Build an Efficient HF Mobile Antenna

An electrically and mechanically sound design is offered, with easy band change coils.

by Frank Kamp K5DKZ

Short, coil-loaded antenna designs are all compromises when compared to full-sized antennas. Resistance losses in loading coils and low input impedances (typically 5 to 20 ohms) are the main efficiency-robbing factors. Efficiency can be optimized by using capacitive top-loading and high-Q loading coils. Top loading reduces the number of turns needed in the loading coil. Air-wound coil designs that utilize #12 or heavier wire will maximize Q and efficiency. Spiral-wound whips are also favored alternatives because their input impedance is relatively high, typically around 20 ohms. A design optimized for efficiency alone might take on the form of a large-diameter, spiral-wound, six-foot coil of heavy wire topped with a three-foot diameter capacity hat and three-foot whip. Such a design would work well electrically, but would pose a significant mechanical challenge and complicate band switching.

My past mobile activities have employed a standard center-loaded whip using interchangeable resonators for band changes. Tuning within the band is accomplished by adjusting the length of the whip at the top of the resonator. This type of antenna works reasonably well on 20 and 15, but becomes top-heavy and flimsy on 75 and 40 meters when used with most standard mobile masts. A single insulated base bumper mounting, along with a heavy center-loading coil, result in a radiator that does not always remain vertical at highway speeds. The "store-bought" version I used over a period of 15 years also developed questionable mechanical and electrical integrity. Connections to the mast were mechanically swedged instead of brazed, soldered or welded.

I needed a mechanically and electrically sound, vertical, all-band antenna. The main bands of interest were 75, 40, and 20 meters. Overall height was to remain under nine feet, with the upper three feet being a flexible whip. I wanted a design optimized for efficiency and easy band changing, but it also needed to be practical. Use of commonly available materials was an important factor in keeping costs down. The end result is a very stable, easily-mounted antenna that uses quick change resonators for band changes. The resonators are pre-tuned for the phone portions of each band and use a common three-foot whip. Only the resonators need be swapped to accomplish a band change.

The Resonators

The 75 meter resonator covers 3.7 through 4.00 MHz in 12 steps. The bandwidth of each coil tap is 20 kHz between 2:1 upper and lower SWR points, and 30 kHz between 3:1 upper and lower SWR points. Fine-tuning at each coil tap is done by adjusting the length of the three-foot whip. Careful adjustment will bring the SWR to 1:1 consistently after the matching coil tap is adjusted for a 50-ohm

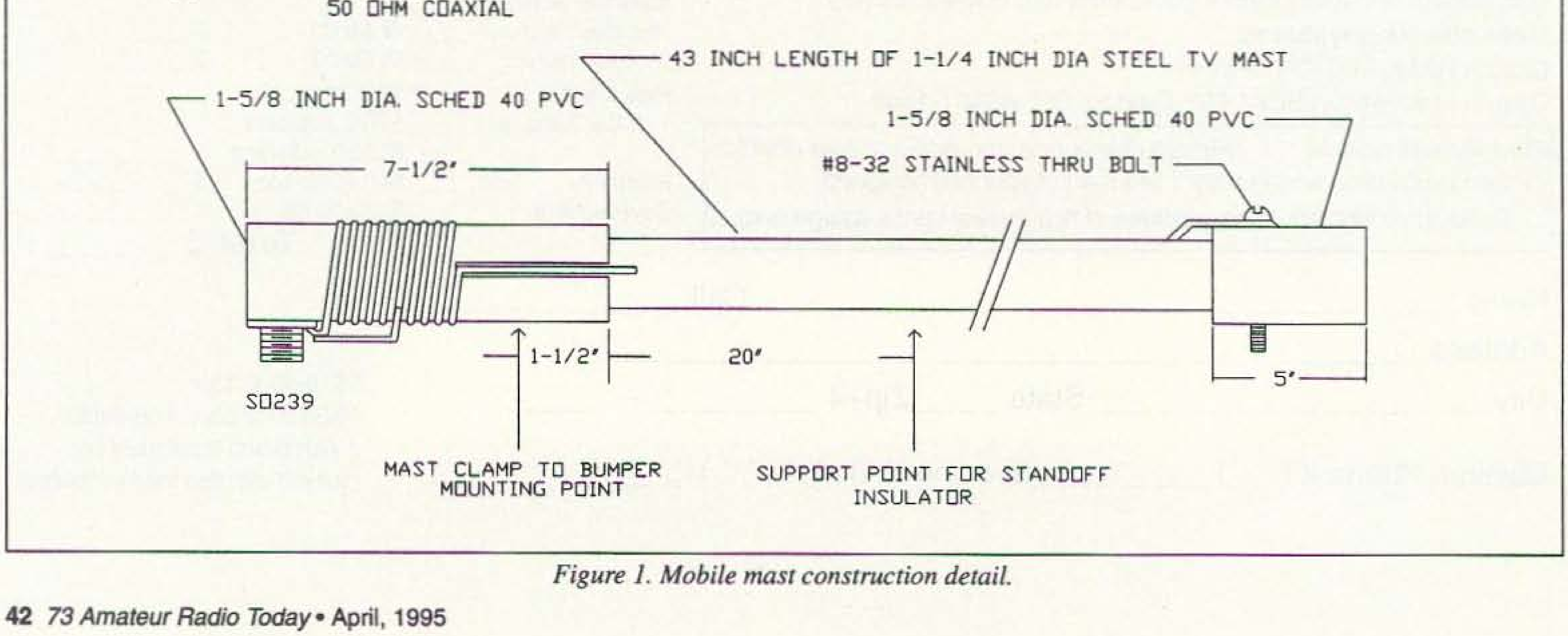

Figure 1. Mobile mast construction detail.

Photo A. 75 meter mobile resonator mounted on the HF mobile antenna mount.

match to the transmitter. Ordinarily, high-Q coils of this type will have a tendency to drift in a mobile environment. The rigid overall construction of this antenna keeps the radiator on frequency.

On-the-air tests show that this is an effective 75 meter antenna. During a recent Sunday morning schedule with a station 200 miles away, my mobile installation received an S-7 signal report. This compares favorably with the S-9 plus 10 dB report I received using the fixed station at the same time, when you consider the conditions. I was running 1,200 watts PEP to an inverted vee up at 60 feet in the fixed station configuration. My mobile setup was limited to 100 watts PEP and the vehicle was sitting in the driveway surrounded by 50-foot trees on all sides.

The 40 meter resonator covers 7.15 through 7.30 MHz without the need for taps. Its bandwidth is 170 kHz between 3:1 upper and lower SWR points and 100 kHz between 2:1 upper and lower SWR points. It is somewhat more efficient than the 75 meter resonator.

The 20 meter resonator covers the entire band from 14.0 to 14.350 MHz with a single untapped coil. The actual 3:1 upper and lower SWR points are 14.0 to 14.4 MHz, and the 2:1 points fall at 14.05 and 14.3 MHz. The bandwidth increases to 300 kHz because the physical length of the antenna becomes a larger percentage of what is required for a quarter wavelength resonator on that band.

Mast Construction

See Figure 1. The bottom portion of the mast is a 43" length of 1.25" diameter steel TV mast. I realize this is overkill but the TV mast diameter provides a nice slip fit with 1.5" schedule 40 PVC pipe. A 4.5" section of PVC pipe is attached to the upper part of the steel mast, with four self-tapping sheet metal screws and serves as the mounting for the base of the resonators. A 7.5" length of PVC pipe is attached in the same way to the bottom of the steel mast. The bottom section of PVC serves as a coil form for the matching coil, an insulator for the bottom antenna mount, and a convenient place to install an SO-239 connector for the feedline connec-

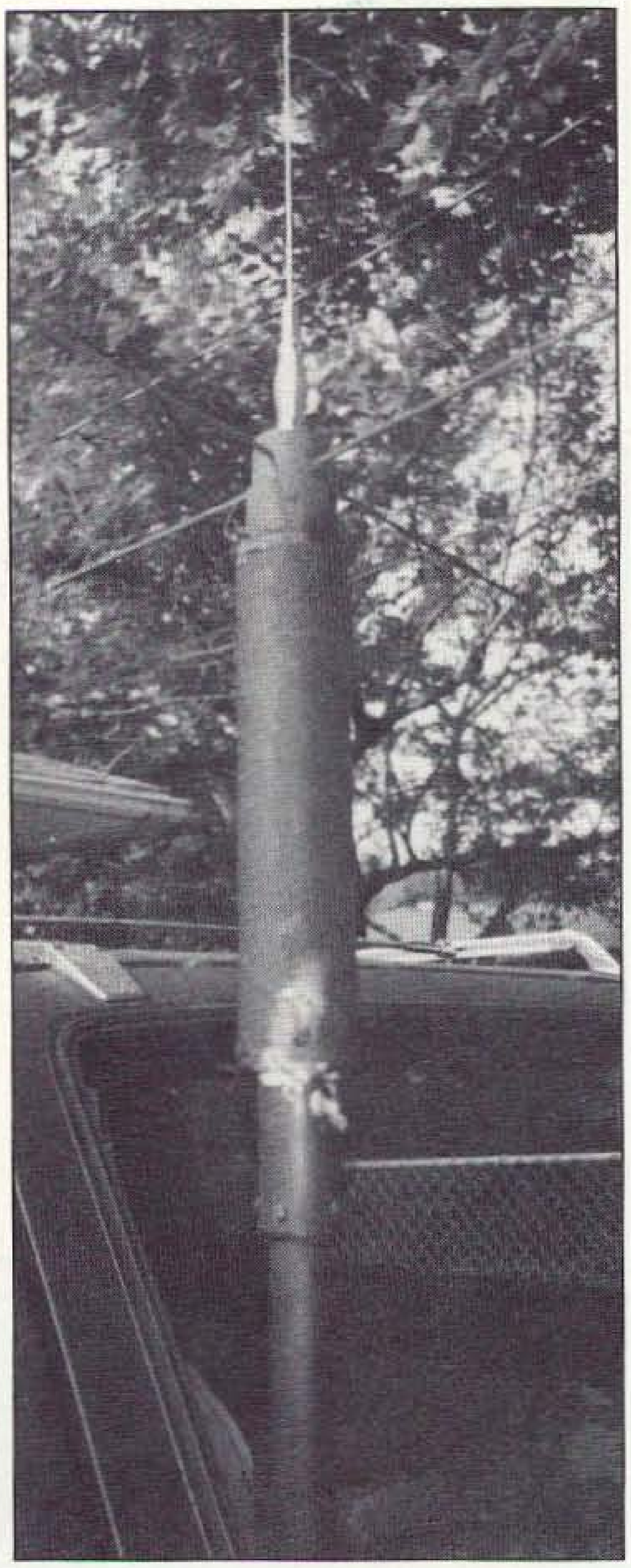

Photo B. Close-up of the 75 meter resonator.

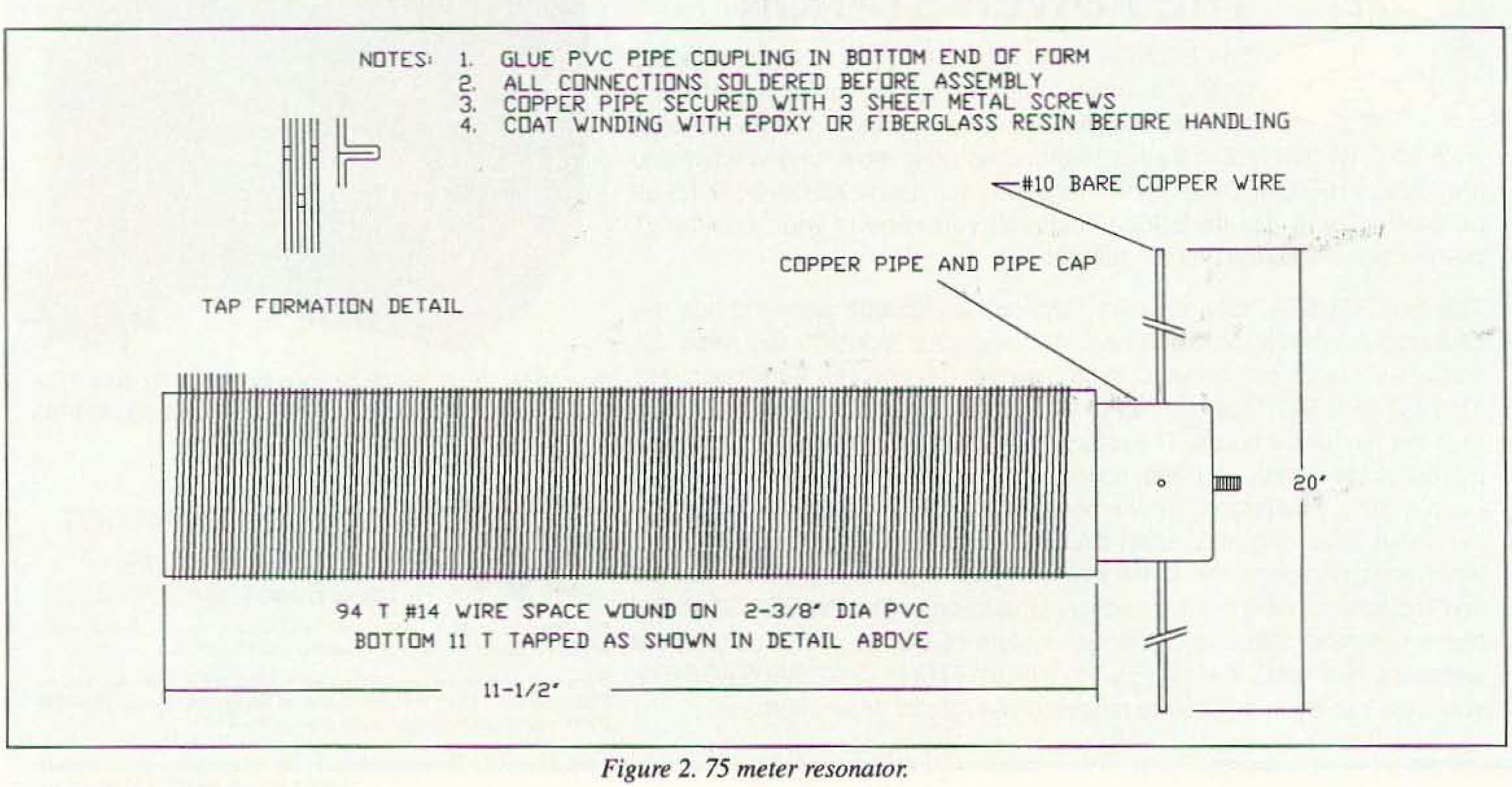

Figure 2. 75 meter resonator.

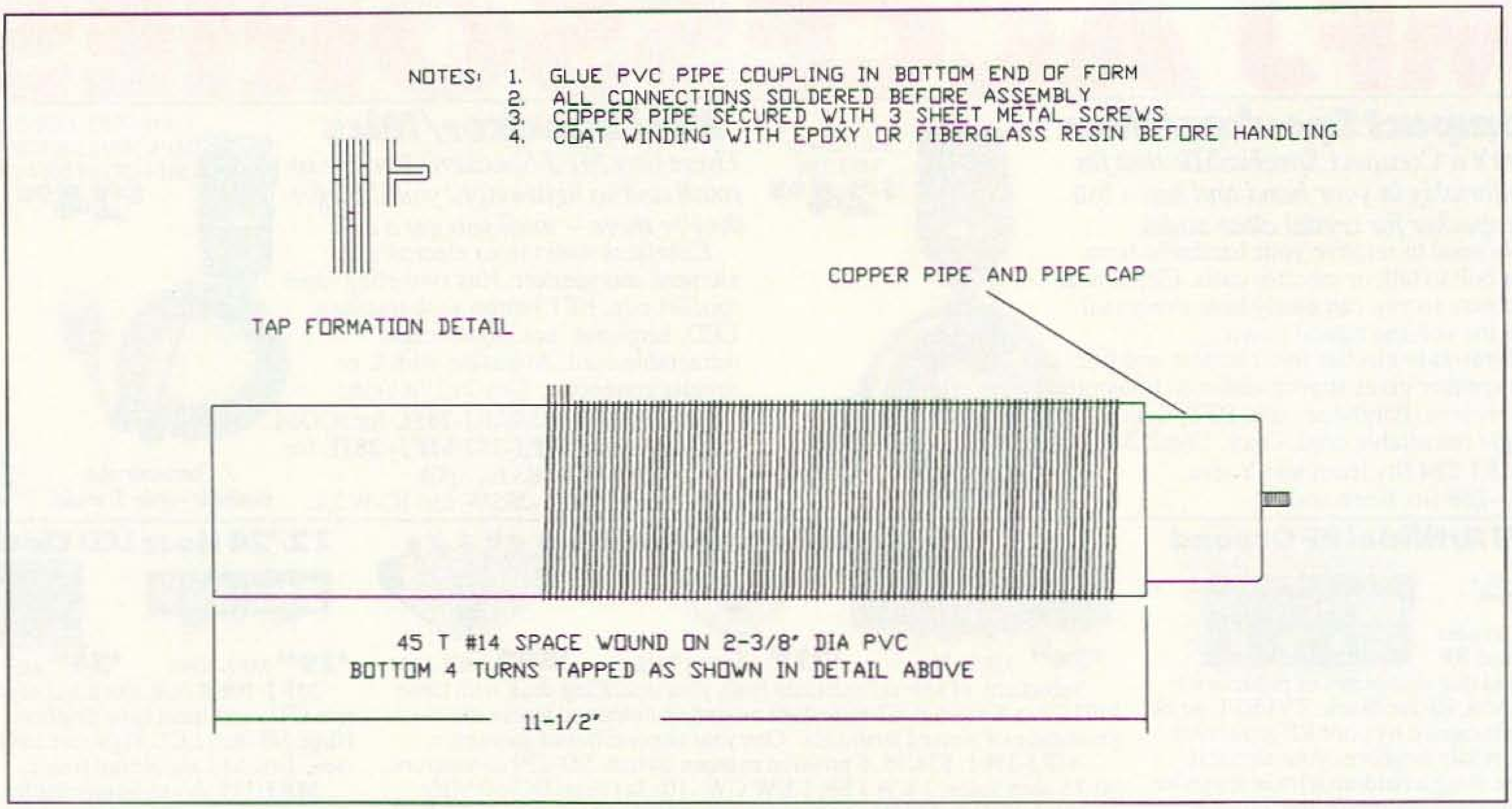

Figure 3. 40 meter resonator.

tion. Electrical connection to the mast is made using heavy copper braid removed from lengths of scrap coax. The braid is soldered to the steel mast. You will need a large soldering iron or propane torch to make these connections and you will want to solder the braid in place before permanently installing the PVC sleeves. Cut a slot down three-quarters of the length of the lower PVC sleeve. This allows the boom-to-mast mounting clamp to compress the sleeve tightly around the lower mast section. It also provides a convenient way to bring the braid down the center of the pipe, where it is soldered to the center of the coaxial connector. The upper, ungrounded end of the matching coil is also soldered to the braid.

The matching coil is 10 turns of #12 wire spaced one-wire in diameter between turns and located between the coax connector and the electrical connection to the mast. The lower end of the matching coil is soldered to the flange of the coax connector. A second length of heavy copper braid is soldered to the coax connector flange and grounded to the frame of the vehicle. These solder connections are made using a propane torch and before mounting the coax connector to the PVC pipe. You will want to use a Teflon-insulated coax connector that will withstand the heat of soldering. Use standard 4-40 hardware to mount the connector. Stainless steel hardware is preferred but not absolutely necessary if the ground connections are soldered. Soldering directly to the flange results in better long-term electrical connections than can be achieved using solder lugs and hardware. The ground connection to the vehicle frame should also be soldered.

Wind the matching coil onto the PVC before mounting it to the mast. Self-tapping screws can be used to secure the beginning and ends of the winding but should not be relied on as a permanent solution. Several vertical bands of epoxy will keep the coil in place. I used Fiberglas resin to fully encapsulate the coil after finding the proper tap for a 50-ohm impedance match.

The bottom part of the antenna is mounted to the steel bumper of the vehicle using a common antenna mast clamp. Two holes are drilled through the bumper for the U-bolt. This provides an inexpensive and rigid mounting. The mast will require a second mounting for stability. This attachment should be about two feet up from the lower mount. I used a 2.5"-wide length of heavy printed circuit board material. After the copper was chemically removed, I drilled one end of the PC board material to match the bolt pattern found on the inside wall of the tailgate mount of my truck. After adjusting the mast so that it was perfectly vertical, I drilled the other end of the PC board and mast together to receive a #10-32 through-bolt. The bolt passes through the mast and secures the PC board spacer. Almost any rigid insulating material can be used for this spacer but I would advise against using Plexiglas. Plexiglas gets brittle with age and will eventually fail. Polycarbonate would be an ideal alternative. This mounting is most suitable for installation on a truck or van. If done properly, it will not interfere with the movement of the tailgate or hatchback.

Resonator Construction

Two-inch-diameter schedule 40 PVC pipe is used as a coil form for the resonators. Its actual outside diameter is just under 2.5". Its inside diameter provides a slip fit for the outside diameter of coupling sleeves used with the 1.5" diameter PVC pipe. The coupling sleeve is glued to the inside of the coil form using PVC cement. The outside diameter of the coupling sleeve is not a critical dimension in the manufacture of the sleeve and may vary from brand to brand; all of them will fit inside the coil form. However, the fit may vary from loose to very sloppy and may require additional PVC material to take up the slack. If needed, thin strips of PVC material can be cut from a scrap of pipe and used to improve a sloppy fit between the coupling and the coil form. A press fit is not needed or desirable as it could fracture the coil form, but a close fit is necessary in making a permanent assembly using the PVC cement. The press fit of the coupling sleeve to the 1.5" PVC pipe is all that is necessary to keep the resonators in place on the mast, even at highway speeds. This mounting is secure and allows easy removal of the resonators.

75 Meters

See Figure 2. A 12" length of coil form is needed for the 75 meter resonator. The resonator consists of 93 turns of #16 solid copper enameled wire wound onto the form and spaced approximately one wire diameter apart. The spacing is not overly critical, but avoid close-winding the coil. Closer spacing will result in more inductance per linear inch, requiring fewer turns. To space the turns, I use braided nylon twine that is slightly larger in diameter than the wire. The wire and twine are wound simultaneously onto the form.

After the winding is complete, carefully remove the twine. You need about 60 feet of #16 wire. Before you start, make sure it has no kinks in it. The surest way of keeping kinks out of it when you wind the coil is to

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lay the wire straight out into a yard. If it does have kinks in it, remove them by tying one end of the wire to a fence post and giving the other end a few good yanks. The 11 taps are located at the bottom end of the coil form where it attaches to the mast. Each tap is staggered from the other by approximately an inch so they don't end up bunched up on top of each other. Before worrying with the taps, complete the coil winding and use epoxy to secure all but the bottom 11 windings. After the epoxy cures (overnight!) unwind the unsecured windings. Scrape the enamel completely from a 1" length of wire and bend it down on top of itself to form a closed loop about 0.25" long. We want the copper in the loop to be bright and shiny because we will later fill the loop with solder. When done, secure the tapped windings with epoxy.

Leave enough wire at the end to install the large solder lug that will be screwed down against the #10-32 stainless steel through-bolt we will install at the top of the mast. This through-bolt is the only mechanical connection in the antenna functioning as an electrical termination. It ties the bottom of the coil to the end of the copper braid from the top of the mast, and is required to allow removal of the resonator. It uses a wingnut fastener. An additional length of wire from the solder lug is bent back up the coil form and soldered to the desired coil tap. This is a semi-permanent connection so, before final assembly, make sure it is in the frequency range you will be using. I don't recommend alligator clips, sliding contacts, or miniature banana plugs; a soldered connection will outperform all of these alternatives.

Glue another 1.5" PVC coupling sleeve into the top end of the coil form. Self-tapping sheet metal screws secure the copper top hat and whip mount into the sleeve. The top hat and whip mount are made from 2"-long 1.5"-diameter copper pipe and pipe cap. Drill the pipe cap in the exact center of its top, and install a bolt here that matches the size and tread requirements of your spring loaded whip. Drill additional holes around the pipe and cap assembly at 90-degree intervals. Insert two lengths of #10 solid copper wire 21" long through these holes and center them on the assembly. Then, using a torch, solder the entire assembly. Don't try to solder just a portion of the assembly; copper is too good a conductor of heat to allow that. All connections will have be soldered at the same time. The top wire from the resonator coil is also soldered to this assembly. The wire can be kept in place by wrapping it around one of the top hat radials prior to soldering. All soldering should be done prior to installing the assembly into the PVC coupling.

40 Meters

See Figure 3. The 40 meter resonator is built like the 75 meter resonator. The minimum required coil form length is eight inches. Space-wind a total of 44 turns of #12 bare copper wire onto the form and secure it with epoxy. Approximately 33 feet of wire is required. The same nylon spacing twine used on the 75 meter coil can be used here, but a crossed-wire top hat is not used. Otherwise, the whip mounting is the same as on the 75 meter resonator. The 40 meter coil becomes resonant at 7254 kHz with the bottom two turns shorted. Each turn of the coil shifts the resonant frequency by about 200 kHz. The

Photo C. 20 meter resonator mounted on the mobile mast.

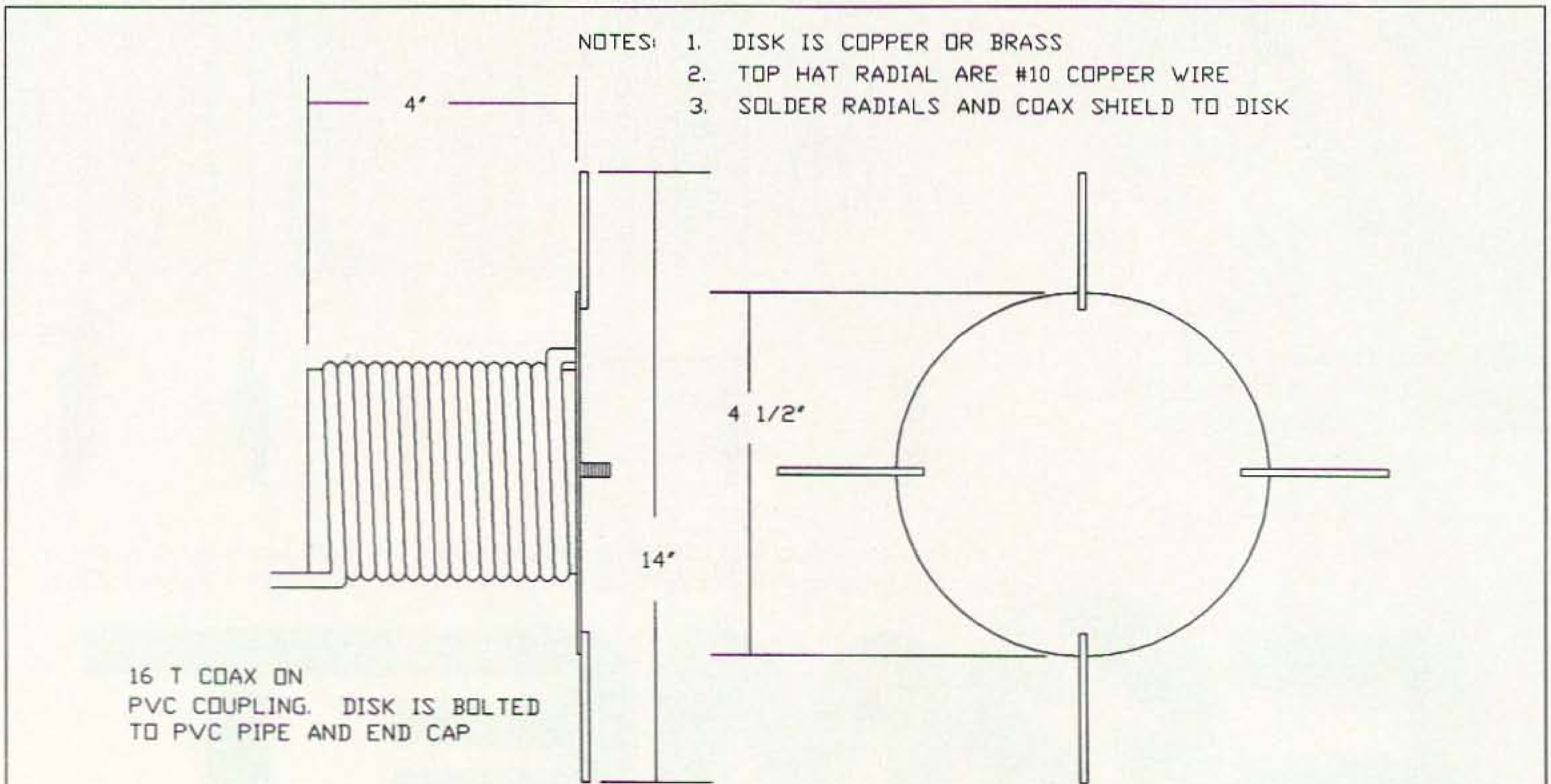

Figure 4. 20 meter resonator.

44-turn coil extends the lower frequency to 6845 kHz. It is possible to cover 40, 20, and 15 meters with this coil by tapping it to short more and more turns, but this compromises efficiency. A significant improvement in efficiency results from using shorter, unshorted coils to cover additional bands.

20 Meters

See Figure 4. The 20 meter resonator is constructed from a coil form made from a 1.5" PVC coupling sleeve and 1.5" PVC pipe cap. The cap and sleeve are connected with a short length of 1.5" PVC pipe and PVC cement. Cap and sleeve are pressed together for a zero clearance fit. Thirteen turns of coaxial cable is then close-wound onto this form and secured with epoxy. Almost any smaller diameter coax such as RG59, RG58, or RG62 can be used here. RG223 may offer superior performance with its silver-plated double shielding. Only the shield is used. Cut the center conductor flush at each end of the coil. A bolt is installed in the center of the pipe cap for the whip. This same bolt is used to secure the 5"-diameter brass disk that serves as a top hat. The top hat is required to bring this resonator down to the 20 meter band because the coil does not provide enough inductance to do the job alone. An additional three turns on the coil would eliminate the top hat, but I had better results using the top hat. The top hat also provides a convenient connection for the upper termination of the coil. The coax braid is passed through a hole in the disk and soldered.

Tuning

After the mast is mounted to the vehicle and the feedline has been routed and connected you are ready to tune the resonators. A grid dip meter is useful but not necessary. Start with the 75 meter resonator. With the transceiver tuned to 75 meters, adjust the taps on the resonator while listening for an increase in noise from the rig. There should be a dramatic increase in noise as you approach resonance. I experienced a difference of four S-units between resonant and non-resonant conditions. You will probably have to tune the rig across the band while experimenting with the taps to find the noise peak. When you have the resonator peaked for noise, use an SWR bridge to find the best tap on the matching coil for a 50-ohm match. I found my optimum match with five turns of matching coil shorted to ground. With 100 watts and the SWR meter set to maximum sensitivity, there was only a slight indication of movement from the meter pointer indicating an insignificant amount of reflected power. Experiments with a pencil drew 1/4"-long arcs of RF from the ends of the capacity hat under these conditions, indicating that power was indeed being transferred to the antenna.

A #47 pilot light bulb or equivalent can also be used to indicate current flow in the antenna. Attach test leads to the bulb. Connect one test lead to the ground connection at the base of the antenna. Connect the other test lead to the lower end of the resonator coil. Key down and *carefully* increase power output while on frequency at a suspected resonance point. There will be a significant increase in brightness as the transceiver is tuned through the resonance point. The test leads can be of equal length as actual location of the bulb is not critical. Total length of the test leads should approximate the distance between the electrical connections of the indicator to the mast to keep the slack in the wire to a minimum.

There are three logical ways to shift the resonance point. Moving the taps on the coil will cause the greatest shift. Adjusting the length of the whip in small increments will cause the smallest shift. Increasing the length or number of radial wires of the capacity hat will shift the point down in frequency; decreasing them will cause an upward shift. With so many ways of tuning it is possible to bring the resonance point very precisely to any frequency in the band. Once you determine the various points of resonance for each coil tap, you may want to make a chart for future reference. As long as the installation is not modified the results are consistently reproducible. A chart would allow frequency changes without the need for an SWR meter.

Tuning becomes less critical as frequency and bandwidth increase. Once you have the antenna working properly on 75 meters, additional adjustments to whip length become undesirable. Any further adjustments to the whip length to fine-tune the other bands will detune the system for the 75 meter resonator. Alternate means of tuning become desirable. On 40 meters, coil tapping is the simplest solution. If coil tapping is not desirable for whatever reason (i.e. inconvenient location on the coil), the addition of a small capacity hat will help fine-tune the system. The strategy here is to end up with a fixed whip length optimized for the lower frequency band. Resonance on the other bands becomes a function of resonator characteristics alone, allowing quick and easy band changes while preserving efficiency. Where used, all the top hats are an integral part of the resonator assemblies.

The input impedance of the system does change from band to band, but a low SWR can still be maintained with the 75 meter matching coil tap. The convenience of a permanent connection on the matching coil for all bands outweighs the minor decrease in efficiency resulting from a 0.5 change in SWR. I found no change in performance between an SWR of 1:1 and an SWR of 1.5:1. In fact, the only downside to running a 3:1 SWR is decreased power output from my solid-state transceiver. I can still communicate effectively at the higher SWR. Feedline losses appear to be near insignificant with a feedline length of only 15 feet and the antenna still radiates the power it receives.

After all the resonators were built, tuned and tested over a period of several weeks, I encapsulated them with polyester Fiberglas resin. This is a smelly, messy process but very effectively seals the coils. No shift in frequency or performance was observed after encapsulation. After the resin cured, I spray-painted all parts of the antenna flat black to improve the appearance of the installation. Take care to ensure that the paint is non-conductive. A flashy metal flake paint job will ensure a disaster instead of the inexpensive and effective HF mobile antenna system desired.