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An All-Band HF Mobile Antenna

Efficient and inexpensive.

by Stephen A. Glowacki KC4TMT

There are many reasons why we build antennas. Often we want something in particular that we either can't buy commercially or can't afford.

As the county's Emergency Coordinator I needed a good mobile multiband antenna. I initiated this design to favor materials available at local hardware stores. This tends to make repair easier and helps keep the overall cost down. The following mobile design can be constructed for about $20, with subsequent band coils costing less than $3-$5 each.

Much of the designing for this antenna was done with the aid of the *ARRL Antenna Book* and the *ARRL Handbook*.

Theory

The main idea behind an HF mobile antenna is to maintain the electrical length while shrinking the physical length to a practical size. The way to do this is to incorporate some sort of loading coil at either the base or the center. Each has its merits. Base loading has the advantage of physically placing the weight of the coil near the car. This avoids the need for guy connections.

I'll include some references to the math, but not many. If you really want the full outline of the calculation process and formulas, contact me and I'll be more than glad to QSO about it.

RF current is maximum at the point immediately above a loading coil. With a base-loading antenna, the efficiency is less because this current tapers off quickly as it goes toward the top of the antenna. However, with center loading, the radiation efficiency improves quite a bit. Optimum positioning is somewhere between 50%-70% up the total length of the antenna.

RF current varies with the cosine of the height in electrical degrees at any point in the base section. In a center-loaded antenna this characteristic results in more current being allowed to conduct higher up the antenna. This is more efficient, compared to a base-loaded antenna. The current then tapers off above the coil normally, resulting in an overall increase in the efficiency of the antenna.

Unfortunately, center loading requires a larger inductance than base loading in order to cancel out the increased capacitive reactance (X_c). (This increase is due to less antenna being available for resonance above the coil.) This larger inductance then requires a larger Q-factor (to maintain the same comparative radiation efficiency as a base-loaded antenna).

Photo A. Stephen Glowacki KC4TMT stands next to his mobile antenna.

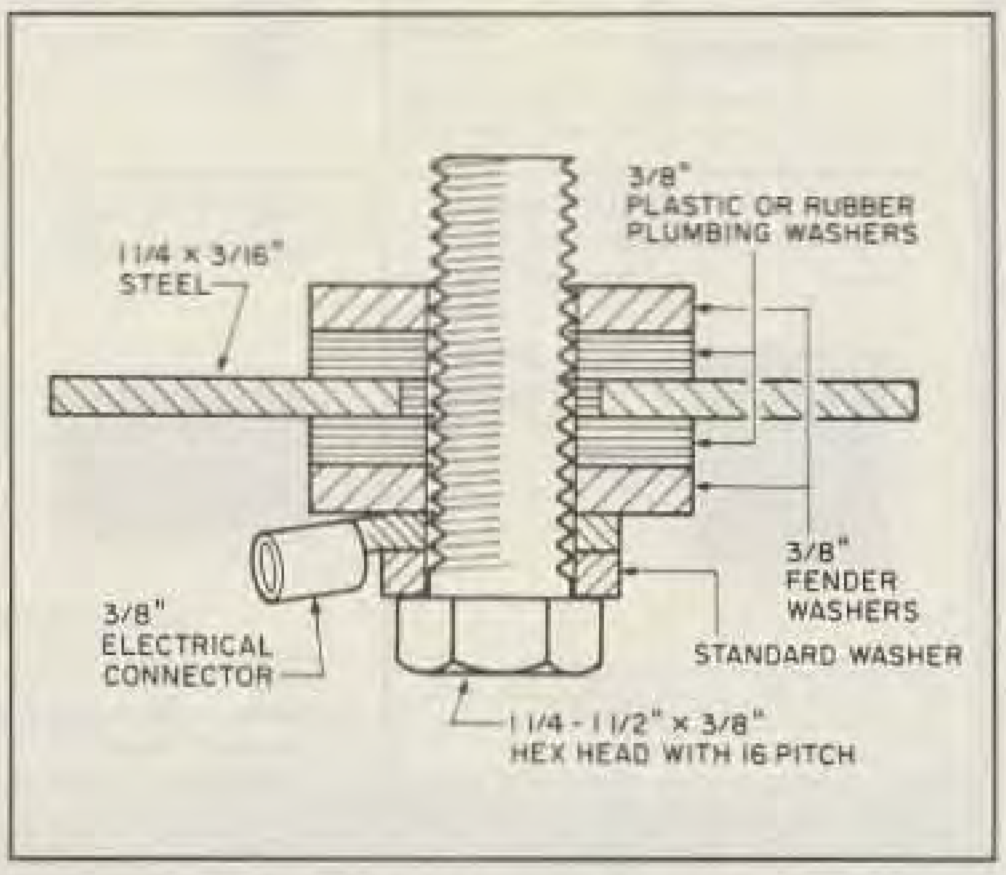

Figure 1. Antenna bracket.

This need for larger inductance and Q-factor forces the construction of physically larger coils. With placement of the coil being higher, wind-loading problems require the use of guy connections. (I hate to think in terms of guy wires when working with my car.)

Theoretically, if the coil is moved much beyond the two-thirds mark, the size of the coil would become impractically large and make it impossible for mobile use.

Most of the dimensions of this antenna resulted from the materials I had on hand at the time. The numbers are only internally significant and changes can be made easily with minor adjustments to the rest of the antenna, i.e. if you shorten the top antenna section, increase the number of turns on the coil; if you lower the position of the coil along the antenna, use less turns on the coil. (The opposite of these remedies is true for reversed conditions.)

To achieve optimum efficiency you need to balance all the characteristics of the antenna. The measurements given will put you in the ballpark, but fine-tuning is always required. Be patient in fine-tuning the antenna to your car. A good way to ensure a favorable outcome is to set plenty of time aside and follow consistently whatever procedure you devise to trim the coil.

The matching system listed here is only one of many. The general approach is to cause the antenna to be capacitive; that is, to have it resonate at a frequency slightly higher than what you want. This will also increase the impedance of the antenna. The increased capacitance can then be canceled by an inductance in the matching portion.

The opposite is also true. However, using an inductor seems to be easier—it's less sensitive to surrounding conditions and, thus, more predictable than an air capacitor.

The third approach is to use a combina-

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Photo B. Close-up view of the loading coil.

tion of inductance and capacitance shunted in parallel to ground. This is most effective since it is basically a custom-made antenna tuner. I recently experimented with this design and found it to be very successful. To make this addition, simply locate a variable air cap having somewhere between 15 and 600 pF and mount it either directly on the car or on an enlarged platform able to hold both. Wire them in parallel and you're ready to go.

I've been able to tune the existing center loads across each entire band with at least a 1.2:1 SWR. Not bad for a $2 addition!

Before you begin, I'd like to note that designing and building antennas is a learning experience. We've all heard the story of the damaged antenna lying on the ground that worked better than when it was on the tower. Antenna performance is not always predictable, so watch for unusual results.

There are many opinions and approaches to what works or doesn't work. What's important to remember is that the antenna is only as good as its SWR and RSTs.

Construction

Preparation and assembly of the antenna is straightforward. First gather the materials. I strongly suggest that the lower portion of the antenna be made of at least 3/8" diameter SOLID aluminum or stainless steel rod. Thinner dimensions will tend to break under the stress of driving.

The length of this rod (62-1/2") will be an overall 63-1/2" when the couplers are attached. The upper whip section measures 50-1/2" overall. This includes the coupler, so measure appropriately. If you need to deviate slightly from these figures no recalculation will be necessary, just allow more turns on the loading coil. Later you can trim the coil to accommodate the changes.

At this point you'll need a tap and die set (see the sidebar). If you don't have one the local hardware store will usually do the work for a small fee. Or visit the local high school metal shop. The teachers are often very helpful and a donation of a few pizzas to the class can go a long way. Die cut a 3/8-16 thread around both ends of the lower solid antenna portion. (Remember to keep in mind that TWO couplers are used on this section and that the overall required length is 63-1/2".)

The top antenna whip can be purchased at most radio shops or at Radio Shack; or, you may have one lying around that will work. The majority will use a 1/4-20 thread. A coupler of the same thread will be used to attach this to the top of the loading coil.

I suggest you use dielectric for all threaded connections. About a month after I installed the antenna I began having problems while tuning up. I found that this was because the threaded portions had some minor corrosion due to weather. Periodically check these connections and, if necessary, treat them with electrical sealer or doping.

Mounting Bracket

The actual mounting bracket design will depend on where you decide to place the antenna on your car. Like many cars, mine has rubber bumpers. This forced me to design a bracket using 1-1/2" x 3/32" flat steel that would be bent to mount against the body BEHIND the rear bumper.

First bend the steel to fit as you would like it. Then measure how far out it needs to be cut to support the antenna. Ensure that the steel doesn't rub against other parts of the car—this would cause static and could effect the tuning of the antenna.

After the final placement and bending is completed, drill two 7/16" holes through the steel and body of the car. Temporarily attach the bracket and determine how far out to drill the hole for mounting the antenna. Mark this spot.

The size of hole to drill here will depend on the outside diameter of the insulating tubing you use around the mounting bolt. The tubing I used had an o.d. of 1/2". This hole should allow the insulating tubing to have a snug fit, so cut the hose to the thickness of the steel plus 1/8".

Drill a second hole (1/4") about 1-1/2" from the first, toward the car. This will be for mounting the coaxial grounding connection.

After all the bending and drilling is completed, paint the bracket with as many coats of clear enamel as necessary to protect it from the weather. Set it aside to dry.

Next, attach two electrical connectors to one end of the 16-1/2" RG-58 coax; 3/8" to the center lead and 3/16" to the shielding. I suggest soldering the ground connector as close as possible to the coax. Be careful not to melt the center lead insulation.

Once the bracket is dry, assemble the 3/8" coupler as shown in Figure 1. When you tighten the coupler the plastic washers will compress against the rubber hose and electrically insulate the bolt.

Then attach the shielded side to the bracket with a 1/4" bolt. Measure the resis-

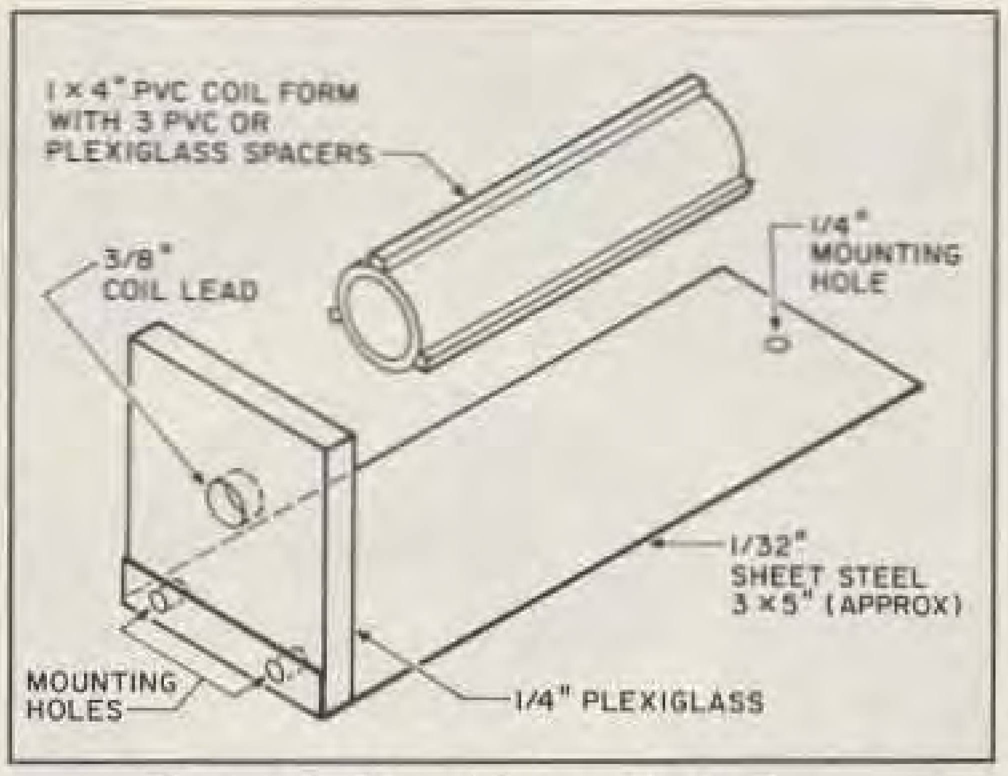

Figure 2. Matching coil platform.

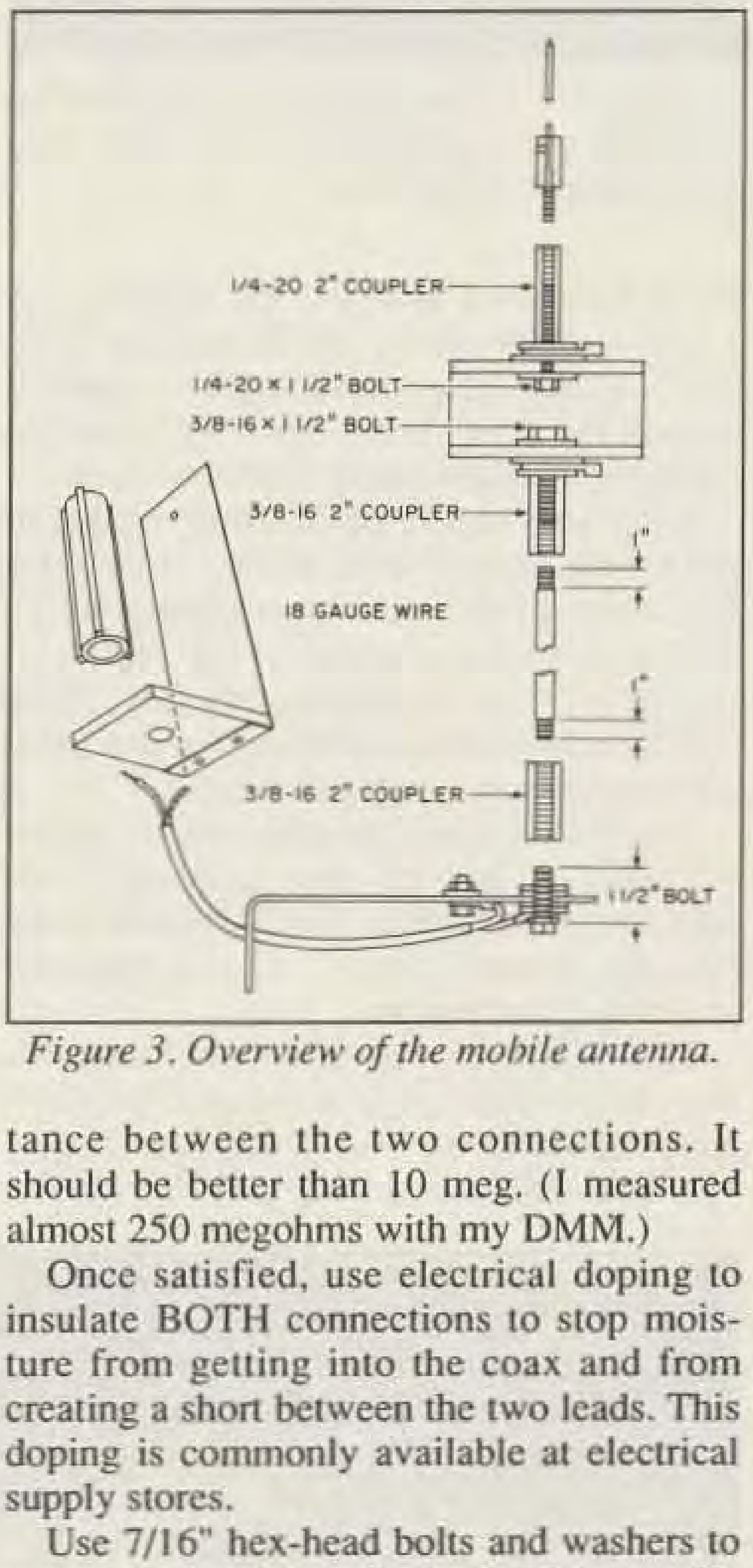

Figure 3. Overview of the mobile antenna.

tance between the two connections. It should be better than 10 meg. (I measured almost 250 megohms with my DMM.)

Once satisfied, use electrical doping to insulate BOTH connections to stop moisture from getting into the coax and from creating a short between the two leads. This doping is commonly available at electrical supply stores.

Use 7/16" hex-head bolts and washers to mount the bracket to the body of the car. To ensure a good grounding contact, scratch off the enamel where the washers meet the bracket. Consider using Lock-tight on the bolts if excessive vibrations are a factor. These bolts should extend inside the trunk about 1" beyond the nut for attaching the grounding strap.

Finally, drill a 3/8" hole through the car body next to the bracket and install a grommet. Feed the other end of the RG-58 coax through the grommet.

This completes the mounting bracket assembly.

Matching Coil

The matching coil is designed to balance an 80 meter loading coil and higher. If you decide to use a 160 meter coil you can add more turns to the matching coil.

The coil is built around a 1" PVC pipe

Photo C. The component parts of the loading coil form are made of a slice of PVC pipe with plexiglas end pieces.

about 4" long. From 1/4" Plexiglas™ cut 3-1/4" x 4" lengths to use as spacers. With PVC cement, glue these, equally spaced, around the PVC form. This will provide room for an alligator clip to be used later.

Wrap 14 to 15 turns of 14 or 16 gauge solid bare copper wire around this form. The width of the total turns should be 3". With a diameter of about 1-1/2", this coil should provide approximately 3.2 µH of matching inductance. Solder two electrical connectors to the leads of the coil.

Construct a mounting platform, as shown in Figure 2, using thin sheet steel and Plexiglas. Use a 3/8" bolt to attach the coil to the Plexiglas portion and a 1/4" to ground the coil to the steel portion.

This platform can be mounted almost anywhere inside your trunk provided it's within reach of the RG-58 feedline. Drill a 1/4" hole and mount this platform with a hex-head bolt. Again allow about 1" extra on the bolt length for the coil and jumper connectors.

Solder the two electrical connectors to the RG-58 antenna feed inside the trunk AFTER IT HAS BEEN FED THROUGH THE GROMMET. (7/16" for the shielding and 3/8" for the center lead.)

To make the jumper, remove the shielding from a piece of RG-58 about 6" to 7" long and solder an alligator clip to one end. Cut a length of heat shrink that will insulate all but 1/4" of this shielding and shrink it on. Slide the alligator clip's rubber cover over the heat shrink to the clip. Finally, solder a 1/4" connector to the other end of the jumper where the bare shielding extends.

Attach both the jumper and one end of the matching coil over the platform's 1/4" bolt. Attach the other end of the coil to the Plexiglas support using a 3/8" bolt (see Figure 2).

If you use 16 or 14 gauge wire for the inductor it will be able to support itself by its leads.

To finish the matching unit, cut a 6" to 7" length of RG-58 coax and connect a PL-259 connector to one end. Solder an alligator clip to the other end's center lead. Insulate the shielding with heat-shrink tubing, as before, with the jumper and attach a 7/16" electrical connector to the end. (Allow these two leads to be long enough for the center lead to extend to both sides of the matching coil when the shielding is connected to the 7/16" bracket mounting bolt.)

At this point you can add a variable capacitor. Remember to wire it in parallel and you're all set.

Loading Coil

Cut a piece of 4" PVC tubing into slices, referring to Table 1. Make these cuts as square as possible. This will determine the straightness of the antenna. Because bolts and washers extend toward the inside of the coil, the PVC slice should not be cut less than 1" wide.

On a sheet of 1/4" Plexiglas, outline two disks for each loading coil by using one of the slices as a guide. I've had excellent results using a saber saw with a moderate tooth blade (12/inch) under moderate pressure. This should avoid chipping but may create melting. Pliers can be used to pull off the melted excess.

Photo D. The matching coil assembly mounts inside of the vehicle. Grounding and feedline alligator clips allow for fine tuning of the resonance and impedance of the antenna.

Drill a 3/16" hole through both disks at the same time to help center the antenna studs. Then drill one of these to 5/16". Drill carefully to avoid chipping or cracking. For added strength, drill three holes in a triangular pattern through both disks. The holes should be about 5/8" in from the edge to provide clearance for the PVC tubing thickness (1/4"). The size of these holes depends on the size of the plastic bolts you'll be using. I strongly suggest that you tap these holes to allow the bolts to thread. Plastic bolts aren't very strong and the added benefit will be needed.

Tap the center 3/16" and 5/16" holes to 1/4"-20 and 3/8"-16 thread, respectively. Using fender washers to help disperse the pressure, thread each bolt through to ensure a clean tap. Back the bolts out about 1/4" and apply a generous amount of instant glue to the threads. Re-tighten to a snug fit.

Placing the threads outward, glue the two disks to a PVC slice with five-minute epoxy (clear type) and let them dry. An important point when gluing is to have all the pieces under moderate pressure to ensure a tight bond. To do this, thread the plastic bolts through and tighten them before the glue dries. DO NOT USE METAL BOLTS FOR THIS—they will interact with the loading coil and could distort the radiation pattern.

Once dry, solder a 1/4" electrical connector to one end of the 18 gauge enamel wire that will be used for the coil. Bolt this to the top part of the coil form using spacing washers and the 1/4" coupler.

With a flat iron tip melt a groove into the edge of the top Plexiglas disk. Press the enamel wire into the groove while it's still soft. This will stop the coil from unraveling. Wrap with an appropriate number of turns for the band you've chosen. Try and keep the turns as tight as possible and pressed together.

Use plenty of electrical tape to temporarily hold the coil wire in place. Mount the 3/8" connector to the lower side as you did with the top side, but don't solder the enamel wire—you'll need it loose for tuning later on.

Fine-Tuning

Attach an SWR meter to the matching coil's PL-259 connector. Hook up your radio as it would normally be and attach the feedline to the other side of the SWR meter. The feedline alligator clip should be attached to the ungrounded side of the matching coil where the antenna feedline is connected. The coil's grounding jumper should be unconnected. (You can clip it to the end of the PVC form.)

Assemble the antenna and attach it to the coupler on the mounting bracket. (I added a second support higher up to allow the lower antenna to stay permanently on the car.) (See Figure 3.)

File the enamel off the tip of the lower loading coil wire that isn't attached. Use an alligator clip to temporarily hold the con-

Table 1. Center Coil Dimensions

Band	Turns	Coil Length	Form Length	PVC Diameter
160	62	2.75"	2.875"	4.5"
80	23.75	1"	1.125"	4.5"
40	10.25	0.5"	1"	4.5"
20	7.50	0.5"	2.5"	2.375"
15	2.80	0.125"	2"	1.875"
10	No center coil necessary; join the two rods together with a coupler.			

nection for tuning. The clip should not have any wire attached to it.

Check for the best SWR, 100 kHz down from the center frequency you want the antenna to resonate at. Adjust by clipping one quarter turn at a time, each time checking the SWR. Don't test by shorting the loading coil—this will degrade the efficiency of the coil and give false readings.

Once you get near the null (where the SWR begins to dip) adjust to your desired frequency and continue by clipping 1/4" to 1/2" at a time. Each quarter turn should increase the resonance by about 50 kHz while half-inch snips should be 10 kHz.

Once you are satisfied, remove the coil and solder the enamel wire to the lower connector. Reassemble and check the SWR. If there are any problems you'll need to restart the fine-tuning from the beginning, and possibly rewrap the coil.

Repeat this process for each band coil. Try not to change the matching unit. The goal is for the coil to be the only necessary change to switch bands.

The matching coil alligator clips are used for within-band adjustments. These will allow for adjusting the SWR within a small range after the overall tuning is complete. The feedline clip is used to balance the matching coil, while the jumper is used to adjust the inductance. You'll need to be patient to successfully tune to different frequencies.

The results could be marked by paired colors, 1/8" jumpers could be soldered to the matching coil at these points for easier reference, or a two-pole rotary switch could be used to make band switching quick and easy.

If you choose to include the variable capacitor in the matching system you'll have more leeway. (The grounding jumper wasn't necessary when I made this addition later.)

Whatever you do, the shorter the leads are the better. Everything effects the antenna. Even the 16-1/2" feedline is part of the antenna and will effect the tuning if it is changed.

Hot glue or five-minute epoxy could be spread on the enamel wire once all tuning is complete. I haven't been able to find heat-shrink tubing big enough to fit over the coil, although this would be best. If you use 2" PVC or smaller for the loading coil form, 3" heat-shrink tubing is available from Electronic Surplus (R&D Electronics) in Cleveland, Ohio.

Finishing

The guy connection I'll leave up to you. High strength fishing line, thin rope, or mason line are all good choices. Either way, guys are necessary to avoid damage. I suggest using two support lines.

I've had many S7-9 reports within a 400-mile radius of my West Virginia QTH on the 80 and 40 meter bands. On the 15 and 20 meter bands I was able to QSO with stations in France and Germany while traveling through northern Ohio.

Although commercial designs may have a 20% improved bandwidth, the quality of this design should meet your needs.

I'm interested to hear of any changes you make to the design, including the matching system, and would appreciate hearing from you about your results. Good luck! 73s. 73

Contact Stephen A. Glowacki at Rt. #3, 205 Hickory Drive, Elkins WV 26241.

Tap and Die

If you're not familiar with the mechanics of a tap and die, no problem. The procedure is straightforward.

First locate the proper size of die. (This is what cuts the threads into a rod to make it resemble a bolt.) Using the 3/8"-16 size as an example, the first number measures the diameter of the outside of the threads, and the second number tells how many threads there are per inch. These numbers appear on the die itself, which can be purchased individually for about $2.

You need a handle to hold the die steady during the process. These cost about $8-$15, depending on the style.

If you want to save money, Sears has a 20-piece Homeowners Set for under $20, available through their catalog store. Whatever you buy, just make sure that the 3/8"-16 and 14"-20 are part of the set. These are common sizes used in amateur radio.

The technique for cutting with a die is simple. Brace the rod steady either in a vise or with Vise-Grip pliers. (I used the latter, attaching the pliers near the base of the rod and then standing on them for bracing.)

Placing the **wide** side of the die toward the rod, turn slowly but with pressure. You'll feel it cut into the aluminum almost immediately.

Make sure that the first two to three thread cuts are square so that the die remains perpendicular to the rod.

The die needs to remain square to the rod **while** it is turning. This is the most difficult part of the whole process. Once the first two to three threads are cut, the rest is easy.

Now the turning technique: Turn the handle clockwise 90 degrees, then reverse and turn back until you feel the metal filings snap. (About 30-40 degrees.) Then, turn clockwise another 90 degrees and again reverse to snap off the filings. Continue this process until the proper length is cut. I find it easier if I imagine north, east, south and west and keep to those points.

It may be necessary to turn continuously for the first thread or so to help the die take hold. Don't be afraid to back off and start again.

Once the cutting is started, have some lubricant available and apply moderately. There are certain lubricants preferred for some metals. Generally, a light oil or kerosene is good for aluminum and stainless steel.

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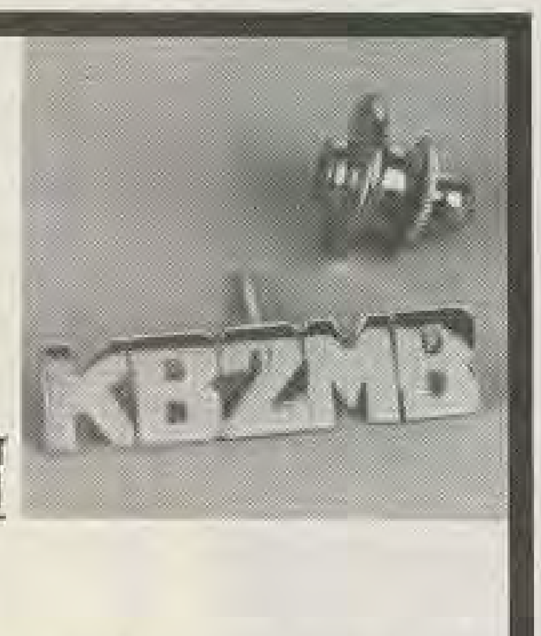

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