Feeding Dipole Antennas

Last month, I covered dipole-antenna basics. This time I'll show what it takes to get RF from your rig to a dipole—and how to make that antenna radiate as much of your signal as possible.

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Communicating via radio fundamentally depends on getting RF to your antenna system—and on making the antenna radiate that energy as efficiently as possible. As simple as this may sound, achieving it can be challenging. Last month, I described how dipole antennas work and how to make them;[1] this time I'll cover getting RF back and forth between your antenna and your radio. This includes two general subjects: selecting the right feed line, and making the *antenna*—not the feed line—radiate your signals.

Feed Lines

Two general types of transmission lines are usually used to feed dipole antennas. One is *coaxial cable*, which is familiar to most people. Basically, it's the same stuff that connects your TVs and videocassette recorders to each other, and to the cable-TV system.

Coaxial cables commonly used by hams, including RG-8 and RG-58 (both of which are somewhat different from TV coax), and similar types, are useful for feeding resonant dipoles.[2] Such cables offer a reasonably good impedance match to the antenna and to your transmitter, are easy to work with, and are fairly inexpensive. If you use coaxial cable to feed a dipole (or elsewhere in your station), follow the guidelines Dave Newkirk, WJ1Z, put forth in his article, "Connectors for (Almost) All Occasions," in April and May 1991 *QST*.

One drawback of feeding dipole antennas with coaxial cable is that most coax has relatively high loss when it's used to feed nonresonant antennas. (*The ARRL Antenna Book* and *The ARRL Handbook* discuss this in their chapters on transmission lines; see "Further Reading.") Using an antenna tuner, you can match the impedance present at the shack end of a coaxial feed line to your radio—even if it's feeding a far-from-resonant antenna—*but a good match isn't an indication of system effectiveness*. For one thing, high cable loss causes the SWR to be lower at the radio than it is at the antenna's feed point. Therefore, if you want to use a single dipole antenna on several bands, coax isn't the best choice.

As I mentioned last month, dipoles are balanced antennas. Therefore, it's best to feed them with balanced transmission lines. In a balanced transmission line the currents flowing in the conductors are equal in magnitude and 180° out of phase, allowing the line to transfer power without radiating it. If *either* of these is not the case, the line will radiate, potentially causing RF interference (RFI) and other problems. Fortunately, you can avoid feed-line radiation by following the guidelines I'll cover in the remainder of this article.

Open-Wire Feed Lines

This feed-line type commonly used by hams is known variously as *ladder line*, *twinlead* and *parallel feeders*. I'll refer to this class as *open-wire line* (even though the conductors may be insulated and are separated by substances other than air). Using open-wire line to feed most dipole antennas eliminates the need for a balun (if the entire feed system is balanced, as discussed later). Open-wire lines have other advantages, especially when used for feeding *nonresonant* dipole antennas. When used to feed high-SWR loads such as nonresonant antennas, open-wire lines have very low loss compared to coax.[3] Even a badly mismatched open-wire line, such as one feeding a 14-MHz dipole at 21 MHz, has a *lot* less loss than RG-8 or RG-58 coax performing the same duty. With moderate to long feed lines, that can make a *big* difference when it comes to making contacts on the air. Open-wire lines are also much better for long feed-line runs than coax, because open-wire lines generally have lower *matched loss*—loss when operated at low SWR—than varieties of coax usually used by hams.

Characteristic impedances of open-wire feed lines are generally much higher than the 50 Ω of the coaxial cables that hams most often use. Typical ladder line, for instance, has a characteristic impedance of 400 to 450 Ω; TV twinlead, 300 Ω. To use open-wire transmission lines to feed dipoles, you'll also need to use an antenna tuner, because modern Amateur Radio gear is designed for use with unbalanced ≈50-Ω feed lines. If you're planning to use a dipole antenna on several bands, you'll need a tuner anyway, because a dipole's impedance can provide a good match to coax on only one or two HF ham bands.[4]

Widely available from *QST* advertisers (see the sidebar, "Where to Get the Pieces," in last month's article[5]), open-wire transmission lines are usually less expensive than coaxial cable and require no special connectors. If you like, you can easily make your own open-wire line with wire and home-made or store-bought insulators.[6,7]

One area where open-wire transmission lines are less practical than coax is in routing the feeder from the antenna to the station. In properly used coaxial cable, the RF fields are contained almost entirely within the cable, so coax can be run through walls and near other conductors without special precautions. But in open-wire line, RF fields surround the line at least as far as the wires are spaced apart. Thus, when you're routing open-wire line, space it at least its width away from any conductive object, and farther if it runs parallel to a conduc-

[1]Notes appear on p 24.

Further Reading

For more information on baluns and feed lines, 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 page 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). The chapters on transmission lines, matching transmission lines to antennas, and selecting your antenna system contain useful information on selecting and feeding all kinds of antennas.
- C. Hutchinson and L. Wolfgang, eds, *The ARRL Handbook for Radio Amateurs*, 1991 ed (Newington: ARRL, 1990).
- R. Lewallen, "Baluns: What They Do and How They Do It," *The ARRL Antenna Compendium*, Vol 1 (Newington: ARRL, 1985), pp 157-164. This article is a good, down-to-earth technical introduction to baluns, and is required reading for anyone interested in this subject.
- W. Maxwell, "Some Aspects of the Balun Problem," *QST*, Mar 1983, pp 38-40. This, too, is a must-read.
- A. Roehm, "Some Additional Aspects of the Balun Problem," *The ARRL Antenna Compendium*, Vol 2 (Newington: ARRL, 1989), pp 172-174.
- J. Belrose, "Transforming the Balun," *QST*, Jun 1991, pp 30-33. Effective baluns easily made from coaxial cable and ferrite beads are the subject of this article. Transformation ratios of 1:1, 6:1 and 9:1 are covered.
- J. Sevick, *Transmission-Line Transformers*, 2nd ed (Newington: ARRL, 1990), Chapter 9.
- J. Reisert, "Simple and Efficient Broadband Balun," *Ham Radio*, Sep 1978, pp 12-15.

tive object for more than a couple of feet. (Radio Shack sells standoffs meant for supporting TV twinlead adjacent to walls and roofs [1991 catalog, p 86]; these standoffs are usable with most open-wire feeders used by hams.)

There are many ways to route open-wire feeders through walls and windows. Follow these guidelines:

- Try to maintain the wire-to-wire spacing when running open-wire feeders through solid objects.
- Use good-quality, high-voltage-insulated wire (such as the center conductor and center insulator [dielectric] of RG-8 coax) or ceramic standoffs at walls or windows.
- Avoid following other conductors with open-wire lines.
- Seal the holes you make to keep weather and critters out.

One more caveat: TV twinlead is a generally acceptable alternative to open-wire lines intended for Amateur Radio use, but when it gets wet, it can become more lossy than coax at HF.[8]

Making the Antenna Do the Radiating

As I mentioned earlier, how well an antenna works largely depends on how much of the power put into the feed line gets to the antenna. If the feed line radiates or is significantly lossy, your antenna isn't radiating as much RF as it should. Keeping the feed system from radiating, thereby letting the dipole do its job as well as it can, isn't as challenging as you might think.[9] In fact, it's pretty easy in most cases.

If you've chosen to use coaxial cable to feed a dipole antenna, there's a good chance that the cable will radiate some of the applied signal, potentially causing interference and nasty RF burns in the shack. In most cases, a simple balun can eliminate this problem.

A balun is simply a device that interfaces an unbalanced system (coaxial feed line) to a balanced system (the dipole), providing the antenna and the feed line with the terminations they need, and keeps the feed line from becoming part of the antenna. Walt Maxwell, W2DU, put it succinctly[10] when he said that a balun's "*primary* function is to provide proper current paths between balanced and unbalanced configurations." In so doing, a balun forces RF in the feed line to flow into the *antenna*, instead of down the outside of the coaxial cable's outer conductor. (See "Further Reading," especially the articles by Roy Lewallen, Walt Maxwell and Jack Belrose, for the reasons for this.)

Three Simple Baluns You Can Build

Because the 50-Ω impedance of common coaxial cables (such as RG-8, RG-213, RG-58 and miniature RG-8) closely matches the impedance of a resonant dipole, the balun you use doesn't have to perform any impedance transformation. That makes the balun-building task much easier. Three effective and very simple baluns in wide use today are described as *choke baluns* because the high impedance they place on the outside of the coax keeps RF from flowing back down the outside of the cable. Each is made primarily from coaxial cable.

Bead Baluns

You can make an effective and simple balun using special ferrite balun cores[11] stacked over the outside of a coaxial cable. (See Fig 1.) The cores don't affect the RF currents flowing on the cable's center conductor and the *inside* of its braid, but they stop RF current flow on the outside of the braid. Because the beads are one-piece units just large enough to slide over the outside of RG-8/RG-213 cable, put them on before you connect the cable to the antenna. Keeping this balun as close to the antenna's feed point as possible lets the balun do its job best, but it may be effective elsewhere on the line.

Once you've placed the cores over the feed line, securely tape the cores together and to the coax, so that the cores can't slide down the cable. These cores are somewhat fragile (they chip and break easily if dropped), so be careful when handling them.

A Coaxial-Choke Balun for the Shack

In his February 1990 *QST* article,[12] Rich Measures, AG6K, described the rationale for using a choke balun made from coaxial cable, and explained how to build such a balun. You can make this kind of choke balun by winding 15 or so feet of coaxial cable in a single layer on a piece of ABS plumbing pipe between 3 and 5 inches in diameter and about a foot long. (See Fig

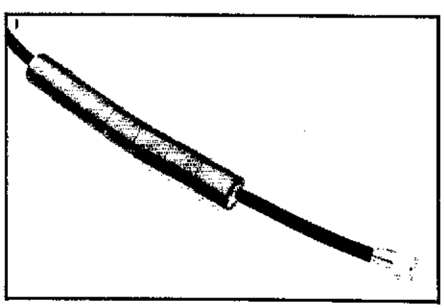

Fig 1—A bead balun made from several ferrite beads stacked on a piece of RG-8 coaxial cable. These cores chip easily, so they should be taped together and to the cable to prevent damage. (Tape is omitted here for clarity.)

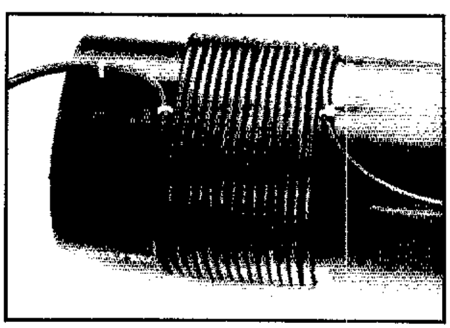

Fig 2—A coaxial-choke balun, wound from RG-58 on a piece of ABS plumbing pipe, effectively stops the flow of RF on the outside of the coax shield, but doesn't impede current flow inside the cable.

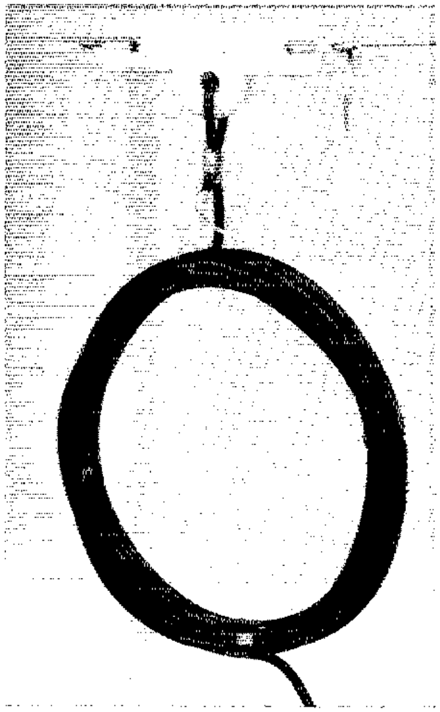

Fig 3—A coaxial-cable choke balun with an air core is effective and light enough to hang from the feed point of a well-supported dipole antenna.

2.) Avoid using miniature RG-8 cables (such as Belden RG-8X and Radio Shack RG-8M) and other foam-dielectric cables for this application, because the center conductor of such cable can wander through the dielectric and arc to the braid if the cable is wound too sharply. Solid-dielectric cables such as RG-8, RG-213 and RG-58 aren't affected this way.

This kind of balun is pretty bulky, so it's best for use in the shack, just after the output of your rig (between the radio and antenna tuner, if you use one).

A Formless Coaxial-Coil Choke Balun

Roy Lewallen, W7EL, described this variation on the coaxial-choke-balun theme in *The 1991 ARRL Handbook for Radio Amateurs* on page 16-9. This effective balun simply consists of a coil of cable, turns taped conveniently together, as shown in Fig 3. A table on page 16-9 of the *Handbook* gives the appropriate number of cable turns you should use in making such a balun. This is a function of frequency and cable type.

A coaxial-choke balun in the shack in conjunction with a bead balun or formless coaxial-cable balun at the antenna covers both bases. In fact, coaxial-choke baluns and bead baluns work comparably; use whichever best suits your situation. Also, keep in mind that all three kinds can effectively stop RF current flow on the outside of coaxial-cable braid when placed at locations other than the antenna's feed point.[13] If putting a balun at the feed point is inconvenient, try placing one elsewhere on the line. Feel free to move it to its most effective and convenient location. Choke baluns are suitable for much more than dipoles. Use them with any low-impedance, coax-fed antennas, such as Yagis, quads, verticals and so on.

Hitching a Feed Line to Your Dipole

No matter what kind of feed line you choose for your dipole, you'll have to securely mount it to the antenna's feed point. Fig 4 shows how to attach both kinds of feed lines to a dipole center insulator. The open-wire-fed dipole insulator needs nothing more than a shot of clear spray lacquer to protect it from the elements. The coax junction, however, unprotected in Fig 4 for clarity, must be *completely sealed* for long-term reliability. Tips on these subjects are offered in the sidebar called "Dipole Construction and Adjustment" in last month's article.

Summary

No matter what you feed your dipole with, it's important to remember that the dipole itself is only part of your *antenna system*. The system consists of every cable, connector and wire that comes after the radio's RF-output jack. If you take shortcuts anywhere in the system, your ability to communicate with other stations may suffer. As you'll hear many hams say, a station is only as effective as its antenna system.

Acknowledgment

Thanks to ARRL Technical Advisor Roy Lewallen, W7EL, for contributing to this article.

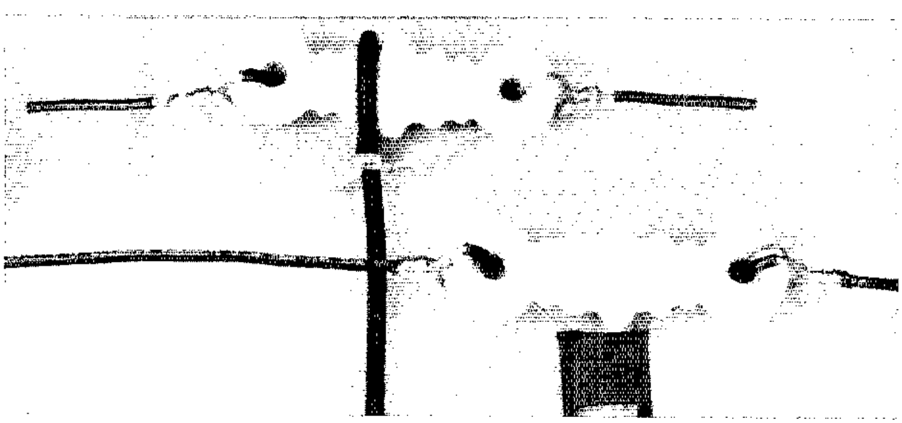

Fig 4—At left, a coaxial feed line is attached to a ceramic center insulator after being wrapped around the insulator. Securing the coax with a plastic wire tie minimizes strain on the cable. Although it's not shown here, weatherproofing is a must on exposed coaxial-cable connections like this one. At right, an open-wire transmission line feeds a dipole. Open-wire lines are inherently easier to use than coax because they require no weather protection except for a shot of spray lacquer at the solder joints to prevent corrosion.

Notes

[1]J. Healy, "Antenna Here is a Dipole," *QST*, Jun 1991, pp 23-26.

[2]"Antenna Here is a Dipole" introduces dipole resonance.

[3]This is because, at HF, feed-line loss is mostly in the conductors (not the insulation). Because open-wire feed lines have higher impedances than coax, lower currents flow in open-wire lines at a given power level, and resistive loss is proportional to conductor current. Lower current therefore translates to lower HF loss in open-wire lines than in coax.

[4]This is true for simple single-wire dipoles, but doesn't apply to multiband, resonant dipoles such as the parallel-multiband and trap varieties described in the last month's "Antenna Here is a Dipole" (see note 1).

[5]See note 1.

[6]R. Measures, "Constructing Ladder (Open-Wire) Transmission Line," D. Newkirk, Conductor, Hints and Kinks, *QST*, Feb 1990, pp 35-36.

[7]Insulators for making open-wire line are available from Davis RF, PO Box 230, Carlisle MA 01740, tel 508-369-1738 or 800-484-4002, extension 1356. For more information and other sources of such insulators, see the sidebar, "Where to Get the Pieces," in the referent of note 1.

[8]See R. Lewallen, "Antenna Feed Lines for Portable Use," D. DeMaw, Conductor, Technical Correspondence, *QST*, Feb 1982, pp 51-52.

[9]In the cases of dipoles that are badly mismatched to the feed line (such as very short antennas), especially lossy antennas, and other unusual circumstances, making a dipole radiate most of the applied RF can be difficult. Garden-variety dipoles, however, tend to be very efficient—usually well over 95%.

[10]W. Maxwell, "Some Aspects of the Balun Problem," *QST*, Mar 1983, pp 38-40. See "Further Reading."

[11]These cores are available from Amidon Associates, 2216 E Gladwick St, Dominguez CA 90220, tel 213-763-5770, fax 213-763-2250 as part numbers FB-77-1024 (for RG-8-size cables) and FB-73-2401 (for RG-58-size cables). See *The ARRL Handbook for Radio Amateurs*, pp 16-9 and 16-10, for more information on ferrite-bead selection for this application.

[12]R. L. Measures, "A *Balanced* Balanced Antenna Tuner," *QST*, Feb 1990, pp 28-32.

[13]Roy Lewallen, private correspondence, May 8, 1991.