# Lab Notes

**Prepared by the ARRL Laboratory Staff**

## Multiband Dipoles Compared

This month, ARRL Laboratory Engineer Mike Gruber, WA1SVF, gives us the lowdown on these popular antennas.

**Q** I just upgraded and can't wait to explore HF. I'd like an all-band antenna, at least until I've had a chance to try them all. I'm looking for something simple, inexpensive and perhaps something I can build. A dipole would fit the bill, but only operates on one band. What options do I have?

**A** You have a number of multiband dipole possibilities. The best antenna for your particular application depends on such things as your operating habits, budget, antenna-size limitations and available supports. Multiband dipoles offer a variety of size, feed-line, pattern, bandwidth, band-switching and other options. You'll also find differences in complexity and efficiency. In general, homebrew dipoles provide surprising performance for the dollar. A little knowledge can go a long way when making your selection. Let's take a closer look and see which might be best for you.

Because a resonant dipole is also resonant somewhat above each odd harmonic (3f, 5f, etc), even a simple garden-variety dipole is suitable for multiband use. In the HF bands for example, a 40-meter dipole is also resonant *near* the 15-meter amateur band. I call this the "diband dipole." **Figure 1** shows radiation patterns of an 80-meter dipole operated at the centers of the 80, 30 and 20-meter bands. (We'll talk about the 20-meter plot later.)

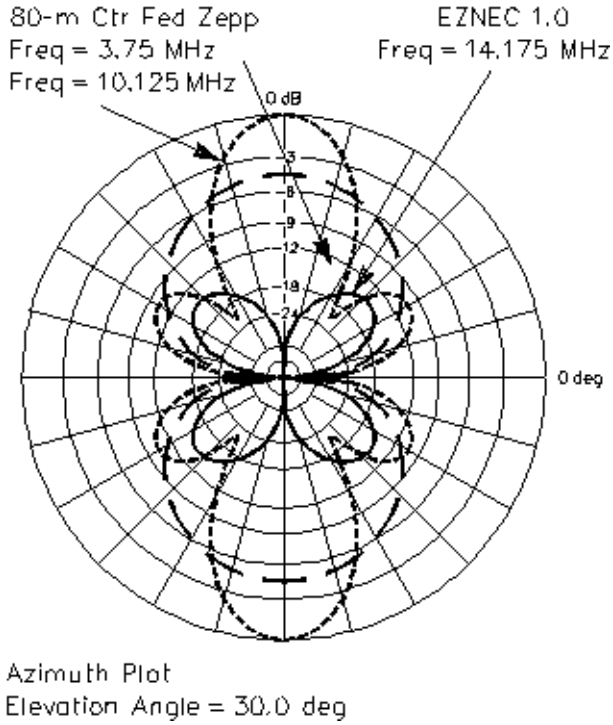


**Figure 1—Propagation patterns for an 80-meter dipole 1/4-wavelength above real ground. These are azimuthal patterns at an elevation of 30°. Curve 80dip@30 is for the same antenna operated at the center of the 30-meter amateur band (roughly third harmonic); 80dip@20 is for 20 meters, the fourth harmonic of 80 meters. The pattern for 20 meters is much stronger at lower elevation angles. It's stronger at 14° than that shown for 30 meters.**

**Q** But that's only two amateur bands. I was hoping for more. What are my other options?

**A** Another simple approach is one I call the "jumpered dipole." Start with a dipole cut for the shortest wavelength of interest and a pair of insulators at each end. Add more wire and insulators for each wavelength you desire (see **Figure 2A**). Finally, install a jumper across each insulator within the antenna. Solder one end of each jumper and install an alligator clip or suitable connector on

the other end. You can select any of the available bands by shorting the appropriate insulators. If you intend to operate with high power, be sure the jumper contacts are suitable. I use a little electrical contact grease on the jumper contacts to prevent oxidation.

When constructing dipoles, leave extra wire for each band segment and do not solder the end connections. Start tuning with the highest frequency and work your way down. Measure the SWR at points across a band and adjust the segment length (shorter = higher frequency) until the lowest SWR is where you want it. (An SWR analyzer or similar instrument can be especially helpful when pruning multiband antennas.)

A jumpered dipole offers low loss (assuming negligible resistance across the jumpers), coax feed, uncompromised bandwidth and a standard dipole pattern without a tuner. The disadvantages are a bit rough. You need a halyard and pulley system to raise and lower the antenna *each time you switch bands*. Each band change requires a trip outdoors, sometimes in inclement weather—not a good choice for rapid or frequent band changes.

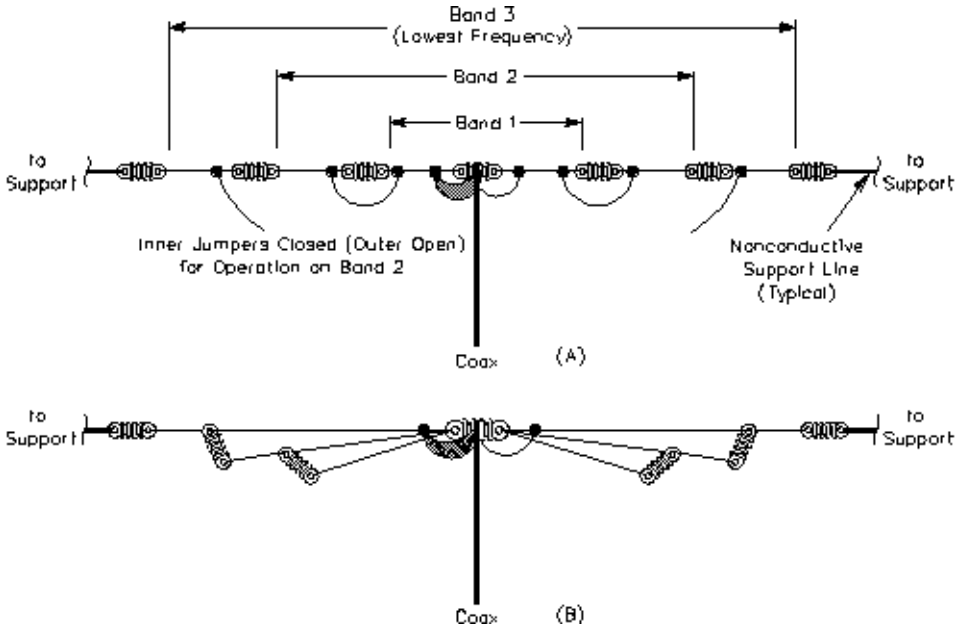


**Figure 2—A jumpered dipole (A) and a fan dipole (B).**

**Q** A jumpered dipole might be good for camping trips. I can roll it up and fit it in my backpack! It's too inconvenient for home use, though. Do you have some alternatives?

**A** You have two basic options for multiresonant center-fed dipoles trap dipoles and multiwire dipoles. Once properly tuned, these antennas require no further adjustments or switching. First, let's talk about trap dipoles.

Traps are tuned circuits inserted along the length of the antenna. Resonant traps are parallel resonant at some frequency, where the trap's high impedance effectively isolates or disconnects the remaining wire from the antenna segment between the traps. A resonant trap is a bit like a frequency-sensitive insulator. Correct trap placement and tuning are important.

Nonresonant traps add reactance to raise or lower an antenna's resonant frequency. When cleverly designed, a pair of traps can provide resonance on several different bands. [1]

Trap-dipole advantages include reduced size, instantaneous band-switching and a standard dipole radiation pattern. Traps serve as inductive loading below their resonant frequencies, so the physical length of a trap dipole may be shorter than a resonant wire on the antenna's lowest band. A trap dipole, therefore, may be just the answer for space limitations or a small lot. On the down side, traps increase loss, expense, complexity and maintenance. The added weight and wind loading require sturdy antenna supports. Traps also tend to decrease antenna bandwidth—a problem if you like to operate at the limits of a single band.

The other multiresonant dipole is known by many names: multiple dipole, multi-element dipole, parallel-wire or fan dipole. It can be constructed a variety of ways, but **Figure 2B** shows the technique I used to build my first antenna. Each element is individually tuned to one of the desired bands. The total feedpoint impedance becomes the parallel combination of all element impedances. Since the impedances of resonant elements should be around 50 to 75 Ω and those of nonresonant elements much higher, the total antenna impedance should be approximately that of a single resonant element. This provides a nice match for coax, and it means that only one element should be resonant on any band. HF combinations to avoid include 40/15 meters and 80/30 meters. For these

cases, cut the element for the lower frequency and let it serve double duty at the odd harmonic.

In theory, we could fashion a four-wire antenna for the 80, 40, 30, 20, 15 and 10-meter bands. In practice, it may be difficult to obtain a good match on all bands. Since the resonant length of a given element in the presence of the others is not the same as a dipole by itself, tuning can be a tedious and difficult procedure. Adjust elements for resonance in order from lowest frequency to the highest. As with the jumpered dipole, I recommend leaving a little extra wire to facilitate pruning. [All of these bandwidth, adjustment and matching problems are easily solved with an antenna tuner at the transmitter, feeding the antenna through 100 feet or less of RG-8 coax.—*Ed.*]

Fan dipoles offer many of the trap-dipole advantages except reduced size. In addition to the tricky and tedious tuning procedure, the disadvantages of this antenna also include reduced bandwidth. The cost of the additional wire and insulators is minimal, so there may be some savings over a trap dipole. A fan dipole may be easier to construct, depending on the complexity of the traps being considered. If the SWR on the line of a fan dipole is low enough that transmission-line losses due to SWR are low, there may be an efficiency advantage over a trap dipole. The bandwidth advantage however, may go to the trap dipole. Trap losses, although generally considered undesirable, can help to improve the apparent bandwidth. The detrimental affects of interaction between fan dipole elements, coupled with “beneficial” effects of trap losses, tend to give the bandwidth edge to the trap dipole.

**Q** Bandwidth limitations are a concern, especially since I like to operate both CW and phone. Do you have any other recommendations?

**A Figure 3** shows one of my favorite multiband dipoles. It goes by a variety of names, the most common is probably “center-fed Zepp.” Other names include the “tuned doublet” and “dipole with tuned feeders.” This is essentially a dipole cut for the lowest frequency of interest and fed with ladder line. An antenna tuner matches the feed-line impedance to 50-Ω coax. Unfortunately, this antenna is widely misunderstood. Let’s clarify a few points—perhaps we’ll even debunk a few myths in the process

1. Ladder line is used because of its inherent low loss at HF. It does not radiate (assuming proper balance), nor does high SWR cause it to radiate.

2. High SWR on a transmission line merely increases line losses relative to those of the matched line.

3. Any power that is *not* dissipated in the feed line, tuner or transmitter is *radiated* by the antenna.

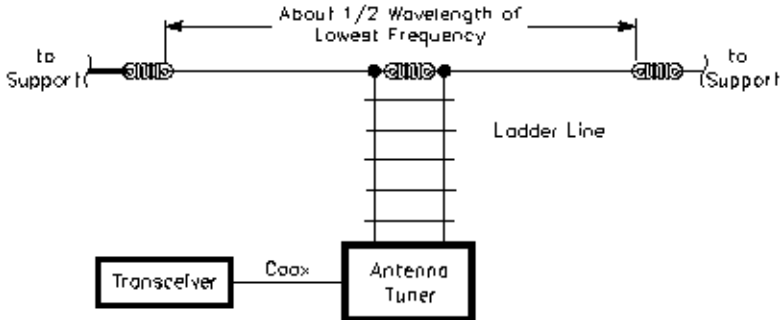


**Figure 3—A dipole fed by ladder line and a tuner is a simple multiband antenna (once the feed-line length has been experimentally determined, see text). This antenna is often called a center-fed Zepp, although any similarity to a true Zepp antenna is purely visual. Drawing is not to scale.**

The center-fed Zepp can be remarkably efficient, despite the relatively high SWR along its feed line. The secret is the ladder line’s low loss, but the antenna tuner is another story. Tuner losses can vary widely with band, impedance mismatch, component quality and circuit design. A balun at the tuner output can be very lossy in this type of system. *Do not install a balun between the ladder line and antenna;* they’re both balanced already!

The antenna length should be about a half wavelength at the lowest frequency of interest for best results, but the length is not critical. A typical length for an 80 to 10-meter version is 127 to 135 feet. There is no magic feed-line length either, but it may require adjustment for your particular installation. Remember, the feed-line impedance varies along a mismatched line. If your tuner has difficulty on some bands or you experience “RF in the shack,” add or subtract 1/8 wavelength (for the troublesome band) of antenna feed line. You may need to repeat this if other bands become difficult to tune, but a little perseverance usually fixes them all.

Advantages of the center-fed Zepp include all-band coverage, minimal weight and low cost. Disadvantages are the expense of

the tuner and the need to retune when changing frequency or bands. The radiation patterns become increasingly complex at higher frequency bands. (The curves in **Figure 1** hint at this. The 30 and 20-meter curves show the third and fourth harmonics. Lobes and nulls increase in number with frequency.) Ladder line lacks the convenience of coax. You must keep it away from metallic objects by at least twice its width—about two inches for one-inch-spaced 450-Ω line. Make any bends as gradual as possible, say a 12-inch radius for 450-Ω line. Twisting the line helps stabilize it in windy environments. I generally twist it 180° for every two feet or so. A high SWR also increases voltages and currents along the line, so the maximum-power capability of a mismatched line is less than its specified rating.

Good luck with your antenna selection and installation. I hope I've been able to help!

### Note

[1]Pages 7-10 and 11 of *The ARRL Antenna Book,* 17th edition (Newington ARRL 1994; No. 4734) show a dipole with two traps that works on *five* bands. For ordering information about ARRL books, see the ARRL *Publications Catalog* elsewhere in this issue. Also see "Two New Multiband Trap Dipoles," by Al Buxton, W9NX (*QST*, Aug 1994, pp 26-29).