The ⅓-Wavelength Multiband Dipole

There's plenty of good antenna installation weather left this season. This compact, high-performance multiband antenna beckons. Try it!

By Andrew S. Griffith, W4ULD
203 Lord Granville Dr, Rte 2
Morehead City, NC 28557

Are you looking for a relatively simple, inexpensive antenna for the HF bands? Are you considering an antenna fed with open-wire (ladder) line, but do you dread the idea of bringing such line through the wall into the shack? Well, relax while I describe a simple antenna system that works well on several ham bands, and is fed with coaxial cable. When properly installed, the antenna system shows an SWR of less than 2.3:1 at its feed point near the middle of the 7, 14, 18, 21, 24 and 28-MHz bands.

The SWR at 3.5 MHz is approximately 5:1. Thus, you may need an antenna tuner (built into your transceiver, or external) on 80 meters. You may also need a tuner on other bands when using a solid-state transceiver because such rigs often reduce their output power when operating into even a moderate SWR, such as 2:1. If you use a tuner, the rig will see a proper load and operate at its full power level. Except perhaps on 80 meters, tube-type transceivers and amplifiers should work into the antenna without a tuner. Since the SWR in the coaxial portion of the feed line is low on most bands, losses are low and efficiency is high.

Fig 1 shows the antenna. Its only unusual aspect is the 375-Ω balanced line between the center of the dipole and the balun. This line is constructed by reforming commercial 450-Ω ladder line for reduced conductor spacing. Reforming the line is a simple procedure that takes about 30 minutes, as I'll describe later.

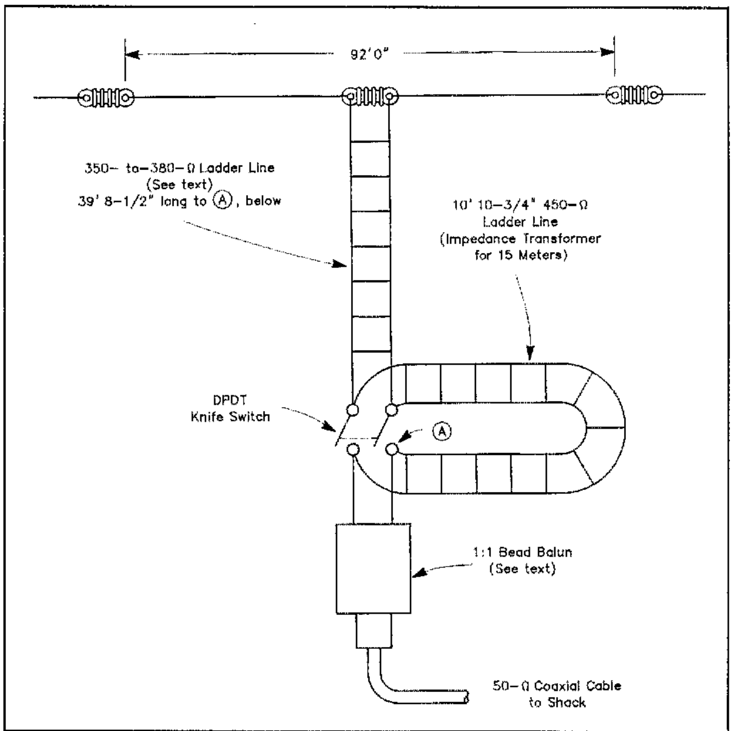

Fig 1—The ⅓-wavelength multiband dipole, with 15-meter impedance transformer and switch. This simple, efficient antenna system has SWR characteristics compatible with most transceivers.

The 1/3-Wavelength Principle

The ⅓-λ dipole was described by Taft Nicholson, W5ANB, in November 1981 *QST*.[1] Nicholson showed mathematically that a ⅓-λ-long dipole, fed with ⅙ λ of balanced line of the proper impedance, exhibits a low impedance at the input (the transmitter end) of the balanced line at the fundamental frequency, and at the second, fourth, fifth, seventh, eighth and some higher harmonics of the fundamental frequency.

Note that the third and sixth harmonics are missing. This means that such an antenna system, cut for 3.5 MHz, will work at approximately 3.5, 7, 14, 17.5, 24.5 and 28 MHz. At 10.1 and 21 MHz, the input impedance will be very high. However, the input impedance on these bands can be transformed to a low value by switching in an extra ¼ λ of feed line at the coax-to-ladder-line transition. Fig 1 shows such a scheme for 15 meters.

Computer Study

To achieve a reasonable SWR on several bands, two factors necessitate a compromise in the lengths of the dipole and balanced line. First, a fixed-length antenna system doesn't resonate exactly at the harmonics of the fundamental frequency.[2] Second, the HF ham-band centers are not exact multiples of any single frequency. So, I performed a computer study to determine the best compromise among dipole length, balanced-line length, and balanced-line impedance. A ⅓-λ dipole at 3.55 MHz is 87.8 feet long, assuming the usual 0.95 K factor for thin wire antennas.[3] One-sixth wavelength of ladder line is 46.2 feet, assuming, for the time being, a velocity factor of 1. I used the *ELNEC*[4] antenna-analysis computer program to determine the impedance at the center of dipoles from 85 to 95 feet in length. For the models, I used an antenna height of 35 feet and #14 wire.

The study showed that the best compromise is a 92-foot dipole, fed with 45 feet of balanced line having a characteristic impedance of 375 Ω and a velocity factor of 1. (The actual line used has a velocity factor of 0.886,

[1]Notes appear on page 35.

Table 1
***ELNEC*-Calculated Data**

Frequency (MHz)	*Dipole Feed-Point Impedance R ±jX ohms*	*Ladder-Line Input (Balun Output) Impedance R ±jX ohms*	*50-Ω SWR on Coaxial Feed Line Measured at Balun*	*Ladder-Line Loss (dB)*	*Total Loss, Ladder Line and Coax (dB)*
3.55	24 − *j*580*	9 + *j*8	5.7	1.1	1.8
7.18	329 + *j*819	52 + *j*40	2.1	0.3	0.7
10.13	4071 − *j*216	56 − *j*0**	1.1	0.7	1.1
14.25	96 − *j*517	33 − *j*0	1.3	0.6	1.2
18.11	340 + *j*765	59 + *j*34	1.9	0.4	1.7
21.30	2396 − *j*2320	53 − *j*0**	1.1	0.9	1.6
24.93	133 − *j*447	59 − *j*7	1.2	0.5	1.3
28.5	345 + *j*647	75 − *j*39	2.1	0.4	2.2

**ELNEC* says the resistive portion of the impedance is 11 Ω. I raised this to 24 Ω because of the low antenna height. See text and Note 5.
**These are transformed impedances with proper lengths of 450-Ω ladder line added at the input to the 375-Ω line. See text.

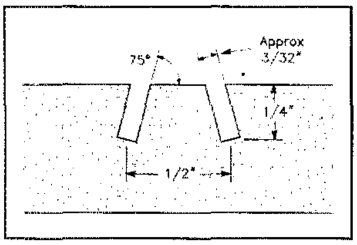

Fig 2—Slot dimensions for the reforming jig, cross-sectional view through board. The 3/32-inch width of the saw blade is perfect for making the ladder-line slots.

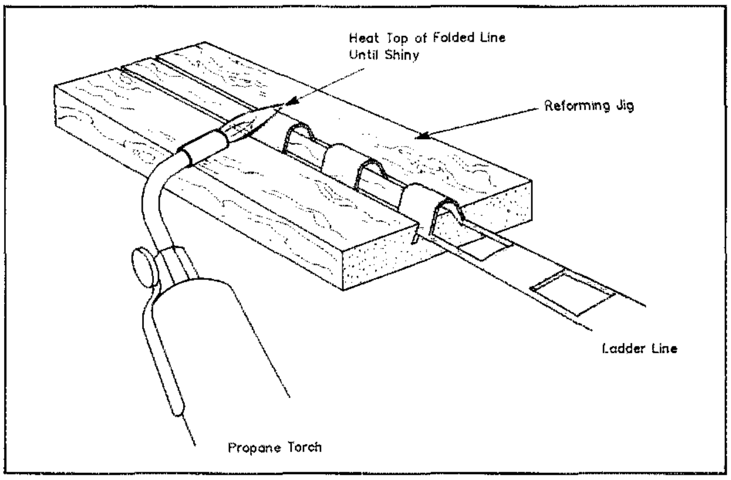

Fig 3—The reforming jig in use. Push and pull the ladder line through the jig as the reforming proceeds. An assistant is helpful for this operation.

so the physical line length must be 45 feet × 0.886, or 39.87 feet.) The lengths are somewhat critical, but balanced-line impedances between 350 and 380 ohms are acceptable. Standard 300- and 450-Ω lines are not acceptable. A summary of the *ELNEC*-calculated data is given in Table 1. Since *ELNEC* predicts erroneously low feed-point resistance values when a horizontal antenna is modeled at heights below approximately 0.2 λ,[5] the resistive part of the antenna impedance at 3.55 MHz was estimated from actual SWR measurements.

Construction

The antenna is easy to build. The only unusual aspect of its construction is reforming the 450-Ω ladder line, which you can buy from antenna-material suppliers. The center-to-center spacing of the line as supplied is approximately 25/32 inch. To make 350- to 380-Ω line, the spacing must be reduced to about ½ inch.[6]

To make a reforming jig for commercial ladder line, use a 2-foot length of wood. Saw two slots lengthwise in the board according to the dimensions in Fig 2. For this task, you'll need access to a table saw or radial saw.

Clamp the reforming jig to a table in a well-ventilated area. Start the reforming by folding toward each other the two wires on one end of the line. Insert the end of the folded line about four inches into the slots at the right end of the jig as shown in Fig 3. Using a propane torch, heat the top of the folded polyethylene until it develops a shiny, almost liquid, appearance. Hold the flame about two inches from the polyethylene and nearly horizontal to the board to minimize charring the line and the board. Push another four inches of line into the slots. Heat the new four-inch section as just described. Continue this process until the reformed line reaches the left end of the jig. By that time, the first four-inch section of the line should be cool. Additional four-inch sections of line can be pulled into the slots from the left while pushing from the right. It's helpful to have an extra pair of hands on the left side to pull the line and coil it into a three-foot-diameter coil. This process may sound tedious, but it's really quite simple. It took me about five minutes to make the reforming jig, and 20 minutes to reform the line without assistance. Fig 4 shows what the reformed line should look like when you're done.

The impedance of my line measures approximately 350 Ω. The velocity factor measures 0.886, which is the same as the stock 450-Ω line. The reformed line is not as flexible as the original, but can be bent easily to a 6-inch radius. Otherwise, the line should be handled like any other ladder line. Make sure that it drops straight down from the connection to the dipole for the greatest possible distance. Keep the line at least 2 inches away from other structures, especially metal ones. These precautions preserve feed-line balance and minimize line radiation. Solder the ladder line at the dipole feed point.

The impedance transformer for the 15-meter band is a loop of 450-Ω ladder line (not reformed). It is switched in and out (shorted) with a small DPDT knife switch such as the Radio Shack 275-1537. I put my switch in a small birdhouse for protection from the weather, but this is not necessary. You can use a remote-controlled relay instead of the manual knife switch; I leave such details to your ingenuity. The form of the loop is not critical, but it cannot be tightly coiled. The dimension given is for an open loop; when I formed the loop into a three-turn helix, the resonant frequency shifted upward from 21.2 to 21.3 MHz.

Instead of the 15-meter transformer, you can use one cut for 10.1 MHz. The transformer should be approximately 25 feet, 3 inches in length. Of course, the antenna can be used without the transformer if an antenna

Table 2

Effect of Coax Feed-Line Length on SWR at Transmitter

Length of RG-8X (feet)	*Frequency (MHz)* 3.55	7.18	14.20	18.11	24.93	28.50
42	4.4	1.3	1.6	2.3	1.3	1.3
52	4.6	1.5	1.2	1.6	1.1	1.5
54	4.6	1.6	1.1	1.7	1.2	1.3
57	4.8	1.6	1.1	1.8	1.3	1.2
64	4.5	1.6	1.5	2.1	1.0	1.5
69	4.3	1.4	1.6	1.7	1.3	1.2
79	3.7	1.2	1.0	1.9	1.0	1.2

Note: These measurements were made without the 15-meter impedance transformer installed.

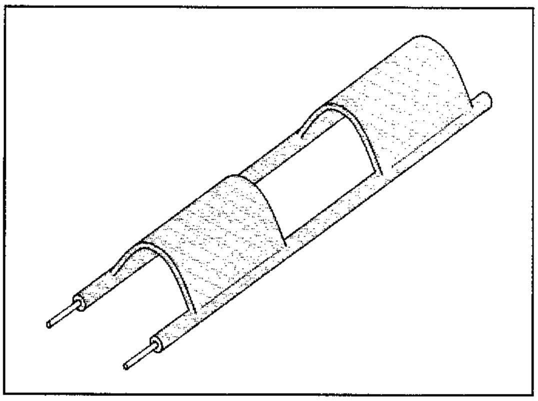

Fig 4—The appearance of the ladder line after reforming.

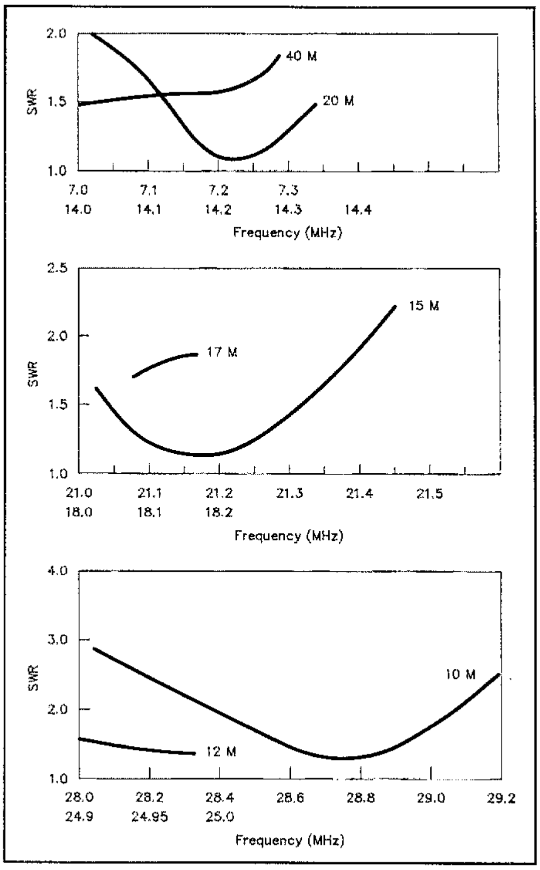

Fig 5—SWR curves for the antenna as built. You can achieve a low SWR on 30 meters by adding an appropriate impedance transformer. See text.

tuner is used. However, the SWR on the coaxial feed line will be quite high, and antenna system efficiency will be low.

The balun consists of 10 ferrite beads (Amidon Associates FB-77-5621) slid over a 13-inch length of RG-8X coax. Solder the coax to the end of the ladder line, and seal it with silicone or windshield sealant. Install a PL-259 connector on the transmitter side of the balun. After installation, seal the balun and the coax connector. I used vinyl electrical tape with a thin coat of sealant. A commercial 1:1 current balun should be acceptable in place of the home-brew unit just described, but I have not tested one.

Evaluation and Operation

After installation, I pruned the ladder line to a length of 39 feet, 8½ inches for the best SWR compromise across the bands. I also pruned the 15-meter impedance transformer to 10 feet, 10¾ inches for best 15-meter SWR. Some pruning of these two lengths may be necessary, so be prepared to experiment a little.

Fig 5 shows the SWR curves for the various bands. I obtained these data with a Bird 43 wattmeter, and with the 15-meter impedance transformer and knife switch installed. I used 57 feet of RG-8X from the balun to the transmitter. Apparently, there was some coupling between the antenna and the coax shield, since varying the length of coax between the balun and the transmitter affected the measured SWR. Table 2 shows this phenomenon. To reduce the variation in SWR with feed-line length, I tried a 1:1 voltage balun, and 10 additional beads on the current balun. These efforts were not particularly successful. In any case, the SWR at the coax input remained reasonable regardless of coax length.

The antenna performs as I expected it would. At 3.5 MHz, signals are not quite as good as with a ½-λ dipole because of the relatively high line losses. At 7 MHz and above, the antenna exhibits some gain over a ½-λ dipole because the antenna is more than ½ λ long. *ELNEC* plots of the radiation pattern show maximum radiation broadside to the antenna at 3.5, 7 and 14 MHz. At 18 MHz and above, the patterns break into four major lobes: 40° from broadside at 18.11 MHz, 35° at 21.3 MHz, 27° at 24.93 MHz, and 53° at 28.5 MHz. The software predicts approximately 3 dB of gain over a ½-λ dipole at 18 MHz and above.

In summary, the antenna works quite well. At 7 MHz and above, it's more efficient than my G5RV. Try it; you'll like it!

Notes

[1] T. Nicholson, "A Compact Multiband Antenna Without Traps," *QST*, Nov 1981, p 26.

[2] J. Hall, ed, *The ARRL Antenna Book*, 16th ed, (Newington: ARRL, 1991), p 2-8.

[3] *The ARRL Antenna Book*, p 2-3.

[4] *ELNEC* antenna analysis software, R. Lewallen, PO Box 6658, Beaverton, OR 97007.

[5] R. Lewallen, "*MININEC:* The Other Edge of the Sword," *QST*, Feb 1991, pp 18-22. See also Feedback, *QST*, May 1991, p 46.

[6] Although I feel that reforming commercially available ladder line is easier, you can build 360-Ω feed line from scratch. Use #12 wire with plastic insulators every 6 inches or so along the line. The conductor spacing should be 0.81 inch. If you choose this alternative, make the line length 42 feet, 9 inches.

Radio and electronics have been Andrew Griffith's hobby since he was 15. He was first licensed in 1951, received his Advanced class license in 1952, and graduated to Extra Class in 1983. In 1943, he earned a BS degree in Chemical Engineering from Virginia Polytechnic Institute. After a tour of duty with the Army in Europe, he received his MS degree in 1947. He spent his industrial career with the Du Pont Company.

Now retired, Andrew devotes his free time to ham radio, golf, and staying out of his wife's hair. His primary radio interests are its technical and building aspects. He still uses a homemade linear amplifier, but most of his home-brewed equipment has been relegated to the attic. He occasionally chases DX and is active in the Volunteer Examiner program.