PROJECT BUILD

Extend Your Handheld's Range with a Simple Ground-Plane Antenna

Parts List

- A female SO239 chassis-mount coaxial connector
- Five feet of #14 electrical house wire
- Heavy-duty wire cutters
- Pliers
- Heavy-duty soldering gun, or a gas torch
- Rosin-core solder
- Coaxial cable
- An adapter to attach the coaxial cable to your handheld transceiver when the antenna is finished.
- PVC pipe
- Hose clamp

TIP The type of adapter needed will depend on the connector your radio uses. Most use SMA connectors, either male or female. You can find adapters on Amazon or at amateur radio dealers.

If you're using a handheld transceiver on a VHF or UHF frequency, you've probably learned by now that the radio's small, flexible antenna — sometimes called a *rubber duck* antenna — limits you to a few miles at best, unless you're on top of a mountain or tall building, or if you have a repeater to help relay your signal.

One of the easiest and least expensive ways to extend your range is by using a *ground-plane* antenna. It's called a ground plane because the wires that stick out to the sides — called *radials* — act as ground returns for the energy your transceiver generates. All antennas need ground returns — even the antenna on your car, where the ground plane is the body of the car itself. Many commercial ground-plane antennas have three or four radials. This simple design uses only two.

Step 1

Cut at least three lengths of the #14 wire (remove any insulation), according to the length needed for the frequency you desire. Though this is a single-band antenna that will work on only one frequency, you may be able to it use with a dual-band VHF/UHF transceiver if you cut the wires for the 2-meter band.

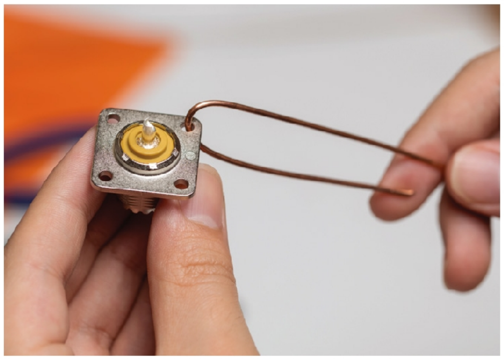
Band	Frequency (MHz)	Wire Length (Inches)
2 meters	146	19 1/4
1.25 meters	223	12 1/2
70 centimeters	440	6 1/4

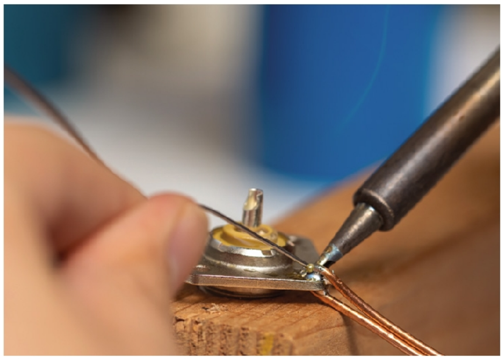
Of the three wires you've created, two will become radials and one will be the radiating element, better known as simply *the element*.

TIP To eliminate sharp ends, bend one end of each wire into a circle.

Step 2

Pass the radial wires through the holes in the chassis mount of the coaxial connector. Choose holes that will place the radial wires are opposite one another. Use your soldering gun or torch to solder them into place.

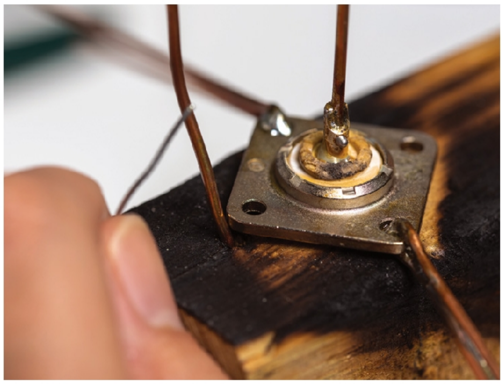




TIP It takes a lot of heat to accomplish this, so sometimes a torch is best.

Step 3

Insert the element wire into the center pin of the connector and solder it into place. This is the pin that is on the opposite side of the threaded part of the connector.



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What is SWR?

To understand the concept of *standing wave ratio*, or SWR, imagine a small pond with a vibrating motor in the center. Those vibrations make ripples radiate outward in all directions. The ripples strike the soil at the edge of the pond and bounce back in the general direction of the motor. These reflected ripples collide with the "new" ripples being generated by the motor. As they collide, they add or subtract from one another.

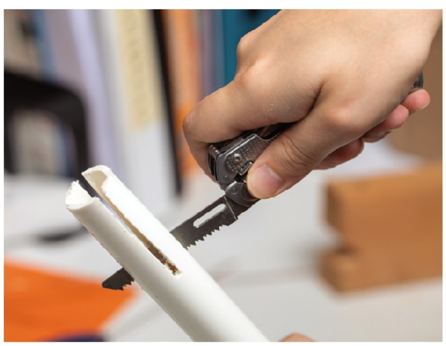
If we were to watch from the shore, we'd see the first ripples striking the pond edge and returning, but within seconds we would no longer see moving ripples at all. Instead, we'd see what appeared to be a fixed, non-moving pattern of waves on the pond's surface. All the traveling waves would collide and merge into a series of *standing waves*.

Similarly, the energy your transceiver sends into the coaxial cable, the *forward power*, travels to the antenna. Some of the energy is radiated, but some is reflected. This *reflected power* goes back down the coax toward the transceiver, where it will ultimately bounce back to the antenna. Along the way, it encounters forward power from the transceiver. These waves of energy interact, adding and subtracting. The result is standing waves on the cable.

SWR is important is because it can play an enormous role in determining how much RF energy is lost in a coaxial cable. As the SWR increases, more RF energy is tied up in the standing waves along the cable, and it will be lost as heat. A high SWR can also damage your radio, especially at higher power levels. That's why many transceivers have circuits that automatically reduce their RF output if the SWR rises above 2:1.

Mounting the Antenna

Use a length of PVC pipe as a mast for your antenna. Cut slots into one end to create flexibility in the width of the pipe's opening, and use a hose clamp to squeeze the pipe around the bottom of the coaxial connector to hold it in place inside the end of the pipe.



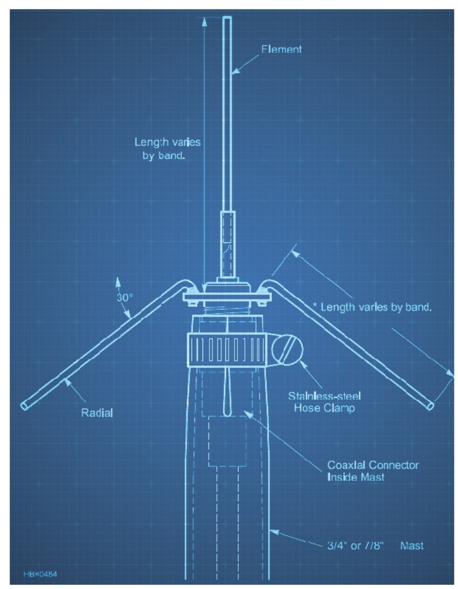
In the drawing at right, note that the coaxial cable is fed through the inside of the pipe where it finally screws onto the connector.

Testing the Antenna

Bend the radial wires down to 30-degree angles (approximately) as shown in the drawing. If you have an antenna analyzer, or know someone who does, attach it to the coaxial cable and measure the standing wave ratio (SWR) at your desired frequency.

If the SWR is greater than 2:1 at your desired frequency, measure above and below the frequency. If the lowest SWR point occurs below the frequency you want, your element wire is too long. Trim the wire by 1/4 inch and measure again. Keep cutting a bit at a time until the lowest SWR occurs at the desired frequency. See the sidebar, "What is SWR?"

On the other hand, if you find the lowest SWR at a frequency higher than the frequency you desire, your element wire is too short. You'll have to remove the wire and replace it with a longer one. Make the replacement wire about an inch longer. In this way, you can trim the wire to bring the low-SWR point exactly where you want it. Once your SWR is under control, you're ready to get on the air with an increased range, thanks to your new ground-plane antenna!

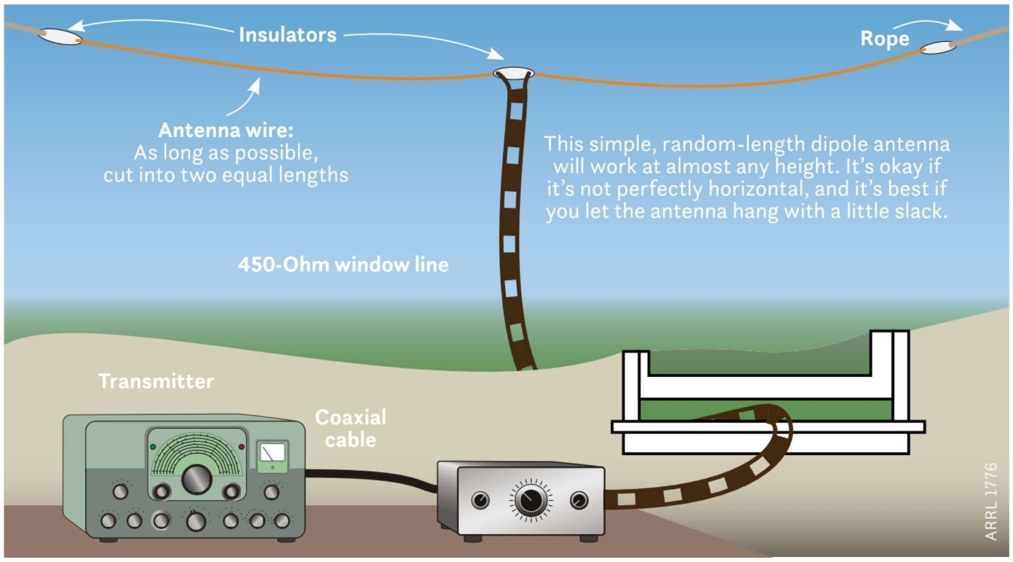


The diagram of our simple ground-plane antenna, using PVC pipe as a support mast.

PROJECT BUILD

One Wire, Many Bands

This easy build uses low-loss feed line and an antenna tuner to give you access to several of the HF bands.



Parts List

- **Antenna wire.** Almost any type will work, but stranded #14 copper wire is best. Choose something strong, to withstand the ravages of weather. The total length of the wire will depend on the lowest frequency at which you hope to operate (see the table, "Ideal Antenna Lengths"), as well as how much room you have for your antenna.
- **Plastic or ceramic insulators.** Just search online for "antenna insulators," and you'll find lots of choices. For the center insulator, consider a *WA1FFL Ladder-Loc*, which is designed to support windowed line.

- **450 Ω windowed line.** Buy only as much as you need to span the distance from the center of the antenna to your transceiver, to minimize energy loss.
- **An antenna tuner (manual or automatic).** If you intend to bring the windowed line directly to the tuner, make sure your tuner has a built-in *balun* (which is short for "balanced-to-unbalanced"), a device that allows a balanced feed line to connect to an unbalanced line. If it doesn't, you'll need to purchase a balun separately (try a 4:1 model) and connect it to the tuner with a short length of coaxial cable (no longer than 10 feet).
- **A soldering iron, solder, pliers and wire cutters.**

Ideal Antenna Lengths

Lowest Desired Frequency (MHz)	Total Length (Feet)
3.5	130
7	66
14	35

This simple wire antenna, known as a *random-length dipole*, works on several HF bands. "Dipole" means "two poles," which, in this case, means the antenna has two wires that function as electrical poles, similar to the plus and minus terminals found on batteries. The "random" length means you don't need to make this antenna a specific length in order for it to work.

The center of the antenna, where the two wires meet, is connected to a type of *feed line* (the wire that carries RF energy between your radio and antenna) known as *windowed line*. Windowed line has very low energy loss, and looks like a brown plastic ribbon about an inch across. Each edge of the ribbon is a wire. The plastic between these parallel wires has slots, or "windows," along the entire length.

To use this antenna with your transceiver, you'll need an *antenna tuner*. Many modern transceivers have built-in antenna tuners, but most of them lack the tuning range to work with the antenna system discussed here. With a wide-range external tuner, however, you should be able load the full output of your radio into the antenna. See the sidebar, "Antenna Tuners," for more information.

1

Step 1

Measure the antenna wire to the maximum length that will fit on your property. Cut the wire into two *equal* pieces. Place an insulator at one end of each wire. Wrap the wires through the holes in the insulators (1), then solder the wires in place.

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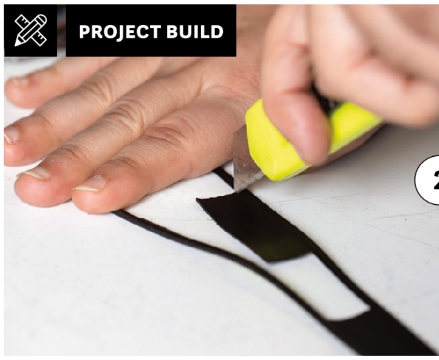

2

3

4

Step 2

You'll need another insulator, or a WA1FFL Ladder-Loc, to form the center of your antenna. Connect the uninsulated ends of each piece of antenna wire to opposite sides of the insulator or Ladder-Loc.

Carefully cut through the solid plastic portion of the window line until you have separated two 5-inch lengths of the wire (2).

Cut away the solid plastic tabs, and strip away about an inch of insulation from the ends of both wires (3).

Solder one wire to the antenna wire on the left side of the center insulator and solder the other wire to the antenna wire on the right side (4). If you're not using a Ladder-Loc, consider using electrical tape or another insulated material to help keep the windowed line from moving excessively. Too much movement will cause it to eventually fail.

Step 3

Tie ropes to the end insulators and string them over tree limbs (or whatever you're using for supports). Raise your antenna off the ground as high as possible. This antenna will work at almost any height, but higher is better. Don't pull the ropes too tightly; you want your antenna to hang with a little slack, especially if it's being supported by trees. This will reduce stress on windy days.

The antenna doesn't have to be perfectly horizontal. If one end is lower than the other, that's fine.

Step 4

Uncoil the windowed line that's hanging from the center of your antenna and lead it back to your station. *Two important tips:* (1) Do not allow the windowed line to coil into itself or tangle into a ball. (2) Keep the windowed line off the soil and at least 5 inches from metal objects such as gutters, aluminum siding, etc.

Step 5

Connect the windowed line to the balanced terminals on your antenna tuner, or solder the windowed line wires to a balun and connect the balun to your tuner with a short length of coaxial cable.

Time to Test

Set your transceiver output to a low level, such as 10 watts. Select a frequency on the lowest band you hope to operate.

For the next step, you'll need a steady signal for the tuner, so place your transceiver into CW mode and hold down your code key to transmit. Alternatively, use AM or FM mode and hold down your microphone's push-to-talk switch.

If you're using a manual tuner with inductance selected by a switch, usually labeled Inductance, set the Transmitter and Antenna knobs at mid-range. Begin

Antenna Tuners

Just as an electrical transformer converts one voltage to another, an antenna tuner converts one impedance to another. Impedance isn't simple to define because it involves mathematical expressions, but suffice to say that every antenna system (the antenna and feed line together) has an impedance that changes depending on the frequency. We measure impedance in ohms, represented by the omega symbol (Ω).

The goal of an antenna tuner is to convert the antenna system impedance to something close to what your transceiver expects. That is usually 50 Ω. We call this an impedance match, and it allows the transceiver to load all of its output power to the antenna system.

There are many types of antenna tuners on the amateur radio market, and they all have different features.

As the name implies, a manual tuner must be adjusted by the station operator. Most are designed with an internal coil with wires attached to it (called a tapped inductor), as well as two variable capacitors. You turn a switch to select a tap, and then adjust the capacitors for the lowest SWR. Others have a coil that, like the capacitors, can also be adjusted.

transmitting and watch the SWR indicator as you turn the inductance knob. You should see a dip in the SWR reading, although it may be slight. Stop when you find the switch setting that gives the lowest reading. Now turn the Transmitter knob until you lower the reading as far as you can. Next, turn the Antenna knob and try to reduce the SWR even further. Go back to the Transmitter knob and adjust again. You may have to go back and forth between the Transmitter and Antenna knobs several times until you've reduced the SWR to the lowest reading possible.

When you're satisfied, write down the settings for all three knobs. Now go to the next higher frequency band and repeat these steps. Soon you'll have a list of your optimum settings and you can return to them easily.

If your antenna tuner has a variable inductance, the steps are somewhat different. Start by turning the Antenna knob fully clockwise; set the Transmitter knob to the middle of its range. While transmitting, turn the inductance knob and watch for the dip in the SWR reading. Once you've found it, turn the Transmitter knob in either direction and watch for another dip. Go back and forth between the inductor and Transmitter knobs until you reach the lowest SWR reading. Then, adjust the Antenna knob and see if you can lower it further, ideally below 1.5:1. Write down the settings for all three knobs, then go to the next higher frequency band and repeat these steps.

If you're using an automatic antenna tuner, the adjustment process is much easier because the tuner does all the work! Just start transmitting at a low power level (less than 10 watts output) and your tuner should respond by rapidly searching for the lowest possible SWR. You may hear it clattering as it searches, and the SWR indicator may fluctuate wildly. Not to worry! This behavior is entirely normal.

Some automatic tuners require you to press a button before they will begin tuning; others sense the presence of the signal and start tuning on their own. Either way, once the automatic tuner has found the best settings, it will automatically store those settings in its memory so that it can find them quickly again in the future.

You may find that you cannot achieve a low SWR (less than 1.5:1) on all your favorite frequencies. However, you should discover that you can operate on several frequency bands and transmit an effective signal!

When shopping for a manual tuner, look for:

- An SWR/Power meter.
- An internal 4:1 balun (sometimes referred to as a "balanced output" in the sales brochure or advertising).
- A continuous (or CW) power rating of at least 100 watts.

Automatic tuners have become particularly popular because they're so easy to use. Some are designed to work within your station, but there are also models meant to be installed outdoors near your antenna.

When considering an automatic tuner, look for:

- An SWR meter or other indicator. (Indoor models only.)
- A continuous (or CW) power rating of at least 100 watts.

It's rare to find an automatic tuner with a built-in balun, so if you're thinking of using an automatic model with the antenna described in this article, you'll need to buy a 4:1 balun separately. If so, make sure the balun is also rated for 100 watts or more.

Left: A Palstar manual antenna tuner.

Below: An MFJ automatic tuner for indoor use.