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Zounds! Grounds!

Here are the down-to-earth details you need to install a perfect ground system.

Every book on longwire or vertical antennas stresses the need for a good ground. If you have ever tried to make an end-fed longwire work without a good ground, then you understand why it is so important. We are also told in countless books and articles that a good ground is necessary to prevent TVI and protect against lightning. What is left unsaid, perhaps assumed to be universal common knowledge, is what constitutes a "good" ground. More pertinent to most amateurs, perhaps, is *how* do we obtain a good ground? For most amateurs, the answer is easy to achieve.

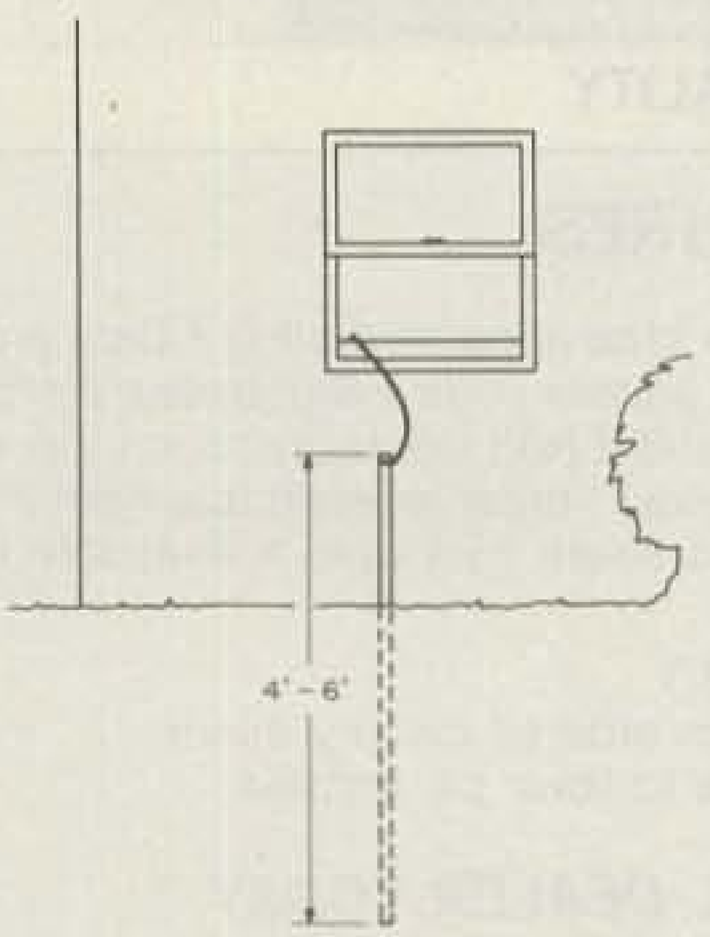

Fig. 1. An ungood ground.

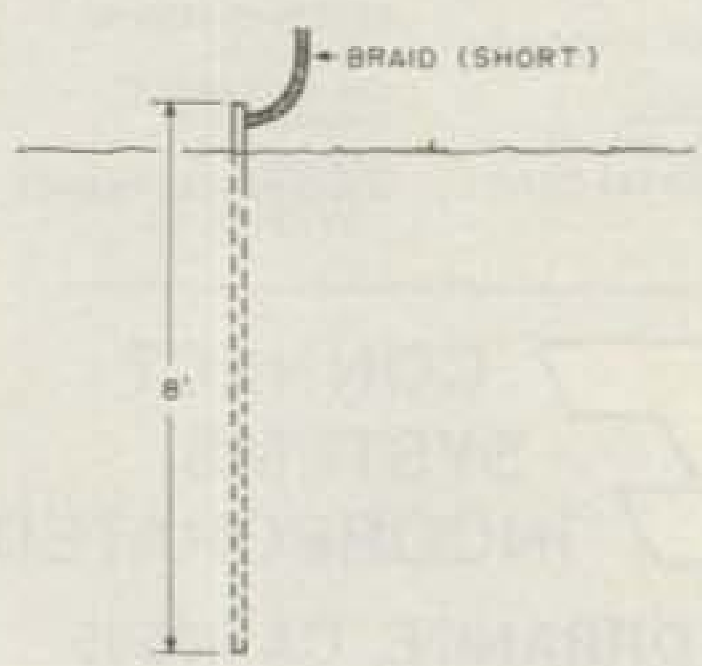

Fig. 2(a). The best ground.

What Is Not Adequate?

One way of defining an adequate ground is to describe situations that are not adequate. Some amateurs try to use the third-wire ground of the ac power line serving their shack as an rf ground. After all, it *is* grounded, isn't it? Well, that depends on what we mean by grounded. That third wire in the power system may be many wavelengths from the point where it is connected to earth ground. To dc and low-frequency ac (e.g., 60 Hz), such a wire is, indeed, low resistance. But to rf, such a long ground wire is a high impedance, so it may be no ground at all!

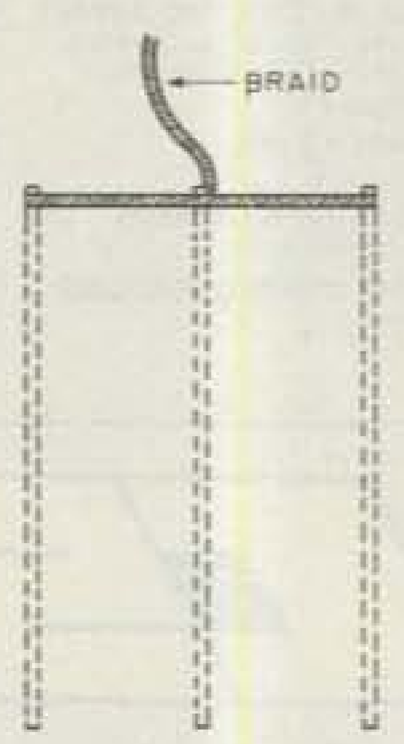

Fig. 2(b). Three ground rods connected in parallel.

In addition to high impedance, there is also the possibility that wire and screw-terminal connections in the system are corroded. Unfortunately, corroded connections are often electrically nonlinear, and that can produce harmonics (TVI!). The power main, therefore, is not good for rf use.

Another form of ungood ground is shown in Fig. 1. I know an amateur who used a 4-foot ground rod driven only halfway into the soil outside his window. Thus, only 2 feet of rod were buried. There are at least two problems with this system. First, the ground rod was buried only halfway into the earth. Second, the darn ground rod was too short in the first place. The 4-foot size is always too short, and a 6-foot rod is considered marginal. The best is the 8-foot size, driven into the ground so that only 4 to 6 inches show, as seen in Fig. 2(a).

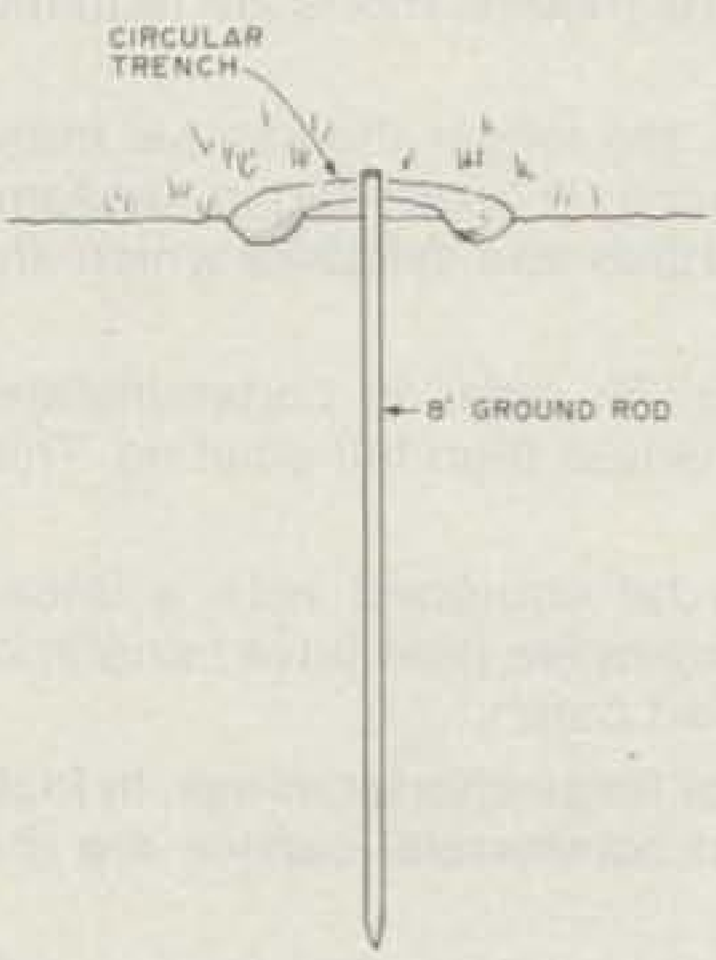

Fig. 3. A method for improving ground-rod effectiveness in very dry or sandy soil.

The wire lead between your equipment and the buried ground rod should be low inductance. For this reason, small-diameter wire is not suitable. Perhaps best is braid wire, or, if braid is too expensive, use the shield from a length of heavy coax (e.g., RG-8 or RG-11). In either event, the wire between the equipment and the ground should be as short as possible.

The electrical connection between the ground rod and the wire must be competent both electrically and mechanically. It should go without saying that a good electrical connection is first a good mechanical connection. For this reason, I prefer to both sweat-solder the braid and clamp it to the ground rod. The clamps that come on the ground rod are marginal, so I use the kind that electricians use. The big problem with the regular clamps is that they are fastened with only a slot-head screw, and they tend to work loose after a while.

The main idea in building a good ground system is to reduce the impedance as much as possible. The resistive component of this impedance is mostly the resistance between the ground rod and the earth. Therefore, the biggest improvement comes from increasing the surface area of the ground rod that is in contact with the earth. This is the main reason why we want the ground rod to be driven in all the way and its length to be 8 feet.

A way to increase the surface area in contact with the earth is to use more than one ground rod. Fig. 2(b) shows three ground rods connected in parallel; I have seen as many as six in one system. A method shown in a book on lightning protection uses five arranged with four on the corners of a square and one in the center of the square.

The 8-foot ground-rod length assumes a reasonably moist soil (even though the surface may be dry). If the soil is very dry or if it is sandy, then some other tactic will be necessary. A method advocated for many decades in ARRL and other amateur publications is shown in Fig. 3. The idea is to dig a 6- to 8-inch-deep trench around the ground rod at a radius of 1 foot or so. The trench is filled with a chemical such as copper sulphate and re-covered. The chemical leaches into the soil and reduces its electrical resistance. The chemical must be renewed every several years.

Another high-surface-area, low-resistance ground is shown in Fig. 4. Here we see a 1-inch-diameter (or larger) copper plumbing pipe used as a ground rod. These pipes normally come in 8-foot and 10-foot lengths. Unfortunately, copper pipes do not survive the pounding required to drive them into the earth. Ordinary ground rods are not actually all

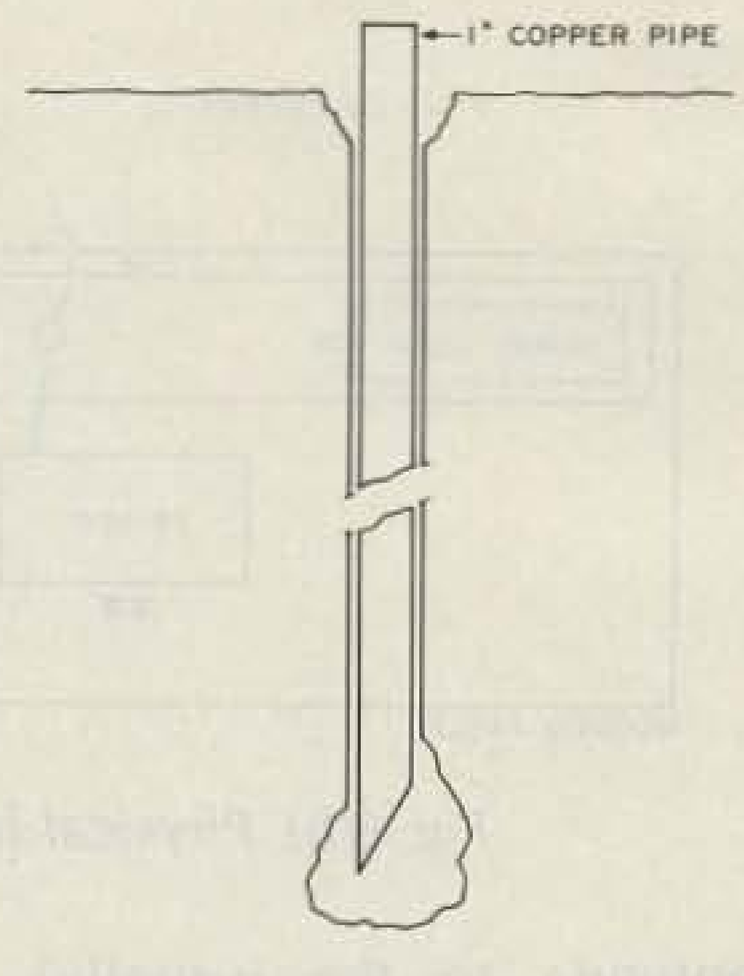

Fig. 4. Copper pipe used as a ground rod.

copper, but are steel with a copper coating on the outside to reduce the rf resistance. The well-known "skin effect" makes the rf current flow only in or near this low-resistance copper coating, and very little flows in the steel core. The steel core, then, can be used for strength.

The 1-inch (or larger) copper pipe will yield greater surface area in contact with the earth (and if we do it right, even the inside will be in contact with the earth) and so should yield a lower-resistance ground. The problem is, however, that the copper pipe is not strong enough to be driven into the ground.

Two people gave me ideas concerning this problem. One was a man at our church who said he used to use a garden hose and water pressure to drive the pipe into the earth, as shown in Fig. 5(a). The end of the pipe is beveled slightly, and then the water hose nozzle is inserted into the upper end. This connection must be held tightly by hand in order to build up water pressure in the pipe. By applying a downward mechanical pressure on the pipe while the water is applying its pressure to drive soil out from under the beveled point, the pipe will sink into the earth rather easily.

During the period when I

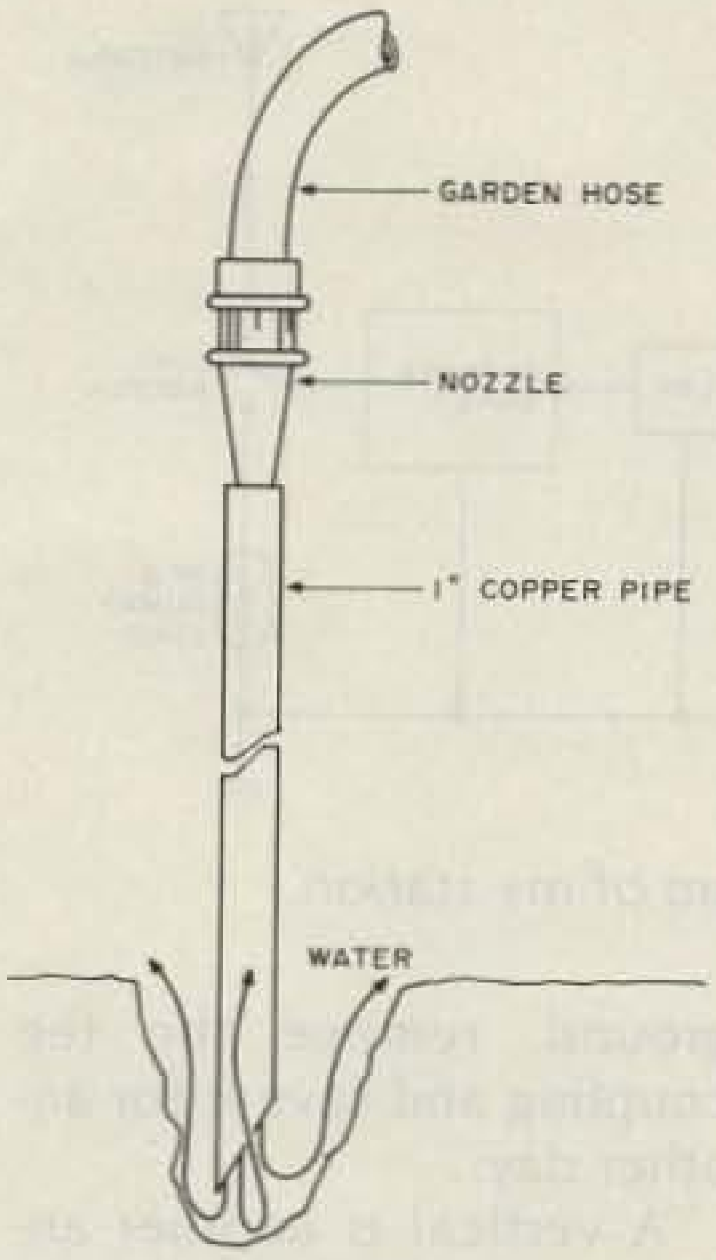

Fig. 5(a). One method of driving copper pipe into the earth.

was writing a monthly column for *Worldradio* newspaper, I discussed this method and used illustrations similar to Figs. 4 and 5(a). A reader wrote in and told me that he has been using that method for many decades of hamming and has improved on it a bit. He demonstrated by drawing the method shown

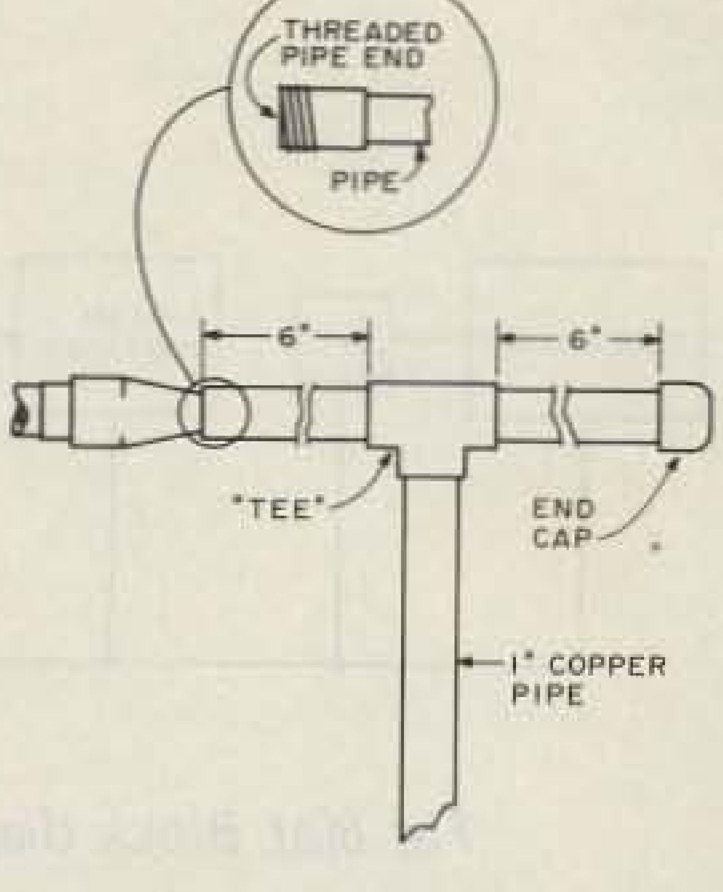

Fig. 5(b). Improved method for driving copper pipe into the earth.

in Fig. 5(b). Here we see a copper tee connector at the top end of the ground pipe. A short (6-inch or so) piece of matching copper pipe is extended out one end of the tee and capped to prevent the leakage of water (sweat-soldering is probably necessary). The

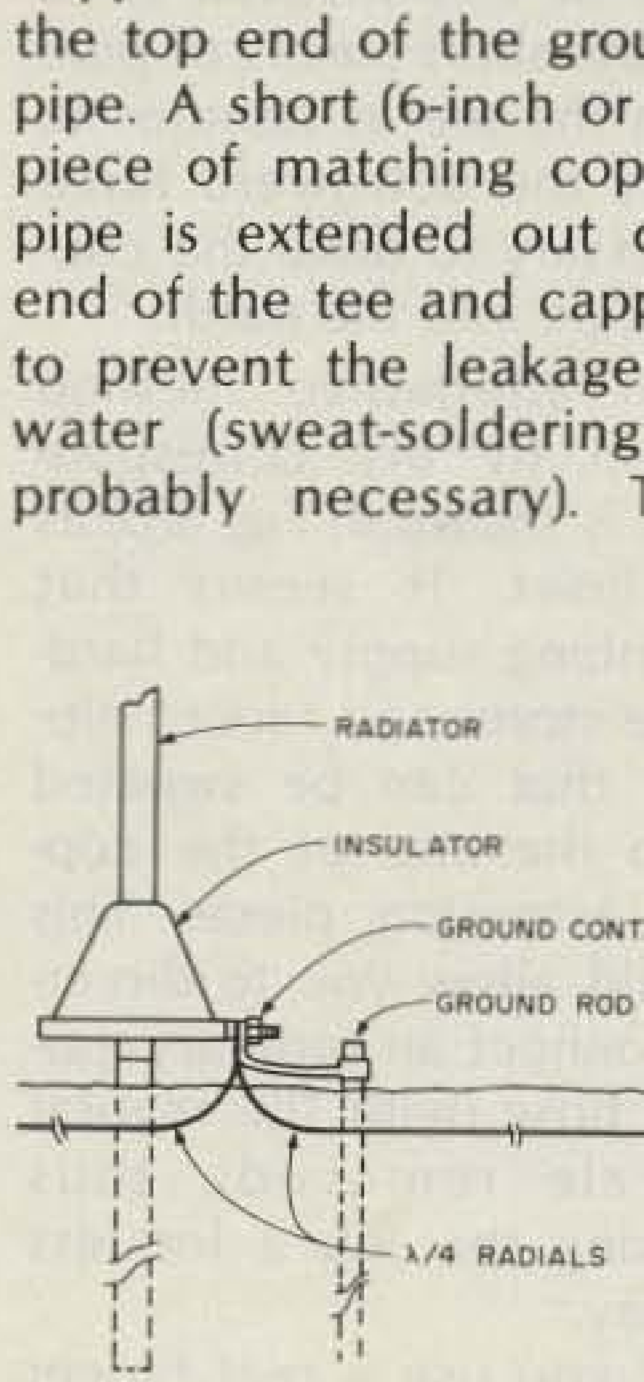

Fig. 6. Grounding a vertical.

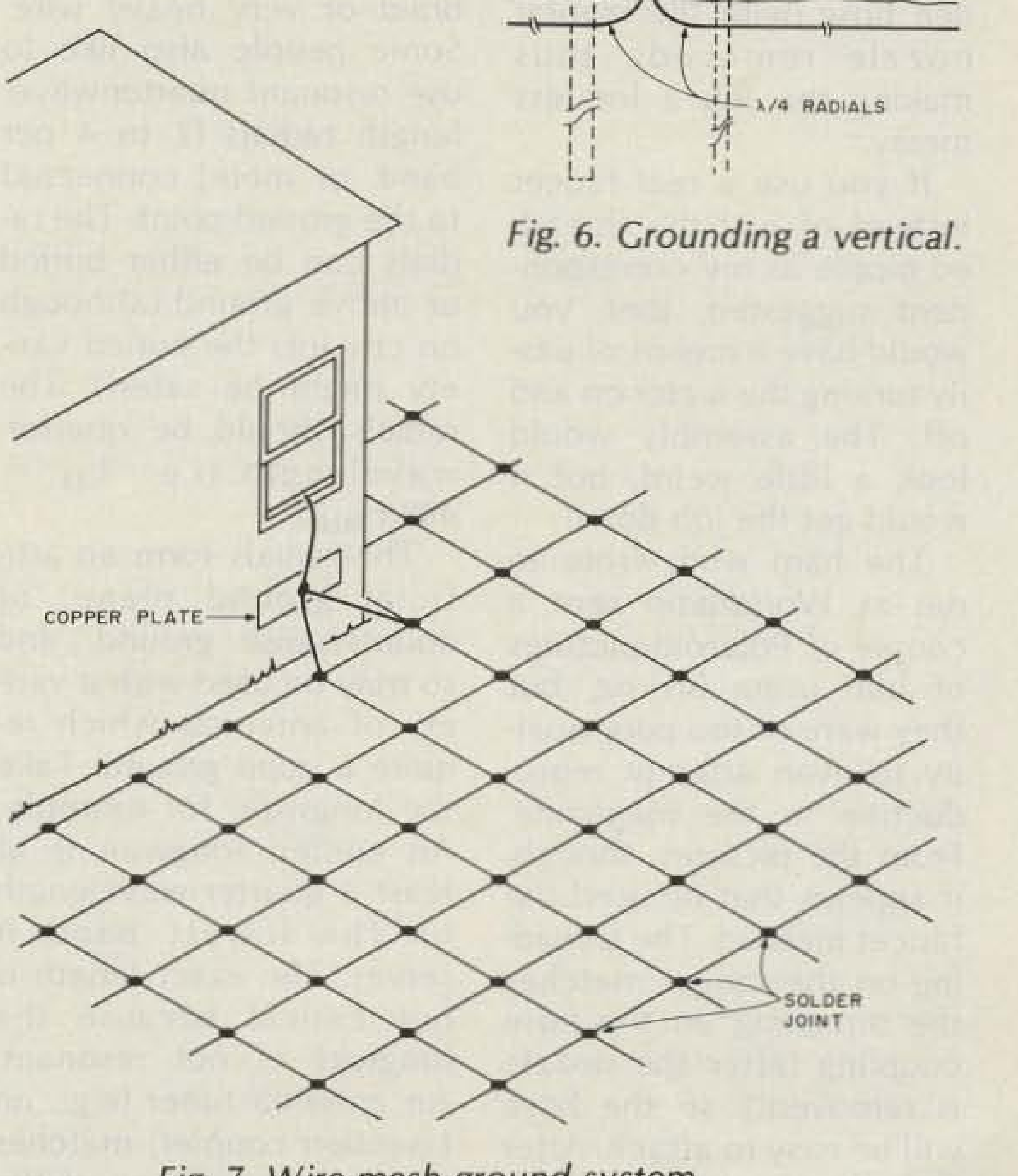

Fig. 7. Wire mesh ground system.

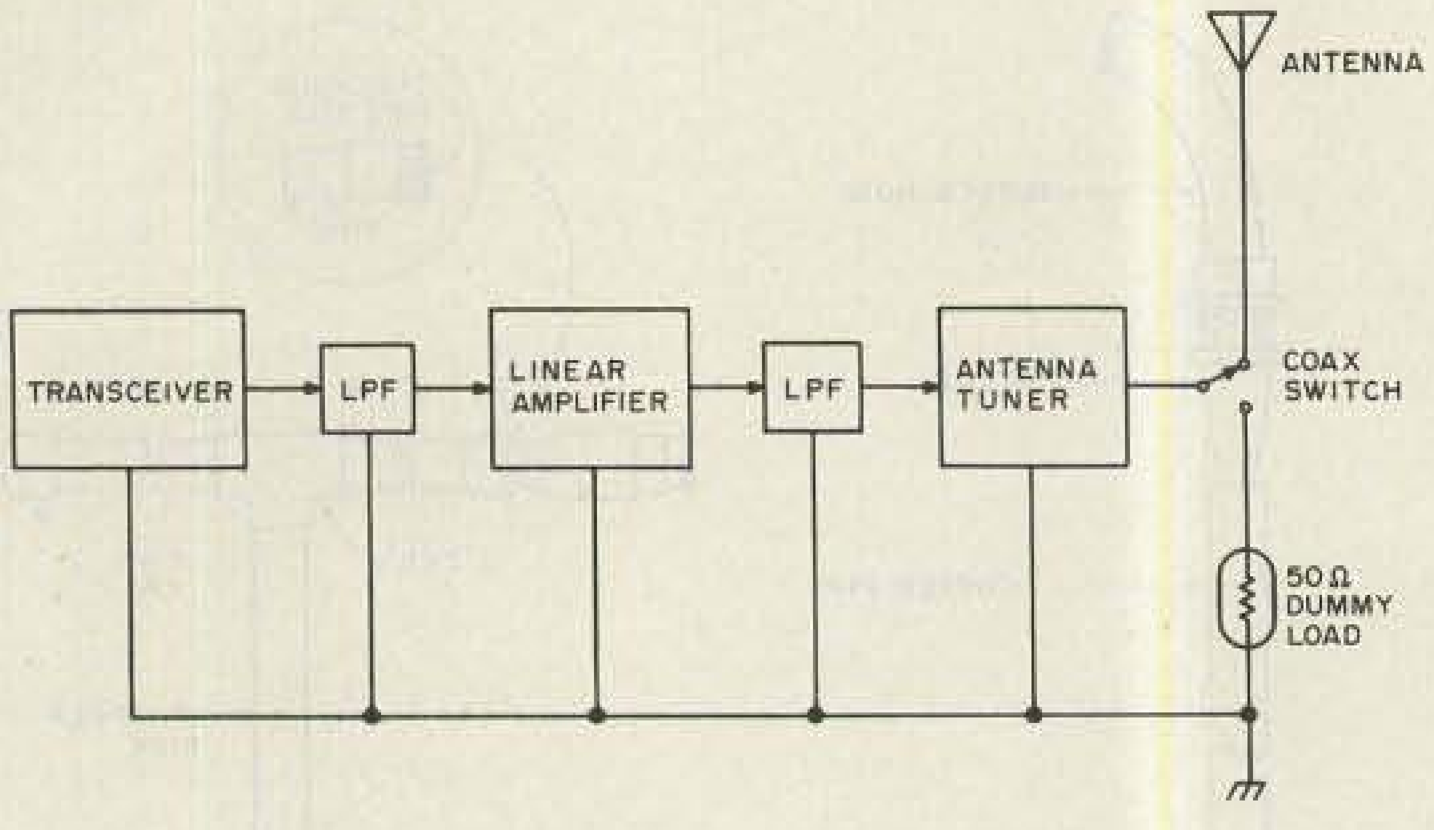

Fig. 8(a). Block diagram of my station.

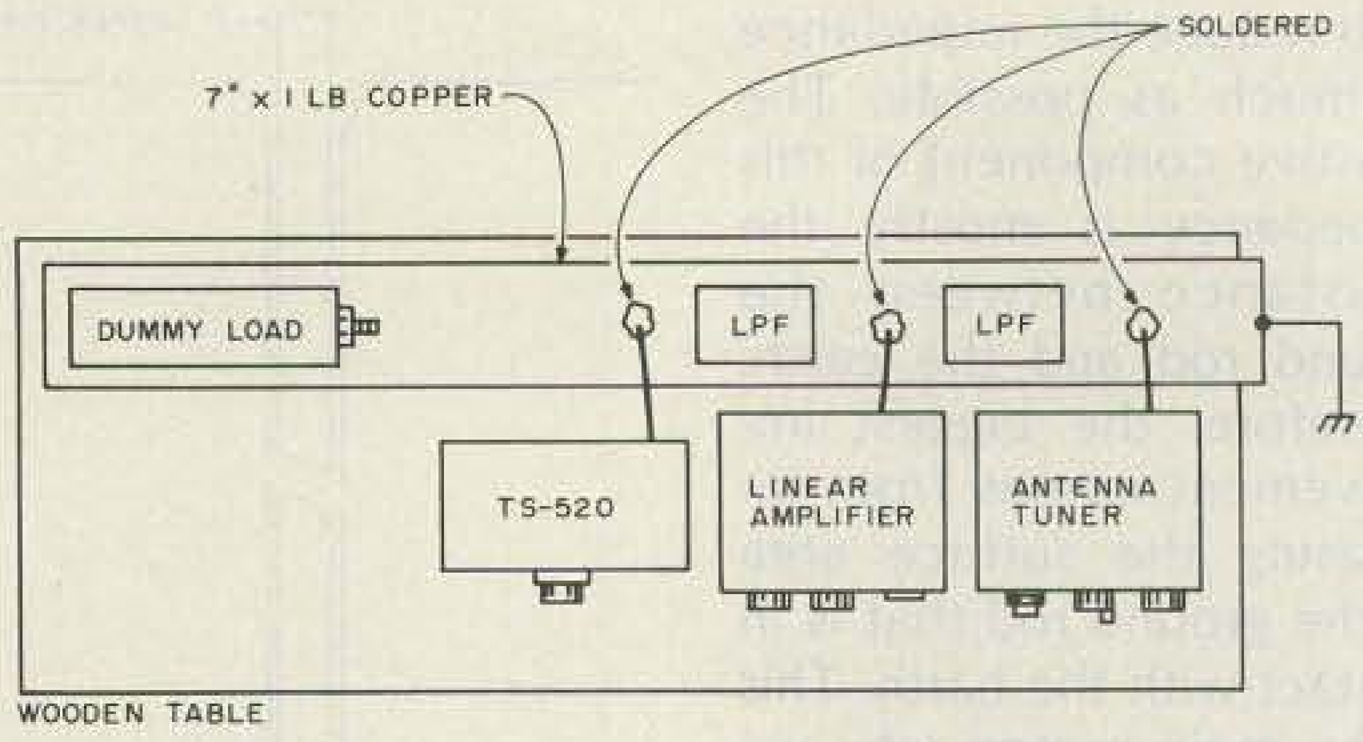

Fig. 8(b). Physical layout of my station.

other end of the tee also has a short piece of matching copper pipe, but this one is uncapped in order to accept the hose. The purpose of this method is to use the short pieces of pipe from the tee as handles to apply the downward force necessary to drive the copper pipe into the earth.

An alternative method shown by my correspondent is shown in Fig. 5(b) as an inset. It seems that plumbing supply and hardware stores sell faucet nipples that can be sweated onto the end of the copper extension piece. This would allow you to directly connect an ordinary garden hose (with the regular nozzle removed), thus making the job a lot less messy.

If you use a real faucet instead of just the threaded nipple as my correspondent suggested, then you would have a means of easily turning the water on and off. The assembly would look a little weird, but it would get the job done!

The ham who wrote to me at *Worldradio* sent a couple of Polaroid pictures of him using his rig, but they were of too poor quality to even attempt reproduction in the magazine. From the pictures, though, it appears that he used the faucet method. The threading on the faucet matches the threading on the hose coupling (after the nozzle is removed!), so the hose will be easy to attach. After the pipe is sunk into the ground, remove the tee coupling and save it for another day.

A vertical is another antenna that requires a good low-impedance ground. All too many people who attempt to ground-mount a vertical antenna will use the mounting pipe as a ground; that's a no-no. That pipe is usually only 2 or 3 feet long and is not a very good ground (galvanized steel).

Fig. 6 shows a method for grounding a vertical. Adjacent to the antenna is an 8-foot ground rod which is connected to the ground terminal of the vertical through a short piece of braid or very heavy wire. Some people also like to use resonant quarter-wavelength radials (2 to 4 per band, or more) connected to the ground point. The radials can be either buried or above ground (although on city lots the buried variety might be safer!). The radials should be quarter-wavelength (i.e., $L_{ft} = 492/F_{MHz}$).

The radials form an artificial ground plane, or counterpoise ground, and so may be used with a variety of antennas which require a good ground. Take the longwire, for example. An endfed longwire is at least a quarter wavelength on the lowest band it serves. The exact length is not critical because the longwire is not resonant. An antenna tuner (e.g., an L-section coupler) matches the high impedance of the antenna to the (usually) low impedance of the transmission line. Almost invariably, discussions of the longwire tell us that a good ground is needed (often without discussing what constitutes a good ground!). As one who had tried to operate longwires in the absence of a good ground, I can confirm that fine advice.

Unfortunately, the very factors which lead us to using a longwire also prevent us from obtaining a good ground for the longwire! A second-floor ham shack, for example, almost never allows a good ground because the ground line is too long. Another example is temporary and/or portable operation. In these cases, using two or more resonant quarter-wavelength radials will work wonders. When we first moved into our home, we had left all of our money with the real-estate-settlement attorney, and none was left for antennas. I was able to get on 15 meters by mounting a Hustler® mobile antenna and two radials in a second-floor window. Only occasionally, when the band was crowded, was I disappointed with the signal report.

Fig. 7 shows the ground system used by an old-timer I knew many years ago. Abe was originally licensed in the 20s when, he claimed, the ground would make or break an antenna system. When he bought his new house, Abe went out before the sod was laid down and constructed the wire mesh shown in Fig. 7. The wires were laid down about 2 feet apart, and each cross-joint was soldered with 2%-silver lead-tin solder. After the wire mesh was in place, the sod company buried it under a layer of sod grass.

My Ground

A couple years ago, the shack at K4IPV literally became a shack: an 8′ × 16′ Leonard shed in the backyard. After the shed was installed, I set about making my first ground-floor ham station. Figs. 8(a) and 8(b) show the equipment configuration.

My station has the usual lineup of equipment: transceiver, kilowatt linear, and antenna coupler. The coupler, by the way, is a coax-to-coax type and is used less for impedance matching than for additional attenuation of harmonics. The low-pass filter (LPF) between the transceiver and linear is used to reduce harmonics as much as possible before amplifying them in the linear. I have seen some amateurs use a low-power antenna coupler (e.g., a Drake MN-4) in this position.

The physical layout is shown in Fig. 8(b). The operating desk consists of a door made into a table. Along the back edge of the table is a copper strip. Sheet copper is specified by width and weight. The 1 pound/ft^2 weight is both acceptable and easy to work. Copper flashing used

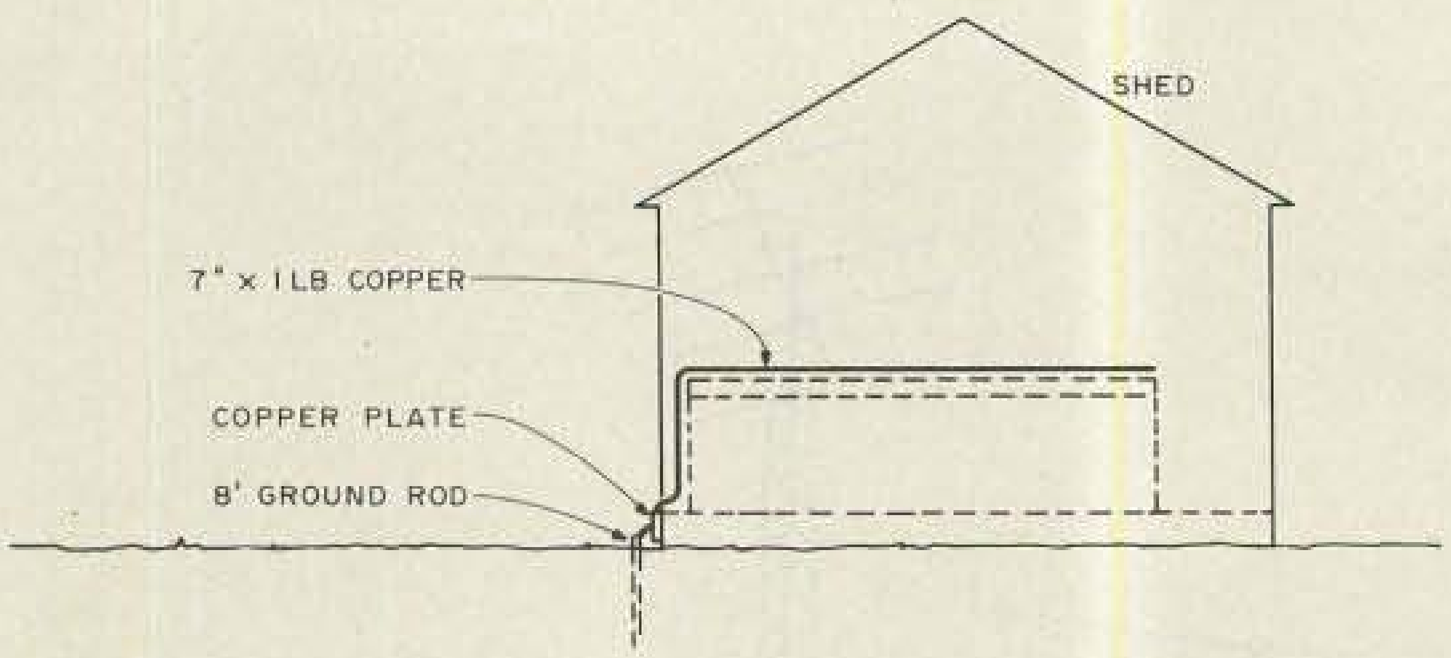

Fig. 9(a). Method of bringing the copper flashing outside.

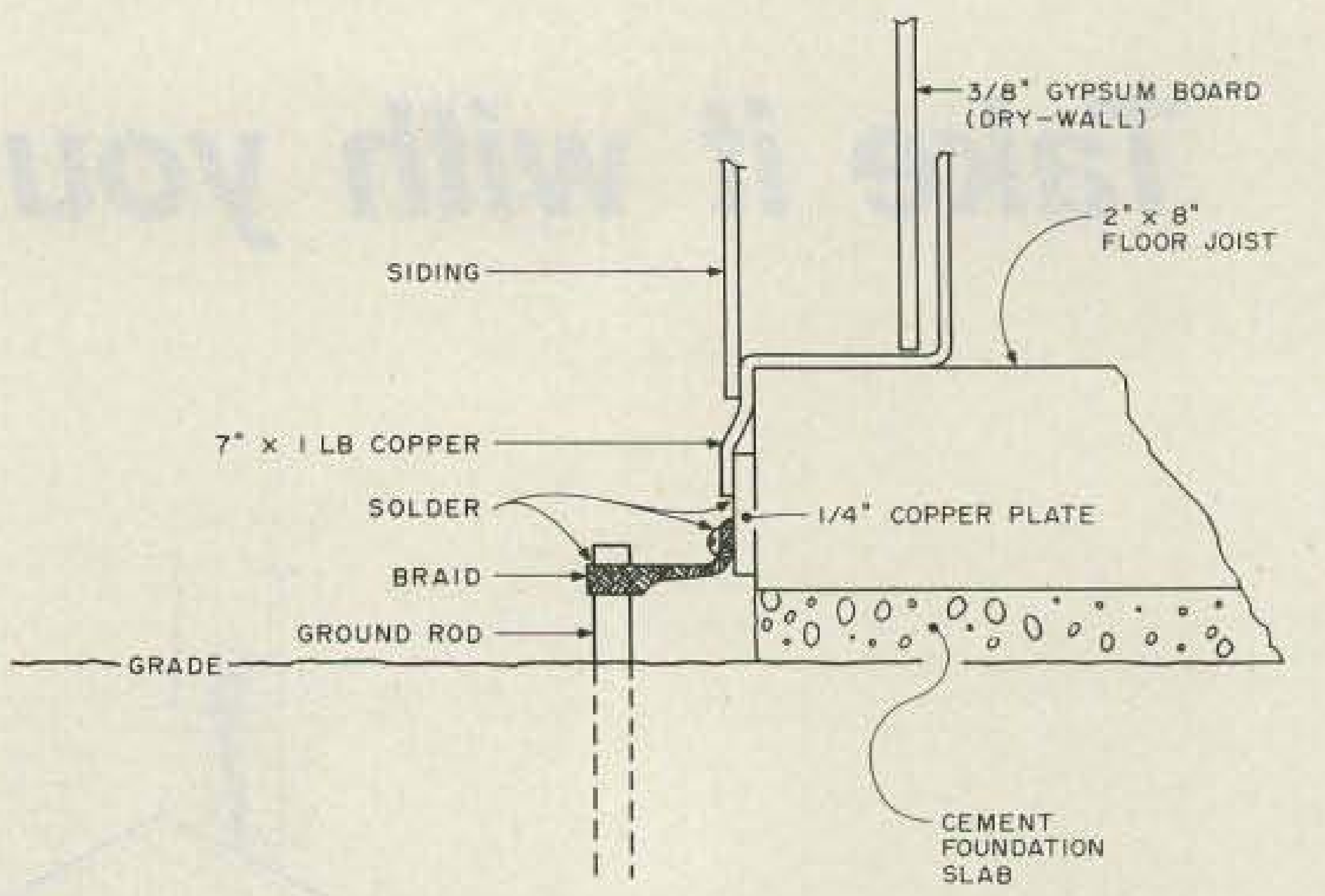

Fig. 9(b). Details of the flashing and copper plate junction.

to be available at all construction supply stores, but aluminum has taken its place. Copper is now found at specialty metal distributors. Each piece of equipment is connected to the copper sheet by short pieces of braid salvaged from RG-8 (or RG-11) coaxial cable.

Fig. 9(a) shows how the copper flashing was then brought outside. The shed uses metal skin, which is loosened by removing sheet-metal screws. The copper flashing was passed under the skin and then both bolted and soldered to a 1/4-inch copper plate. Fig. 9(b) shows the detail of the junction between the flashing and the copper plate.

Soldering to this system can be a bit torturous. I suppose that an old-fashioned 500-Watt soldering iron would do the trick. In my case, however, a 200-Watt soldering gun was the biggest available and it was insufficient. I instead used a propane torch with the Bernz-o-matic soldering tip. The solder was solid plumber's solder with paste flux. *Warning*: use *only* solid solder with resin paste or a heavy grade of resin-core solder. Some plumber's solder or paste is acid based, and that is a super no-no! Acid-core solder, or acid-based soldering flux, will *corrode the joints*.

The connection to ground consists of one 8-foot ground rod and four 6-foot ground rods driven (with two weekends of hard work) into hard Virginia red-clay soil. These rods are connected in parallel with each other at the 1/4-inch copper plate. Again, very short leads are used.

The term "very short" keeps popping up when discussing ground systems. Just what does "very short" mean? Is something which is very short at 80 meters also very short at 10 meters? Not necessarily, because very short is a relative term comparing a wire length to wavelength. In general, very short means "a small fraction of a wavelength." Typically, a length should be less than 1/8 wavelength. Obviously, a ground wire that is very short at 10 meters is also very short at 80 meters. Yet, a wire that is also very short at 80 meters may well be a good vertical antenna at 10 meters!

In addition to being short, an antenna ground wire should be low inductance. Thus, braid or strap should be used. Some people use multiple strands of heavy-gauge wire in order to reduce the inductance. These methods will also reduce the rf resistance of the ground wire. While dc currents flow through the entire diameter of a conductor, rf currents only flow near the surface; this is the so-called *skin effect*. By paralleling conductors or by otherwise increasing the cross-sectional area of the ground conductor, we reduce the conductor resistance.

Conclusion

That a good ground is a worthy goal needs little comment. In order to achieve that goal, we must be cognizant of the nature of the soil around us and of what constitutes a good ground. Obviously, a person operating from a desert community will have to follow a more rigorous path than a person living in a swamp. In either case, it is a matter of achieving a low-impedance path to ground. Some rules of thumb are:

1. Get as much surface of the conductor as possible underground.
2. Use short, low-inductance ground leads.
3. Use a counterpoise ground of quarter-wavelength radials if the two above are difficult to achieve. ■