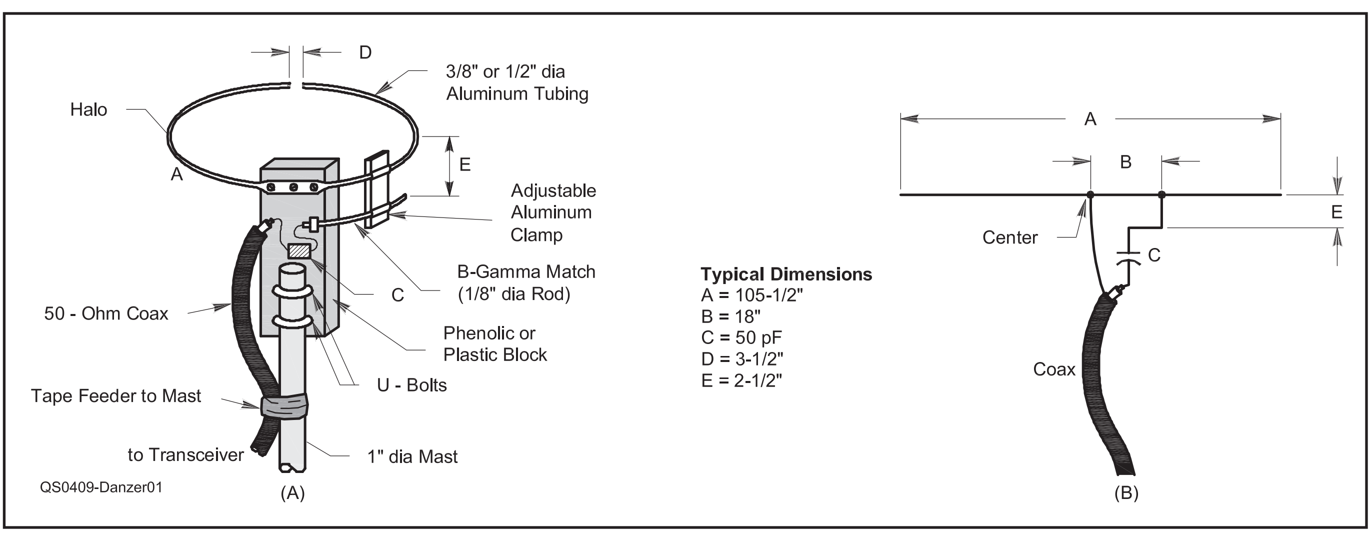


Figure 16.18 — The 6 meter halo design as originally published in the 1975 *ARRL Handbook*. The author substituted copper tubing in his version.

Penetrox for all unsoldered metal-to-metal connections to avoid corrosion.

Tuning the Halo

Tuning of the halo's resonant frequency can be done by changing the size of the gap between the dipole ends. Use electrical tape to temporarily attach the tubing ends to the PVC pipe stubs. Once you are satisfied with results, mark and drill the PVC fitting, then attach the tubing with the sheet metal screws.

To adjust the gamma match for lowest SWR at the resonant frequency, a 50-100 pF variable capacitor can be used. Once the proper setting has been obtained, measure the variable capacitor's value and replace it permanently with a fixed value capacitor. The author used two capacitors in series for the final value of less than 20 pF. The antenna then presented an SWR of less than 2:1 over the range of 50.0 to 50.4 MHz. Be sure to use capacitors rated for at least 100 V for use at 100 W and higher voltages if higher power is used.

Waterproof the electrical connections at the SO-239 and gamma capacitor connections with silicone sealant.

Other Halo Designs

Construction of halos and squalos is a popular antenna-building activity. You may also enjoy reading two additional construction articles included on this book's CD-ROM; "Six Meters from your Easy Chair," by Dick Stroud, W9SR in the January 2002 issue of *QST* and one of the original halo articles, "A Two-Band Halo for V.H.F. Mobile," by Ed Tilton, W1HDQ, in the September 1958 issue of *QST*.

16.7 REFERENCES AND BIBLIOGRAPHY

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