A Glass-Mounted 2-Meter Mobile Antenna

Want a no-holes, no-paint-scratching antenna? This easy-to-build glass-mounted mobile antenna is the answer!

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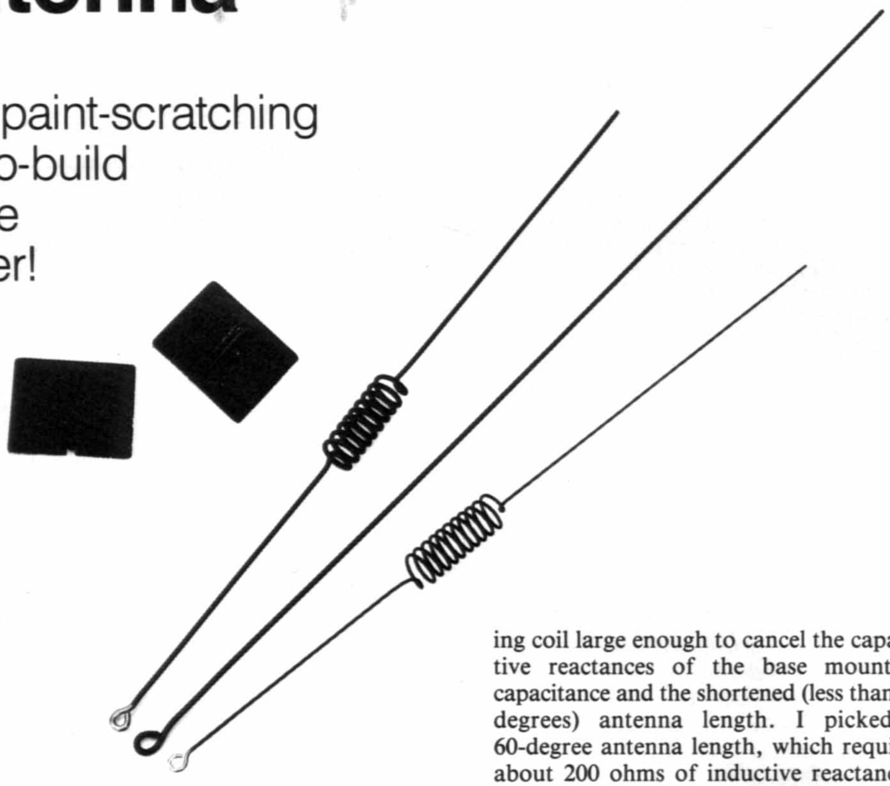


To me, mag-mount antennas are a pain in the neck. Yet, I couldn't bear to drill a hole in my car to install a permanent mobile antenna. So, I found an alternative. In this article, I'll tell you how to build an attractive glass-mounted antenna that looks like those used for cellular-telephone service.

The antenna is easy to build. No special tools or skills are required, yet the antenna's appearance is compact and high tech. Instead of having an untidy mess on your car roof, people will think you are one of the nouveau riche. If you're not up to building one of the antennas, you can get one ready to install.[1]

The System

Fig 1 shows a schematic of a glass-mounted antenna system. At A is the electrical equivalent of a ¼-λ antenna. Why the need for L and C, and how does the signal get from the coax to the antenna without a connecting wire? The reason—and the way—is capacitance. The mounting plates on either side of the glass act as capacitor plates separated by a glass dielectric—your windshield or window. This capacitor exhibits a negative reactance. To cancel the negative reactance, inductance (L) is used. Because C and L have equal but opposite reactances at the frequency of interest, the feed line sees just the ¼-λ antenna. This antenna can be a simple ¼-λ whip, or it can be physically shortened with a loading coil to give it the cellular-phone look. More on this later.

Note that the feed-line shield is grounded near the capacitor. Because we're using a ¼-λ antenna, this is an important part of the system. Obviously glass makes a bad ground plane, but there is still plenty of metal around to do the job.

Antenna Design

The size of the antenna mount was determined by structural and appearance considerations. I made the mount as big as my taste would allow. I calculated the mount's capacitance to be 10 to 20 pF. (I can't calculate it any closer because I'm uncertain about the dielectric constant and thickness of the glass and adhesive.) This capacitance range equates to a reactance of about 60 to 120 ohms at 2 meters. Therefore, the inductive reactance required to cancel the mount's capacitive reactance is 60 to 120 ohms.

How do you build the right amount of inductance into the antenna? Look at Fig 2. This graph is from *The ARRL Antenna Book* (Fig 36, p 2-36). When an antenna is shorter than 90 degrees, it looks capacitive to the feed line. When it's longer than 90 degrees, it looks inductive. Armed with this information, I went on two design paths:

- Make a whip antenna longer than 90 degrees to provide the inductance needed to cancel the base mounting capacitance. From Fig 2, this is about 96-106 degrees, which calls for an antenna length of 20 to 22½ inches. Using no. 10 copper wire, my antenna ended up being 21½ inches long.
- Make a shortened antenna with a loading coil large enough to cancel the capacitive reactances of the base mounting capacitance and the shortened (less than 90 degrees) antenna length. I picked a 60-degree antenna length, which requires about 200 ohms of inductive reactance.[2] Adding an appropriate amount of inductance to that needed to cancel the base capacitance—and allowing some extra—I decided on a ½-inch diameter, 9-turn coil 2 inches long. This is all very approximate, but we don't have to worry too much about precision here. All sins will be forgiven when the antenna is trimmed.

Antenna Elements

I tried several materials for making antenna elements. Stainless steel is by far the most durable. It is hard to work in sizes over 1/16 inch, but 1/16-inch welding rod is workable with ordinary tools. Bare copper wire is by far the easiest to work, but it is too flexible unless first stress-hardened by stretching.[3] (To ensure proper mounting-flange spacing, be sure to stretch the wire before making the antenna mount described in the next section.) Stress-hardened copper wire stands up well to freeway driving. Feel free to experiment with other materials.

Fig 3 gives finished dimensions for antennas I've made. The length for best SWR may be slightly different when the antenna is mounted on your car, but that shouldn't matter because you'll be starting with a longer element length and trimming to size.

Making a long whip is easy. Cut a 24-inch length of straight wire. Bend one end into a small loop with needle-nose pliers. Be sure the loop will pass a no. 6

[1]Notes appear on page 34.

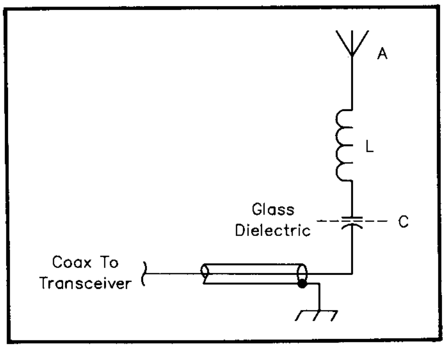


Fig 1—Schematic of a glass-mounted antenna system. The signal passes through the glass via the plates of the antenna mount, which form capacitor C. This capacitance is canceled by inductance L. Therefore, the feed line just sees the ¼-λ antenna A.

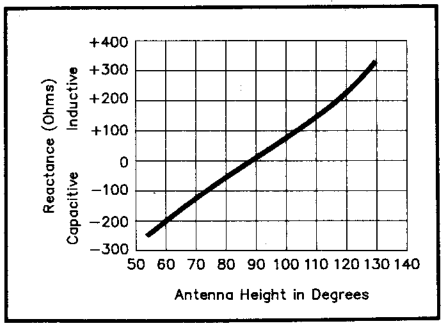


Fig 2—Approximate reactance of a vertical antenna over perfectly conducting ground. The wavelength/diameter ratio is about 2000. Actual reactance values vary considerably with wavelength/diameter ratio.

screw. Except for painting, you're done.

Making the shortened antenna is only a little more complicated (see Fig 4). Sand the antenna wire before forming the coil. To make the coil, clamp one end of a 3-ft length of straight wire in a vise. Bend the free end into a small loop as for the long whip. Then place the center of a ½-inch wooden dowel six inches from the center of the loop and roll the wire up on the dowel for 9 turns, moving toward the vise. Remove the wire from the vise and cut off the bent end. Hold one end of the coil with pliers and bend the free end so it cuts through the axis of the coil perpendicular to it. Then hold the bent portion with pliers near the coil edge and bend the wire so it is on the axis of the coil. Bend the free end on the other side of the coil along the coil's axis in the same way. Cut the end that was in the vise 7 inches or more from the coil. Space the turns so that the finished coil is about 2 inches long.

The Antenna Mount

The antenna mount (see Figs 5 and 6) is made from brass strips that are readily available at hobby stores. The details are shown in Fig 5. The inside plate is a 1½ × 2-inch piece of 0.016-inch brass with a 3/16-inch-wide tab cut from it. Brass of this thickness can be cut easily with metal shears. Just make two cuts ¼ inch long and bend the tab down. The tab is shown at the top of the plate in Figs 5 and 6, but it could be placed on the side if that better suits you. (The feed line will eventually be soldered to this tab.)

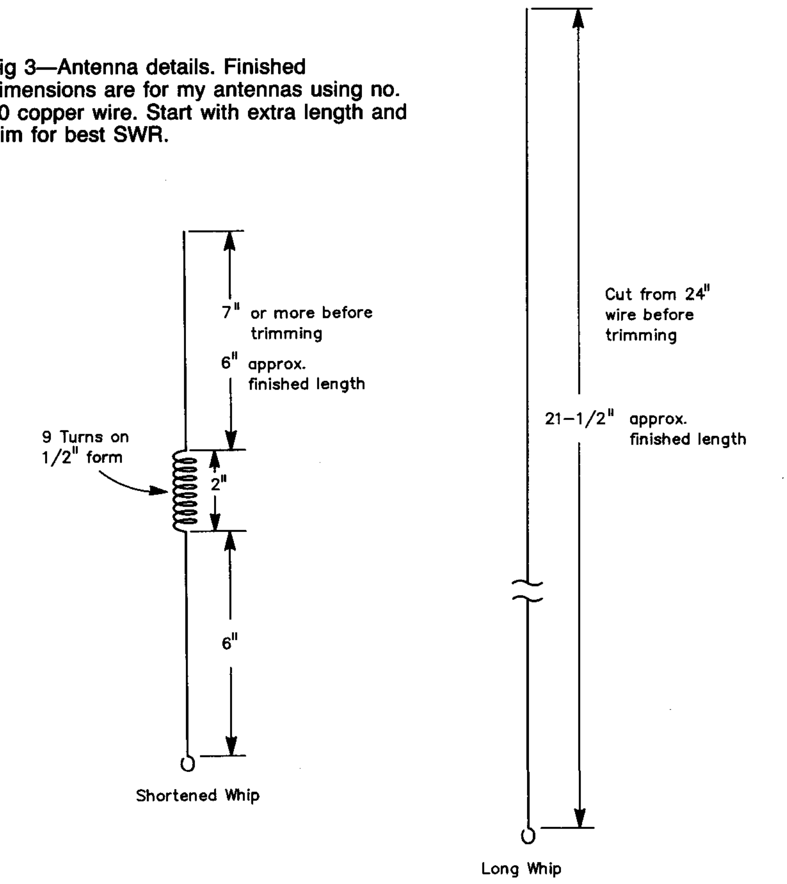
Now assemble the outside mount. Note that the right-angle flanges that hold the antenna are made from 1-inch-wide by 0.025-inch-thick brass strip. You'll need heavy-duty metal shears or a hacksaw to cut this brass. Start with 1- × 1-inch pieces and cut the corners off as shown in Fig 5. Then bend them by clamping them in a vise and hammering them over. Drill the hole in one flange before soldering to the mounting plate. To solder the flanges to the outside mounting plate, first apply solder to both parts. Then, press the flange onto the plate with a soldering iron to melt the solder. Before removing the iron, apply pressure with a screwdriver to keep the flange in place until the solder hardens. An iron with a reasonable amount of power is needed. (I used my 140-W gun.) After mounting the first flange, space the second flange from the first using the antenna wire. After both flanges are soldered in place, drill the second hole using the first hole as a guide. Be sure to file off all burrs, and for a neat appearance, round the corners and file off all solder blobs and flows. Set the mount aside for now.

Painting

Although it's not necessary to do so, I painted my mount and antenna. (*Don't paint the sides of the mounts that will be glued to the glass.*) Flat black paint provides a clean, finished look. Before painting, clean off all flux and sand surfaces with fine sandpaper until they are uniformly clean and bright. To paint, bolt the antenna in the outside mount and stand it upright. This makes it easier to paint and ensures that the electrical contact surfaces are not coated.

Brass doesn't take paint well. I primed my first prototype with auto primer. Although the paint looked fine, it chipped easily. An etching primer works much better. A primer designed for brass is best, but primers designed for aluminum will work, too. Flecto Ferrothane Surfabond no. 52 is one of these. (Marine supply stores carry brass primer.) Once the metal is primed, apply a finish coat of a good quality flat black paint intended for metal. I used Rust-Oleum Bar-B-Q Black. It is a high-temperature paint that stands up to soldering.

Fig 3—Antenna details. Finished dimensions are for my antennas using no. 10 copper wire. Start with extra length and trim for best SWR.



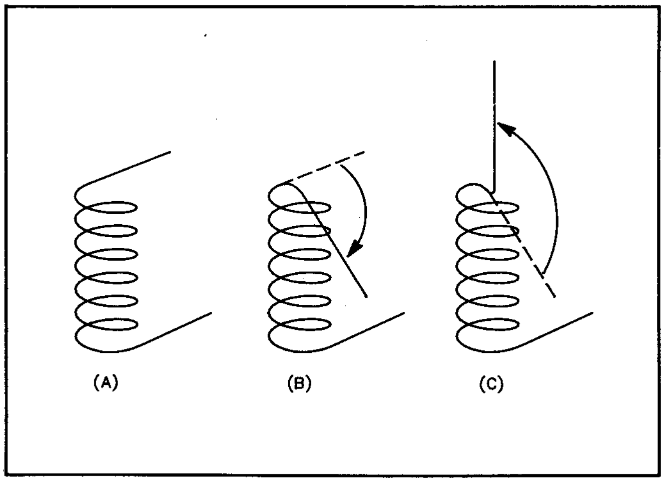


Fig 4—Bending the shortened antenna. After forming the coil (A), bend one free end so it crosses the coil axis perpendicular to it (B). Then bend up along the coil axis (C). Repeat this procedure on the other end so both ends are along the coil axis.

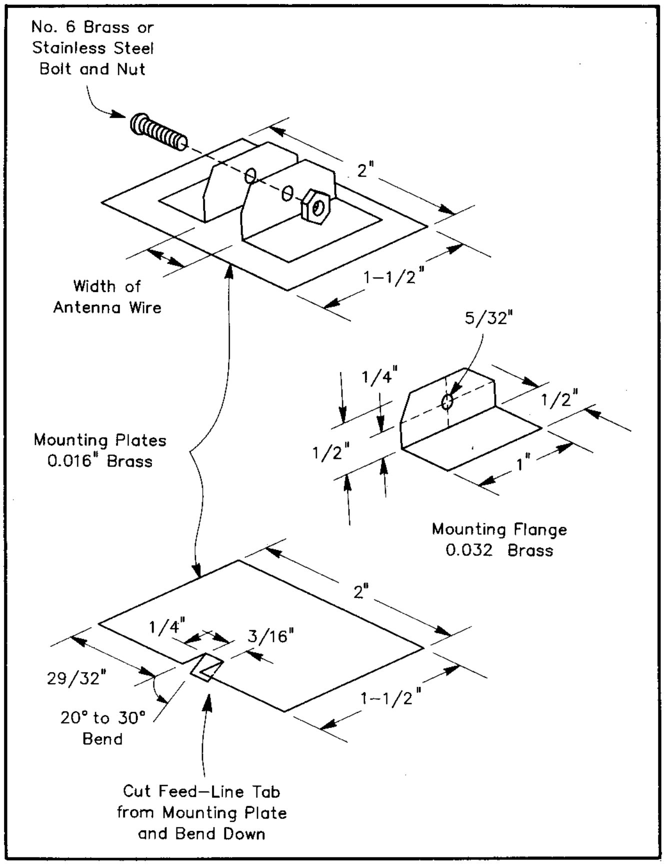


Fig 5—Antenna-mount details. Solder mounting flanges centered on the top mounting plate. The mounting flanges are cut from brass strips available at hobby stores.

Assembly

The most popular position for mounting on-the-glass antennas seems to be the top center of the rear window.[4] I have a station wagon, so this wasn't convenient for me. I located my antenna at the top center of the windshield. I like it in this position because the inside mount is neatly behind the rear view mirror and the coax route to the rig is short.

Before sticking the mount to the glass, solder the center conductor of the feed line to the inside plate's tab. Solder the coax braid to a ring lug, leaving enough braid exposed to reach a nearby screw in the headliner trim or mirror mount for grounding to the vehicle body. The grounding screw should be close to the mount, near the glass. If you don't have a screw conveniently close, put one there. *The antenna won't work right without a properly grounded shield.* If needed, drill a small hole in the headliner trim into the mounting metal, and insert a self-tapping or sheet-metal screw. After installing the mount, remove the screw, place the ring lug over it and replace the screw.

I tried several adhesives for the mount, but the easiest to use is double-sided foam tape. Radio Shack tape (RS 64-2361) appears to be Scotch no. Y-4950, which is described as having "high peel strength and excellent weatherability." The tape comes in 1-inch-wide strips so use two strips side by side on each plate. Clean the glass and the mounting plates with rubbing alcohol before application. Apply tape to the mounting plate first, then stick it to the glass. Once it's applied, don't move it. If you make a mistake, remove the mounting plate, clean it up and put on a new adhesive strip. Although this tape should weather well, it's a good idea to seal around the edges of the outside plate with a thin bead of a silicone sealer (such as Radio Shack 64-2314).

Use RG-58 cable for the feed line if you mount the antenna on the windshield. This small-diameter coax is easily routed to the

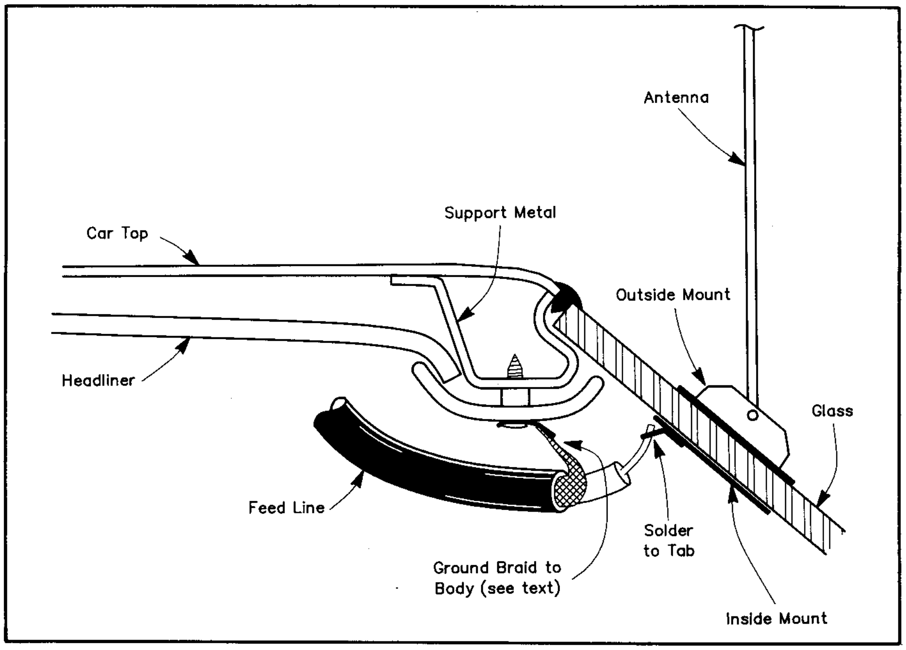


Fig 6—Antenna-mount installation. Mounting plates are applied to opposite sides of the glass. The antenna is bolted to the outside mount. The center conductor of the feed line is soldered to the inside mount. Ground the coax braid to the body using a nearby screw.

transceiver. RG-58 has rather high loss at 2 meters. For the lengths used here, however, losses are below 1 dB, so they won't be noticeable. For line lengths over 10 or 15 feet, use RG-8X (Radio Shack RG-8M) coax. It has a slightly larger diameter than RG-58, but losses are lower.

Routing the feed line to your rig requires some ingenuity if you want the feed-line run to be invisible, or almost so. If you install the antenna on the vehicle's rear window, you may want to route the coax under the headliner. Look for screws or other headliner retainers around the trim edges. You should be able to drop some of the headliner and snake the coax through. I tucked the feed line into a gap between the headliner and the windshield trim along the top of the windshield, then used small dabs of cement to run it in an indentation along the door post to my transceiver. This worked well because my car's black trim matched the coax outer covering. Terminate the transceiver end of the feed line with a connector to match the one on your rig. If you're going to use a hand-held transceiver, cut the coax a bit long.

Pruning the Antenna

Once the antenna is installed, trim it for minimum SWR. Insert an SWR meter between the rig and the feed line. With your rig set for low power, check the SWR near the bottom and top ends of the 2-meter band. The SWR should be lower at the low end of the band. If not, and both SWR readings are over 2:1, the antenna is too short. There isn't much you can do to fix this except make a new antenna element. Most likely, however, everything will be okay. Using wire cutters, trim about 1/8 inch from the antenna tip, rechecking the SWR near the center of the band. It's best to remove only 1/8 inch at a time to avoid cutting off too much. Keep trimming the antenna length and checking the SWR until you get it near 1:1. Check the SWR near the band edges and at your usual frequencies of operation. Trim carefully if you want better SWR at the higher end of the band. I trimmed my antenna for lowest SWR at 146 MHz. At the band edges, the SWR of my antenna is 1.4:1, giving good performance over the whole band.

Summary

There you have it! With a glass-mounted antenna, there is no need to drill holes through your roof or put up with a mag-mount mess. A glass-mounted antenna gives you convenience and a high-tech look.

My operating experience confirms that these antennas perform about the same as a regular ¼-λ antenna. The long whip should have slightly more gain than the shortened one, but both should be within 1 dB of a roof-mounted ¼-λ antenna. This is plenty good unless you are in a fringe area. In fact, higher-gain antennas won't necessarily help you if you are in a "hole" in hilly terrain. This situation is common where I live in the San Francisco Bay area. I have been very pleased with the shortened antenna's performance and appearance.

Notes

1. Contact William J. English, 81 Meadow View Rd, Orinda, CA, 94563. (The ARRL and *QST* in no way warrant this offer.)
2. Actually, this coil-sizing method applies only to a base-loaded antenna with a coil small enough that its radiation can be neglected. Our antenna is center loaded (this increases the inductance required) with significant radiation (reduces inductance required). Rather than sorting these effects out mathematically, I just made the element long and trimmed for best SWR.
3. Here's how to stretch no. 10 copper wire. Place one end of a length of wire in a vise. Wrap several turns of the other end around a crowbar about 6 inches from the fulcrum end. Leave enough free wire between the vise and bar for the antenna you are making. Place the fulcrum end of the bar against the edge of your work bench opposite the vise, or against another solid object. Pull until you feel the wire give several inches. Not only will this stiffen the wire, but it also straightens out all the kinks. Cut the wire at the crowbar end. Leave the straight wire clamped to the vise to form the coil if you are making the shortened antenna.
4. A letter from Joseph Butcher, KE9FZ, prompted your editor to seek some information on the RF properties of tinted window glass. Mounting on-glass antennas to factory-tinted (deep-tint) windows, he says, results in problems with high SWR.

   Rex Greenshade of the Ford Motor Company told me that he believes OEM-specified tinted glass does not cause the problem: Aftermarket heavily tinted glass is the gremlin. Rex said that the maximum OEM glass tinting must conform to certain specifications, one reason being that police officers must be able to view the occupants of the vehicle when approaching on foot.

   Ken Brown of the Ford Motor Company told me that no Ford OEM glass tints interfere with RF. However, Instaclear—not a tint—*does* interfere with the transmission of RF. Radar cannot penetrate it and it does interfere with the installation of glass-mount antennas. Instaclear is a Ford option that permits rapid clearing of ice and snow from a car's windshield. Instaclear glass has a conductive powder added to the layers of windshield glass. Although Instaclear is not designed as a tinting element, under certain lighting conditions and viewing angles it can appear as a pink or bronze tint that is highly reflective and virtually opaque. Ken said that Instaclear does not violate any existing state laws governing tinted window glass.

   Scott Staedtler, N8ILG, of Antenna Specialists Co, told me that in his experience, the degree of tinting *does indeed* have an effect on glass-mounted antennas. He's aware of Instaclear, but claims that the *OEM privacy glass tint* (as used on Ford vans and Broncos, for instance) as well as *aftermarket* tints *can* cause problems. Rear-window defoggers/deicers do not interfere with on-glass antennas so long as you avoid mounting the antenna on the wire trace(s).—*Ed.*

Bill English began studying electronics as a hobby in the early '80s. This led to his interest in Amateur Radio. He received his Technician license in October 1988, and upgraded to Advanced class in February 1989.

In 1978, Bill graduated from the University of Toledo with a Bachelor of Science degree in Chemical Engineering. After seven years of engineering assignments as a refinery engineer for a major oil company, Bill now works in supply and distribution.

Bill's Amateur Radio interests lean toward the hardware side. He enjoys designing and building 2-meter antennas, and has constructed HF antennas and station accessories and test equipment. Bill's on-air time is spent on 2 meters and chasing phone and CW DX on the HF bands.

New Products

The ARRL and QST *in no way warrant products described under the New Products banner.*

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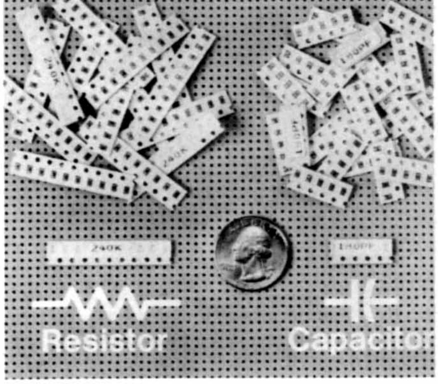
☐ Communications Specialists, seeing the plight of small-volume chip capacitor and resistor users, now offers these components in small quantities. Numerous values of both resistance and capacitance are available (call for specifics). Resistors are sold in strips of ten and sell for $2.50 per strip, and capacitors, packaged in strips of five, cost $1.25 per strip. Each strip is marked with the component value. Communications Specialists's minimum order is $10, and all values are in stock. CS accepts Visa, MasterCard, COD or prepayment. For a brochure or more information, contact Communications Specialists, 426 W Taft Ave, Orange, CA 92665-4296, tel 800-854-0547 or 714-998-3021; 24-hour fax, 714-974-3420.



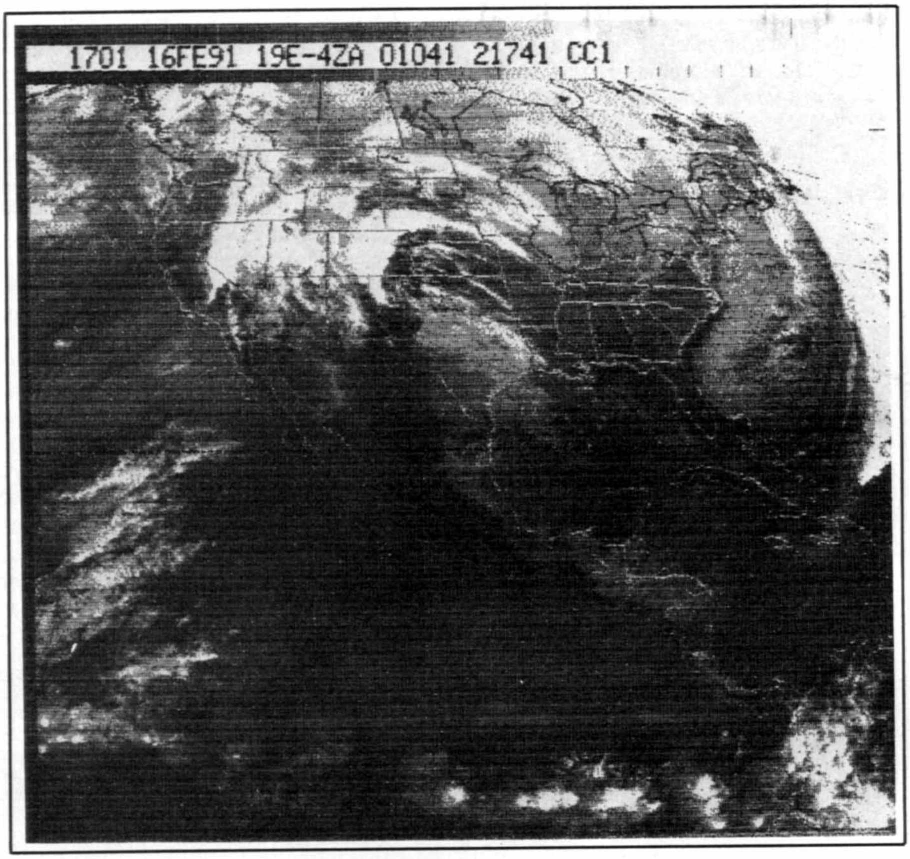


Fig 3—A 14-gray-shade HF weatherfax infrared IR image. On a cold winter day, the warmer Gulf Stream is visible off the East Coast. IR imagery is used mainly to determine cloud height by measuring the cloud temperature. This image was printed on a Seikosha SP-1000I printer.

incorporates a print program that minimizes paper use (see referent in note 2).

• HIREZ—To get the highest resolution possible (see Fig 2) and maintain a proper aspect ratio with a near-letter-quality (NLQ) printer, this program stores every line of incoming fax data at 960 pixels per line. A minimum of 512 kbytes of RAM is needed.

• 14GREY and 8GREY—These programs provide 14 and 8 shades of gray, respectively. 8GREY needs 512 kbytes of RAM; 14GREY requires 640 kbytes. 14GREY uses a double printer-head pass to produce the additional gray shades (see Fig 3). 8GREY, which uses a single printer-head pass, is adapted for use with inkjet printers that "blot" adjacent pixels when the two printer passes of 14GREY are used. 8GREY can also be used to reduce printing time, printer wear and memory storage requirements.

All of these programs are written in BASIC, so they save the images in 64-kbyte files. The use of BASIC allows you flexibility in creating your own programs for scheduling the reception of many images and properly storing them.

Printing and Viewing

• LOPLAYBK, HIPLAYBK, 14PLAYBK and 8PLAYBK are used to load into memory fax maps and pictures stored on disk. If you've saved an image using 14GREY, you can view and print the image using 8PLAYBK, if you want to print it on an inkjet printer (or if you have a fresh ribbon in your dot-matrix printer).

An Epson-compatible printer that accepts the graphic command ESC "L" n1 n2 and the carriage advance command ESC "3" n is required to print the images.

Image-Reception-Scheduling Programs

• 14SKED, 8SKED and LOSKED. The first two, 14SKED and 8SKED, are higher-resolution image-reception programs that allow you to schedule reception of a mix of maps and satellite images throughout the day, store them on disk and play them back for viewing and printing at a later time. If you look at the same maps every day, you can use the same file names and overwrite older files. If you want the files stored somewhere other than the default drive, you can do so by simply including the path in the file name (for instance, A:36hour). Both programs use HIREZ for maps and the specified gray shades choice for pictures.

In their present forms, the programs can handle up to five images. With a little BASIC programming, you can easily expand that number.

LOSKED is similar to 14SKED and 8SKED, but used for lower-resolution map reception. If the prevailing signal-to-noise ratio is excellent, LOSKED provides adequate results with a minimum of memory usage.

Copies of the programs, a sample picture and more-detailed program and operational information are available from me. Please send me a formatted disk (360-kbyte, 5¼", 720-kbyte or 1.44 Mbyte, 3½") in a self-addressed disk mailer bearing 45 cents First-Class postage.—*Ben Vester, K3BC, 4921 Bonnie Branch Rd, Ellicott City, MD, 21043*

MORE ON THE GLASS-MOUNTED 2-METER MOBILE ANTENNA

☐ I received some comments regarding my article "A Glass-Mounted 2-Meter Mobile Antenna System,"[3] that may be of interest to readers.

Howard W. Wease, KB7IBG, has a fiberglass-body car and wanted to know how to terminate the coax braid at the feed point, because there was no convenient metal body part to use for the ground point. The solution may also be of interest to those who don't want to drill into the trim of a metal-bodied car to affix a grounding screw.

Recall that this is a ¼-λ antenna. A traditional ¼-λ ground-plane antenna can be made by connecting ¼-λ radials to the braid at the feed point. Usually three or four radials are used, but two—or even one—will suffice.

I used #22 hook-up wire for the radials. See Fig 4. I don't have a Corvette to try this on, so I tested the antenna on a glass pane away from other objects, and in my car, to bracket the problem. Sure enough, 19½-inch radials did the job on the glass pane, presenting a low SWR when the radials were bent downward 45 degrees relative to the vertical element. The SWR with the radials at 90 degrees to the vertical element was acceptably below 2:1.

In my car, I tucked the radial wires into a groove between the headliner and trim—near lots of metal. As expected, there was lots of interaction between the radials and the car body. The 19½ inch radials were too long—the SWR was a little over 2:1 at the high end of the band, and about 1.5:1 at the lower end. I gradually trimmed the radials to a length of 14¼ inches. At this point, the SWR was under 1.5:1 across the band.

Here's the bottom line: If you have a fiberglass car, use 19-inch radials and trim the radiating element for best SWR. You may not get minimum SWR without trimming the radials too, because the car

[3]B. English, "A Glass-Mounted 2-Meter Mobile Antenna," *QST*, Apr 1991, pages 31-34.

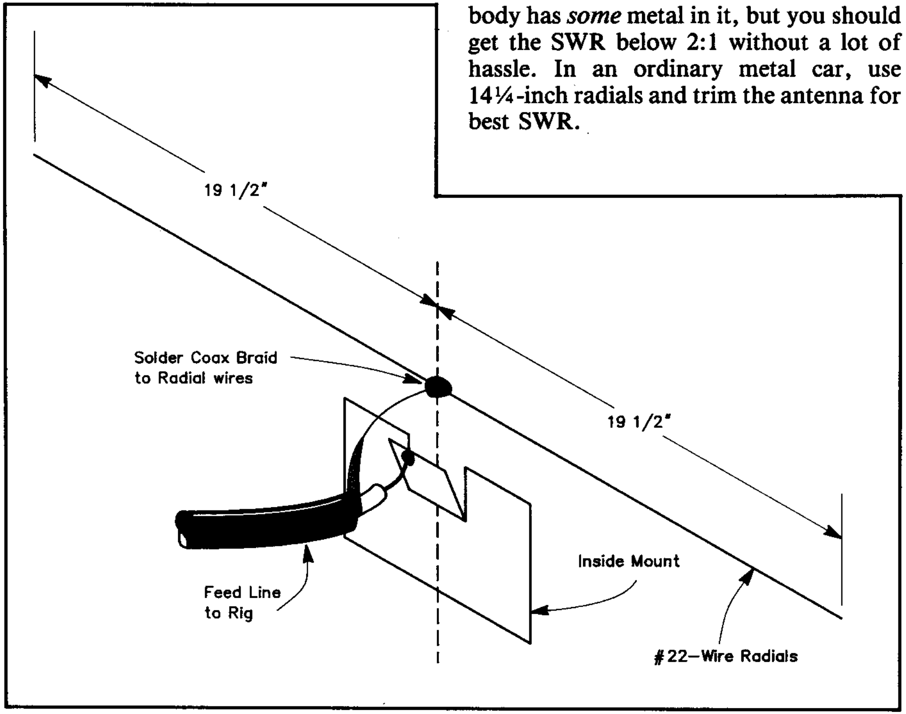


Fig 4—If the feed-line braid can't be grounded to the car-body metal, use a pair of wire radials. Solder the feed-line braid to a pair of #22-wire radials which can be tucked into the car's headliner or trim.

body has *some* metal in it, but you should get the SWR below 2:1 without a lot of hassle. In an ordinary metal car, use 14¼-inch radials and trim the antenna for best SWR.

Charles Davis, KA4RBN, built and installed his antenna so quickly that his letter arrived the same day as my copy of April *QST*! Charles offers a safety tip (sorry for the pun!): Drill a hole the diameter of the antenna wire part way through a plastic bead, and glue the bead to the end of your antenna. This eliminates a sharp antenna end that may poke you when you wash your car.

Antennas are still available for $39.95. Please allow 4-6 weeks for delivery. Add 2 weeks for personal checks to clear the bank. Because most folks want the shortened, cellular-look antenna, I prefer to supply them exclusively. However, if you really want the long whip, let me know! In addition to the antenna element, you'll receive inside and outside mounts painted flat black, with double-sided tape applied. You supply the feed line. Full installation instructions are included with each antenna.—*Bill English, N6TIW, 81 Meadow View Rd, Orinda, CA 94563*

Note: All correspondence addressed to this column should bear the name, call sign and complete address of the sender. Please include a daytime telephone number at which you can be reached if necessary. (The ARRL and *QST* in no way warrant offers of products or services presented herein by correspondents.)