Antenna Here is a Dipole

You've probably heard this phrase in many QSOs. Just what *is* a dipole antenna, and why are they so popular?

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Dipole antennas have been widely used since the early days of radio. Simplicity and effectiveness for a wide range of communications needs are the reasons for this—and they're also the properties that make dipoles worthy of your consideration. There's more to building and installing an effective dipole antenna system than choosing the wire and insulators, as you'll see. Next month, I'll discuss choosing the right feed line for your dipole, and related subjects.

What is a Dipole?

The dipole gets its name from its two halves—one on each side of its center (see Fig 1). (In contrast, a *monopole* has a single element, usually fed against ground as a vertical.) A dipole is a *balanced* antenna, meaning that the "poles" are symmetrical: They're equal lengths and extend in opposite directions from the feed point. In its simplest form, a dipole is an antenna made of wire and fed at its center as shown in Fig 1. (This may look familiar: You may have received a QSL card with a sketched dipole, resembling Fig 1, to denote the antenna the other station used during your contact.)

To be *resonant*, a dipole must be electrically a half wavelength long at the operating frequency. A dipole's resonance occurs at the length at which its impedance has no reactance—only resistance—at a given frequency. As it turns out, that resonant impedance range is compatible with many common coaxial feed lines. Within limits, however, resonance isn't necessary for a dipole to be effective, as I'll explain a bit later. Resonant half-wave dipoles range in size from about 16 feet for the 10-meter band (28-29.7 MHz) to 260 feet for the 160-meter band (1.8-2 MHz). See Table 1.

The lowest frequency at which a dipole is resonant is known as its *fundamental resonance*. A dipole works best at and above its fundamental-resonant frequency. But if a total-length limitation imposed by property boundaries or the spacing of available supports keeps you from doing this, make the antenna as long as you can, even if it's not a half wavelength. Resonances repeat, for half-wavelength-long dipoles, at *odd multiples* of the fundamental-resonant frequencies. For instance, a dipole resonant at 2.5 MHz is also resonant at 7.5 MHz, 12.5 MHz, and so on. These higher-frequency resonances are known as *harmonic resonances*.

As I mentioned earlier, a dipole doesn't have to be resonant to work well. More important than resonance are good construction and efficient power transfer from the transmitter to the antenna. Using an antenna tuner, you can match dipoles that are far longer or shorter than resonant length, but the feed line plays an important role in efficient power transfer, as I'll discuss next month. If you're primarily interested in operating on only one band, a resonant dipole is a good choice. If you're interested in multiband operation with a single antenna, the picture is a bit different. In this situation, it's a good idea to make the antenna resonant at the lowest frequency you plan to use it on (that's where the antenna is longest, because antenna length is proportional to wavelength).

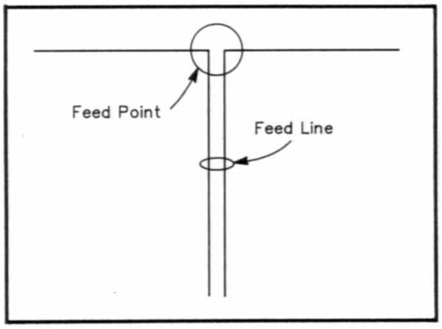

Fig 1—One of the simplest antennas used by hams, the dipole is also one of the most effective, considering the relatively small space it requires. In its simplest form, a dipole is a wire fed at its center.

Table 1
Approximate Lengths of Half-Wave Dipoles for the MF/HF Ham Bands*

Frequency	*Length*
28.4 MHz	16 ft, 6 in.
24.9 MHz	18 ft, 10 in.
21.1 MHz	22 ft, 2 in.
18.1 MHz	25 ft, 10 in.
14.1 MHz	33 ft, 2 in.
10.1 MHz	46 ft, 4 in.
7.1 MHz	65 ft, 11 in.
3.6 MHz	130 ft
1.8 MHz	260 ft

*General equation for half-wave dipole length: $\ell = 468 \div f$, where ℓ is length in feet and f is frequency in megahertz. This equation yields good starting points; you may have to lengthen or trim your antenna to achieve resonance. See the sidebar entitled "Dipole Construction and Adjustment."

Why are Dipole Antennas so Popular?

For almost any kind of MF/HF operation, dipoles are easy to build and install, and they give good results when put up at any reasonable height. "Reasonable heights" are anywhere from a few feet and up, depending on the band. A good general height guideline is half a wavelength or more, but that's impractical for many of us, especially on 40, 80 and 160 meters. At the least, a dipole should clear any surrounding buildings, and other large obstacles, for good performance.

Many hams do quite well with dipole antennas that are electrically low; for instance, an 80-meter dipole strung between two trees at 50 feet (less than a quarter wavelength) allows me to work Europeans regularly on 80-meter CW with a 100-watt transceiver. As a bonus, this antenna works even better at higher frequencies, where it's electrically much farther above ground, as I'll also discuss later.

Variations on the Theme

Part of the beauty of dipole antennas, like many other simple things, is their flexibility. Dipoles can be installed in an infinite number of configurations other than the classical flat-top arrangement (Fig 1). Some of the more common variations include the inverted **V** (sometimes called the drooping dipole—Fig 2A [page 26]); parallel-multiband dipole (Fig 2B); sloping dipole (*sloper*—Fig 2C); vertical dipole (Fig 1, rotated 90°); folded dipole (Fig 2D); and trap dipole (Fig 2E).

Inverted-**V** dipoles are probably more common than flat-top versions. As you might expect, the inverted **V** gets its name from its shape. The main advantages of inverted **V**s are that they need only one high support, and that you can get more total wire into the same horizontal space using

Dipole Construction and Adjustment

Dipoles can be made of almost any kind of wire or tubing, but how well they work and how long they last is determined by the quality of the parts and care you use in building them. With that in mind, here's what it takes to make a dipole antenna.

• *Wire.* Stranded and solid copper, and copper-plated steel (Copperweld), are the most popular types used for antenna construction. Don't use soft, solid copper (such as house wire) for long unsupported runs in resonant antennas; solid wire can stretch enough after installation to detune the antenna. Use reasonably large wire (no. 16 or larger) for permanent antennas. No. 18 or smaller wire is generally okay for low-profile or temporary antennas, or those cut for 14 MHz or higher frequencies. There's little difference between antennas made from insulated and uninsulated wire, although the presence of insulation generally lowers the resonant frequency of a given length of wire by a bit. Insulated wire is heavier and thicker, which, depending on its color, can make it more or less visible than its uninsulated equivalent. Davis RF (see "Where to Get the Pieces") carries uninsulated, stranded no. 14 copper that's made of 168 strands of wire. This is good stuff for dipoles (or home-brew balanced feed lines) because it's very flexible and easy to work with, doesn't stretch, and resists breakage well.

• *Insulators.* A dipole should have insulators (Fig A) at its center (feed point) and at each end, where ropes (or other restraints) support the antenna. The center insulator serves two primary purposes: (1) it separates and supports the feed-line conductors, making for strong mechanical wire joints that minimize stress on solder joints; and (2) it gives you a convenient place from which to support the dipole with a rope, if your dipole is center-supported. End insulators serve another purpose: They provide an isolated support point at the high-voltage ends of the antenna wire. (Potentials at the ends of a resonant dipole can be in the kilovolts—even with just a 100-watt transmitter!)

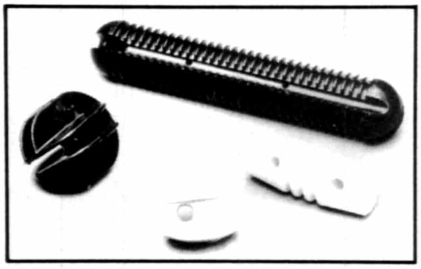

Fig A—Several varieties of insulators are commonly available to hams. The lower-center ceramic unit and the plastic insulator on the left are current Radio Shack products. The others, and close variants, are available from many mail-order sources (see "Where to Get the Pieces").

Plastic, ceramic or porcelain insulators are fine for most applications. Home-made varnished hardwood is also acceptable. There's no need to use a special center insulator at a dipole's feed point—the impedance, and therefore the RF voltage, there is low—although doing so can make construction easier.

• *Rope.* Nylon, Dacron and similar materials are best. Avoid polypropylene; it rapidly deteriorates in sunlight. Also avoid hemp and other natural materials. They tend to stay damp and rot in the center after getting rained on, with no outwardly visible signs of damage. If you select nylon rope, use the braided variety and carefully seal its cut ends by melting them with a match or cigarette lighter. This rope is very strong, but unlike Dacron, it also initially stretches as much as a few percent.

To make a dipole that'll stay up and that's easy to work on, using the right knots is important. Learn (or relearn) to tie a *bowline* (an unsliding loop); a *clove hitch* (for attaching rope to poles, tower legs, and such); a *taut-line hitch* (a sliding knot for adjusting the tension in a rope); and a *sheet bend* (for joining the ends of two ropes). These knots are simple to tie, and are described in every edition of the Boy Scout *Handbook* and *Fieldbook*, as well as some merit badge booklets (look under Boy Scouts of America in the Yellow Pages for local suppliers of BSA materials). Another good reason to be acquainted with these knots: When (if) you start working on towers (or other supports) and bigger antennas, these knots can save your *life*, not to mention your hardware.

• *Soldering.* To make permanent

this configuration. This is often an important advantage on the lower-frequency bands, where real estate and support height suitable for putting up a full-size dipole are at a premium. Inverted **V**s usually work almost as well as horizontal flat-top dipoles when the dipole's height is the same as the feed-point height of an inverted **V**. It's important to keep the antenna ends high enough above the ground so that people, vehicles and such can't come into accidental contact with them.

Another common dipole configuration is the multiband parallel version. In such an antenna (Fig 2B), multiple dipole elements are fed at the same point, with a single feed line, and supported by spacers attached to the longest dipole element. The main advantage of parallel dipoles is multiband coverage with resonant elements on each band, allowing the use of a single coaxial feed line for several bands without

Where to Get the Pieces

Here's a brief list of suppliers of wire, insulators, feed line, connectors, and other items you'll need for making and installing dipole antennas. For a more complete list, see the advertisements in this and other issues of *QST*.

• Radio Shack stores (antenna wire, coaxial cable, ceramic and plastic insulators, connector-sealant tape and other supplies). See 1991 catalog, page 137.

• Davis RF, PO Box 230, Carlisle, MA 01740, tel 508-369-1738 or 800-484-4002, extension 1356 (high-flexibility antenna wire, coaxial cable, several varieties of prefabricated balanced line [and parts to make your own], ceramic insulators, aluminum tubing and other supplies). Catalog available.

• Ocean State Electronics, PO Box 1458, Westerly, RI 02891, tel 401-596-3080, fax 401-596-3590 (antenna wire, coaxial cable and connectors, 300-Ω twinlead, insulators). Catalog available.

• Certified Communications, Rte 2, Pittman Rd, Landrum, SC 29356, tel 803-895-4195 (coaxial cable, balanced feed line).

• The Radio Works, PO Box 6159, Portsmouth, VA 23703, tel 804-484-0140, fax 804-483-1873 (antenna wire, coaxial cable and connectors, balanced feed line, baluns, insulators, rope, sealant and other supplies). Catalog available.

• Most major Amateur Radio equipment dealers (Amateur Electronic Supply, Ham Radio Outlet, and other *QST* advertisers) carry parts for dipole construction.—*NJ2L* connections that will stand up to wind and weather, you'll need a soldering device that can quickly heat the wires to be joined. A 30-W iron probably won't do an acceptable job with wires larger than no. 16; a 100-W or larger soldering gun is best. If you're using relatively heavy wire and ceramic or porcelain insulators, you can use a propane torch (preferably with a soldering tip) for soldering. (If you do this, heat the joint first, then remove the flame and let the heat of the wires melt the solder into the hot junction.) Use 60/40 (or similar) rosin-core solder (available from Radio Shack and most hardware stores). Use caution when soldering close to plastic insulators; too much heat will damage them. Don't breathe solder or insulation fumes!

• *Tape, sealant and similar protective coverings.* Protect your solder joints and feed-line connections from the weather after soldering by tightly wrapping them with high-quality electrical tape (such as Scotch 33 or 88) or silicone adhesive tape, or covering them with Coax-Seal (or equivalent). Solder joints at end insulators can be sufficiently protected by spraying them with clear lacquer, available from most hardware and home-supply stores. Weather-proofing properly soldered end-insulator joints is optional, but *seal the center insulator* as if you were planning to use it underwater. The last thing you want is rainwater in your coax!

In dipole construction, it's important to make strong mechanical junctions

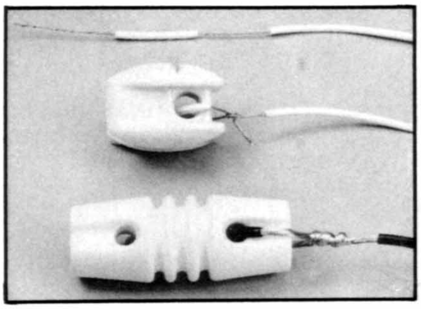

Fig B—Secure end-insulator connections are important to long antenna life. Top to bottom: Leave part of the insulation from the wire end to protect the wire where it goes through the insulator eye; wind several turns of wire back on itself to make a strong mechanical connection; solder the joint; and spray it with clear lacquer to prevent corrosion.

in the wires. An antenna that depends solely on solder joints to handle wind stresses will surely fall down sooner than one that's made with good mechanical connections. RF interference can also result from deteriorated solder joints. Fig B shows how to make a solid mechanical connection at an insulator.

Bringing a Dipole "On Frequency"

To resonate a dipole that's fed with coaxial cable, select a band and cut the wire a couple of feet longer than the appropriate length shown in Table 1. Then, install center and end insulators and attach the coaxial feed line (Fig C shows how to attach

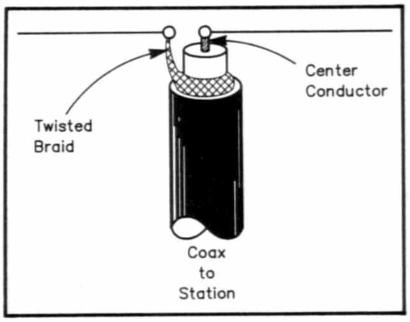

Fig C—Coaxial cable feeding a dipole antenna. The center insulator is omitted for clarity. When measuring and adjusting a dipole fed with coax, keep in mind that the stripped coax center-conductor and shield lengths *add to the antenna length.*

coaxial feed line to a dipole). Support the antenna a few feet above ground, measure the SWR and trim the antenna (equally from each end) to raise the resonance to the desired frequency. If the antenna is too short, splice in some additional wire, or attach equal amounts at the end insulators and let it hang from them. Copper-and-brass split-bolt clamps, made for attaching copper ground wires together and available from most home-improvement stores, are great for making these additions.

Selecting supports and installing antennas is the subject of many other articles. See the references listed under "Further Reading" for a few of these.—*NJ2L*

Further Reading

For more information on antenna construction and installation, see the references listed below. The issues of *QST* cited here may be available at your local library; if not, contact the Technical Department Secretary at ARRL Headquarters (see p 3 of this issue) for any photocopies you need. (There is a nominal charge for this service.)

• G. Hall, Ed., *The ARRL Antenna Book,* 15th ed (Newington: ARRL, 1987). If you're aware of this book, you may think that it's a highly technical reference intended for those with lots of antenna knowledge and experience. In truth, it's intended for hams at all experience and license levels, and even those who aren't yet licensed. All of the subjects I've covered in this article are treated from basic to detailed levels in *The ARRL Antenna Book,* and it should be the key reference in your quest for antenna wisdom.

• C. Hutchinson and L. Wolfgang, Eds, *The ARRL Handbook for Radio Amateurs,* 1991 ed (Newington: ARRL, 1990). Chapter 17, "Antenna Fundamentals," provides a good technical introduction to dipole theory and feeding.

• D. Brede, "The Care and Feeding of an Amateur's Favorite Antenna Support—The Tree," *QST,* Sep 1989, pp 26-28, 40.

• W. Calvert, "The EZY Launcher," elsewhere in this issue.—*NJ2L*

the need for an antenna tuner. An inherent disadvantage of parallel dipoles, however, is narrower bandwidth than single dipoles provide.

Two other fairly popular dipole variations are the trap dipole and the folded dipole. Traps are tuned circuits (consisting of inductance and capacitance) that electrically isolate the inner and outer sections of the antenna at certain frequencies, providing multiband resonant coverage from a single antenna. At a trap's resonant frequency, it presents a high impedance and therefore isolates the outer segments of the dipole, making the antenna electrically shorter than it is physically. At frequencies below the trap's resonance, it has a low impedance, which makes it transparent to RF (ie, it doesn't isolate any part of the antenna).. Traps aren't used only in dipoles:

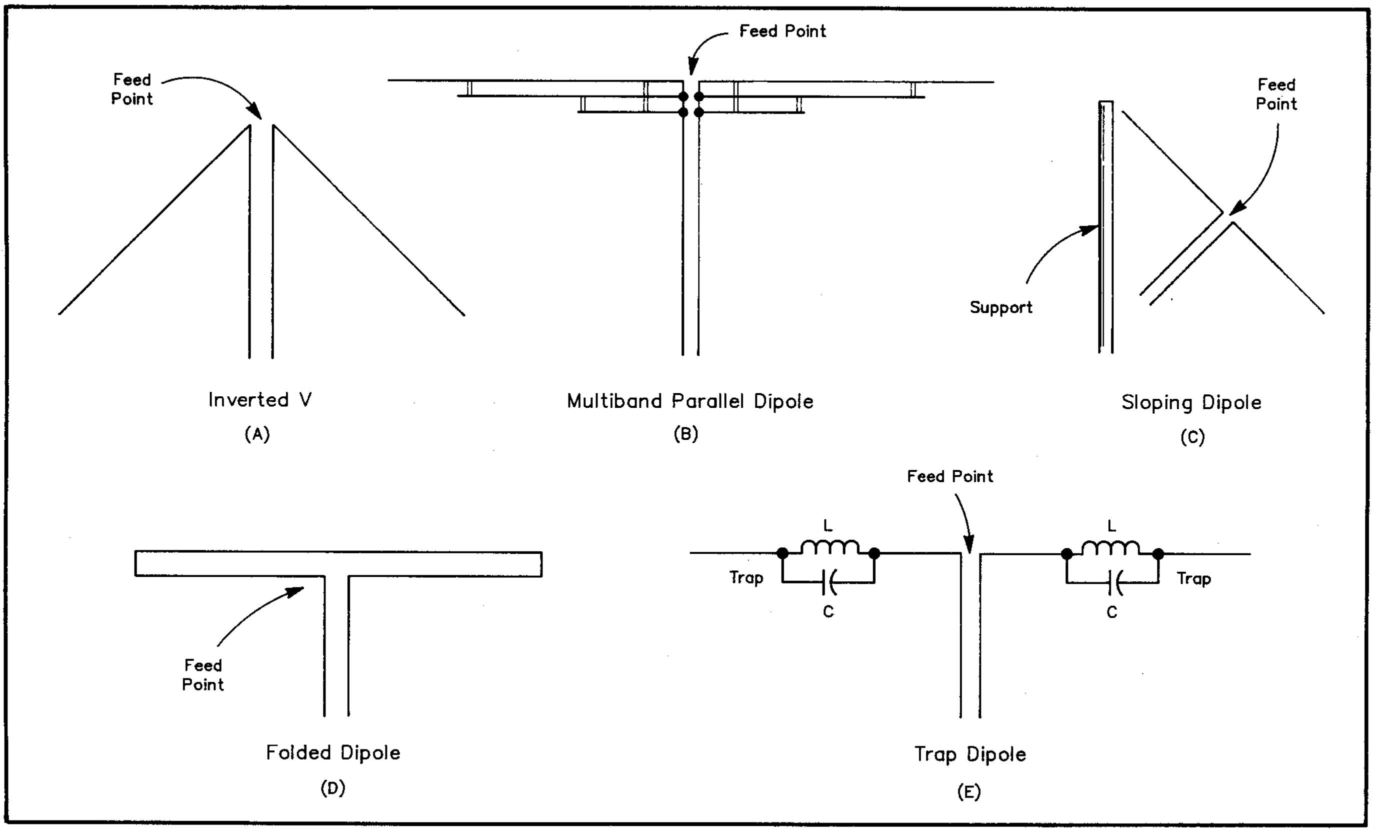

Fig 2—Variations on the dipole are numerous: at A, an inverted V; at B, a multiband parallel dipole; at C, a sloping dipole (sloper); at D, a folded dipole; and at E, at trap dipole. Dipoles of the multiband parallel, trap and folded varieties can be installed in sloping or inverted-V configurations.

Trap Yagi beams and verticals are also popular. Folded dipoles are a bit less common in Amateur Radio use; they use full-length parallel wires shorted at the ends, and have feed-point impedances that provide good matches to balanced feed lines. FM-broadcast receivers usually use folded dipoles made from TV twinlead. *The ARRL Antenna Book* and *The ARRL Handbook* cover trap and parallel dipoles in more detail (see "Further Reading").

The Dual-Band Dipole

Two popular ham bands, especially for Novice and Technician Class operators, are those at 7 and 21 MHz. As mentioned earlier, dipoles have harmonic resonances at odd multiples of their fundamental resonances. Because 21 MHz is the third harmonic of 7 MHz, 7-MHz dipoles are harmonically resonant in the popular ham band at 21 MHz. This is attractive because it allows you to install a 40-meter dipole, feed it with coax, and use it without an antenna tuner on both 40 and 15 meters.

But there's a catch: The third harmonic of the Novice 40-meter allocation (7100-7150 kHz) begins at 21,300 kHz; yet the Novice segment of 15 meters is 21,100-21,200 kHz. As a result of this and other effects, a 40-meter dipole does not provide a low SWR in the 40- *and* 15-meter Novice segments without a tuner.

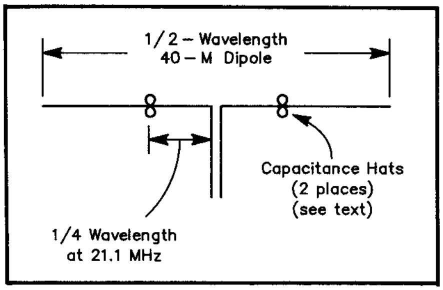

Fig 3—Figure-8-shaped capacitance hats, made and placed as described in the text, can make your 40-meter dipole resonate anywhere you like in the 15-meter band.

An easy fix for this, as shown in Fig 3, is to *capacitively load* the antenna about a quarter wavelength (at 21.1 MHz) away from the feed point in both wires. Known as *capacitance hats*, the simple loading wires shown lower the antenna's resonant frequency on 15 meters without substantially affecting resonance on 40 meters.

To put this scheme to use, first measure, cut and adjust the dipole to resonance at the desired 40-meter frequency, as described in the sidebar called "Dipole Construction and Adjustment." Then, cut two 2-foot-long pieces of stiff wire (such as no. 12 or no. 14 house wire) and solder the ends of each one together to form two loops. Twist the loops in the middle to form figure-8s, and strip and solder the wires where they cross. Install these capacitance hats on the dipole by stripping the antenna wire (if necessary) and soldering the hats to the dipole about a third of the way out from the feed point (placement isn't critical) on each wire. To resonate the antenna on 15 meters, adjust the loop shapes *(not while you're transmitting!)* until the SWR is acceptable in the desired segment of the 15-meter band. You can make all these adjustments with the dipole just a few feet off the ground; raising the antenna to its permanent height shouldn't shift the SWR much. Recheck the antenna's 40-meter resonance before raising it, though.

Feed-Line Considerations

The antenna wire and insulators, how you put them together and where you string them up is only part of a dipole-based antenna *system*. Next month, I'll cover selecting and using a feed line for your dipole(s). In the meantime, I suggest that you have a look at the two parts of Dave (WJ1Z) Newkirk's article, "Connectors for (Almost) All Occasions," in the April and May issues.