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QST Issue: Aug 1991
Title: RFD-1 and RFD-2: Resonant Feed-Line Dipoles
Author: James Taylor, W2OZH

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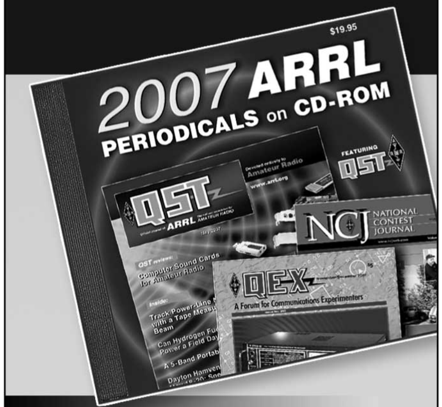

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RFD-1 and RFD-2: Resonant Feed-Line Dipoles

This unique design offers simplicity and general utility. In short, these are "reel" great antennas for the HF bands.

By James E. Taylor, W2OZH
1257 Wildflower Dr
Webster, NY 14580

During several decades of operation on the 80-meter band, I have encountered a number of hams who need an antenna system that is efficient, simple to construct, and yet can be deployed easily in difficult locations. The resonant feed-line dipoles described here provide an excellent match to the transceiver without a separate antenna tuner. They are easily transported on plastic cord reels. The basic design is extensible to other bands—all of this without a dangling feed line to contend with!

Consider some realistic situations encountered by fellow hams in their efforts to get on 80 meters:

Scenario 1: You live on a small suburban lot with trees, but there is no way to stretch a straight 120-foot-long dipole with a feed line.

Scenario 2: Your small backyard ends at the edge of a steep decline. A radiator wire could be snaked through the trees, but running a separate feed line is out of the question.

Scenario 3: You live in a high-rise building and could secretly stretch a wire upward or downward, but there is no way to install a feed line.

Scenario 4: You're going on vacation to the mountains and you know that your cottage is nestled among hundred-foot-high pines. You can take along a bow and arrow and cord, but then what would you do?

In response to these problems, I began to search for a universal solution under the following ground rules. (1) No separate antenna tuner would be required, (2) the antenna could be deployed with no more difficulty than stringing up a length of coax, and (3) the antenna could be easily stored and unwound from a cord reel without a tangle of cable and wire.

Several years ago I used a 10-meter vertical linear coaxial sleeve antenna, as shown in Fig 1. A vertical dipole is constructed from a quarter-wave whip and a quarter wavelength of shielding braid. Its feed line passes through the braid, yielding a simplified geometry. Although this concept could be adapted to 80 meters, who wants to deal with 60 feet of shielding braid? The important lesson I learned was that the RF current has no trouble traveling up the inside of the coax and making a 180° turn to travel back on the outside of the braid!

Because this is true, perhaps we don't need the separate outer braid. Why not just use the outside of the coax itself? If we do this, however, how do we let the RF "know" when it should stop flowing and reflect back toward the center of the radiator, as it did when it came to the end of the added braid in the 10-meter vertical? The current on the outside of the coax shield is called "common-mode" current—there is no counteracting equal and opposite current as there is inside the coax. One design approach utilizes the primary function of a balun transformer: to place an unbalanced reactance in the path of this common-mode current without affecting the desired balanced transmission line currents. The development of this concept is discussed in the Appendix.

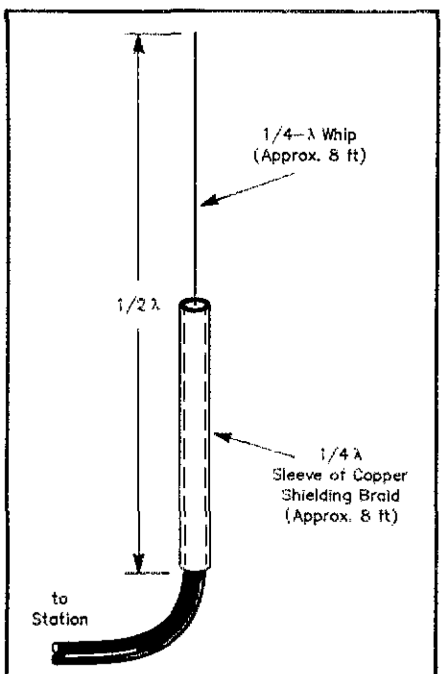

Fig 1—A vertical linear coaxial sleeve antenna for 10 meters.

The common-mode current on the coax shield is transformed by a quarter-wavelength stub to maximum near the transceiver. It was not surprising to note experimentally that a coil of a few turns placed at the fed end of the dipole decreases the resonant frequency of the system substantially (because of the added inductive reactance). However, an unexpected dividend of this is that, at the resonant frequency, an almost perfect impedance match to the 50-ohm source is realized! Now we have the design for our simplified antenna system! We can increase the resonant frequency by moving the coil along the cable away from the current maximum while retaining the perfect match. And at the same time we can decrease the common-mode current on this part of the line, because of the coil's inductive reactance. For the values chosen, the coil is near self-resonance from the distributed capacitance of the coil windings. The equivalent parallel-resonant circuit serves to increase the reactance at this point in the antenna, which assures a reflection when the RF reaches this virtual end of the dipole. To my knowledge, this configuration and method of resonating is unique and novel, and I refer to it as a T choke.

Construction, Installation and Adjustment

The simple arrangement of the resonant coaxial linear dipole is shown in Fig 2. The

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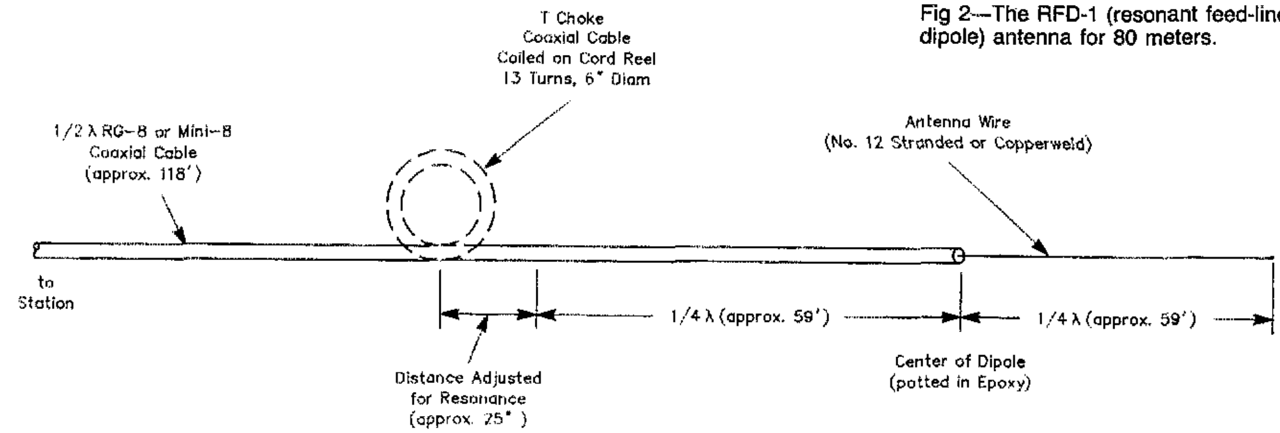

Fig 2—The RFD-1 (resonant feed-line dipole) antenna for 80 meters.

dimensions and test results are for a nominal frequency of 3.95 MHz. To dramatize the simplicity of the antenna, I list all required parts in Table 1.

The coaxial cable connector is assembled at the input end of the coax for connecting to the transceiver. The center conductor of the far end of the cable is connected to the antenna wire to form a hook and eye, and is securely soldered. This junction is potted in the center of a short length of PVC pipe to form a robust center insulator assembly. At the outset, 13 turns of cable can be wound on the cord reel at a point approximately 59 feet plus 25 inches from the center of the dipole. The 13 turns can then be taped in place on the reel with duct tape or equivalent. The remaining coax and wire can now be wound on the reel for ease of transporting. To avoid kinks when unwinding, secure the end of the wire and rotate the reel, keeping the wire and coax taut.

Ground losses are a great enemy of an HF antenna, especially at the lower frequencies, so place the dipole for 80 meters as far above the ground as possible! After installation, check the resonant frequency with a noise bridge or an SWR meter. If these construction details are followed, the resonant frequency should be approximately 3.95 MHz. If the resonance indication is indefinite or if the resistance is not close to 50 ohms, adjust the self-resonance of the coil by moving the turns slightly on the reel. This alters the inter-turn capacitance, permitting adjustment of the reflection of RF at the end of the dipole. During this adjustment, remember that the greatest effect is between the input and output turns, where the voltage difference is greatest. If you want to lower the resonant frequency of the antenna, remove the tape and rotate the reel to increase the 25-inch distance, thereby increasing the length of the dipole. This is done in a manner to retain the 13-turn coil—you are winding and unwinding equal lengths of cable. When the desired resonant frequency is attained, you are ready to operate! This is a broadband antenna, and not much adjustment is required.

Table 1
RFD-1 Parts List

1—118-foot length RG-8X (minifoam) coaxial cable
1—59-foot length no. 12 stranded or Copperweld wire
1—PL-259 male coaxial cable connector
1—10-inch-diameter cord reel (Doscocil model no. 32500 or equiv.)
1—3-inch length of ½-inch OD PVC pipe (for center insulator)
1—Epoxy potting compound (sufficient to fill pipe)

The 13 turns is mentioned only as a nominal coil size. I have used both 11-turn and 13-turn coils. Self-resonance can be adjusted as mentioned earlier. As the number of turns is increased, the initial 25-inch distance will be decreased. For example, in my test installation a change from 11 turns to 13 turns altered this distance required for resonance from 68 inches to 25 inches. A greater impedance at this point serves to improve the isolation of the dipole from ground.

The RFD-2 for Two-Band Operation

The preceding construction information is for an antenna dedicated to a single amateur band, the RFD-1. With a slightly different configuration, referred to as the RFD-2, the RFD-1 design can be extended to cover the 40-meter band without severing the coaxial cable. Conversion from 80 to 40 meters and back requires only a few minutes. The RFD-2 design allows you to change operation to 40 meters for a few days without permanently altering the 80-meter lengths. In other words, the total dimensions of the 80-meter coaxial feed-line dipole are retained but operation is adapted to 40 meters. This is done simply by winding coaxial cable on reels. This is readily achieved by altering the winding of the coax on the original reel and then adding a second coil near the far end of the dipole. Once the values have been established, this band change is accomplished simply.

The RFD-2, as it has evolved at W2OZH, is shown in Fig 3. Total dimensions are given in Fig 3A. The length of the feed line has been increased from that of the RFD-1 to 143 feet to make allowance for the cable used in the 13-turn coil. This assures an isolating stub which is approximately ¼ λ on 80 meters, and at the same time permits a stub length that is close to ¾ λ on 40 meters, thereby achieving the desired high impedance for isolation on both bands. Also, the no. 12 terminating antenna wire has been replaced by a length of coaxial cable—the outer jacket provides insulation so the coax can now be coiled to provide the desired dipole length on 40 meters.

As pointed out earlier, a self-resonant coil is used to assure a high coefficient of reflection at the fed end of the 80-meter dipole. For other bands it is necessary to calculate the approximate number of turns required to approach self-resonance. A suitable winding for 80 meters was determined to be 13 turns on a 6-inch diameter reel, so the numbers for other bands can be obtained by a simple scaling calculation. Details are given in the Appendix. For guidance in adapting the design for the other HF bands, the approximate number of turns for the terminating coils is shown in Table 2.

For wavelengths shorter than 40 meters it may be desirable to use a radiating section longer than ½ λ. The length either side of center can be any odd number of quarter wavelengths. For example, on 20 meters the radiator could be 3/2 λ (three quarter waves either side of center). Depending upon the antenna orientation, the additional radiation lobes may be advantageous. Also, the unused conductor lengths at the ends are less apt to cause trouble because of parasitic excitation from the main radiator.

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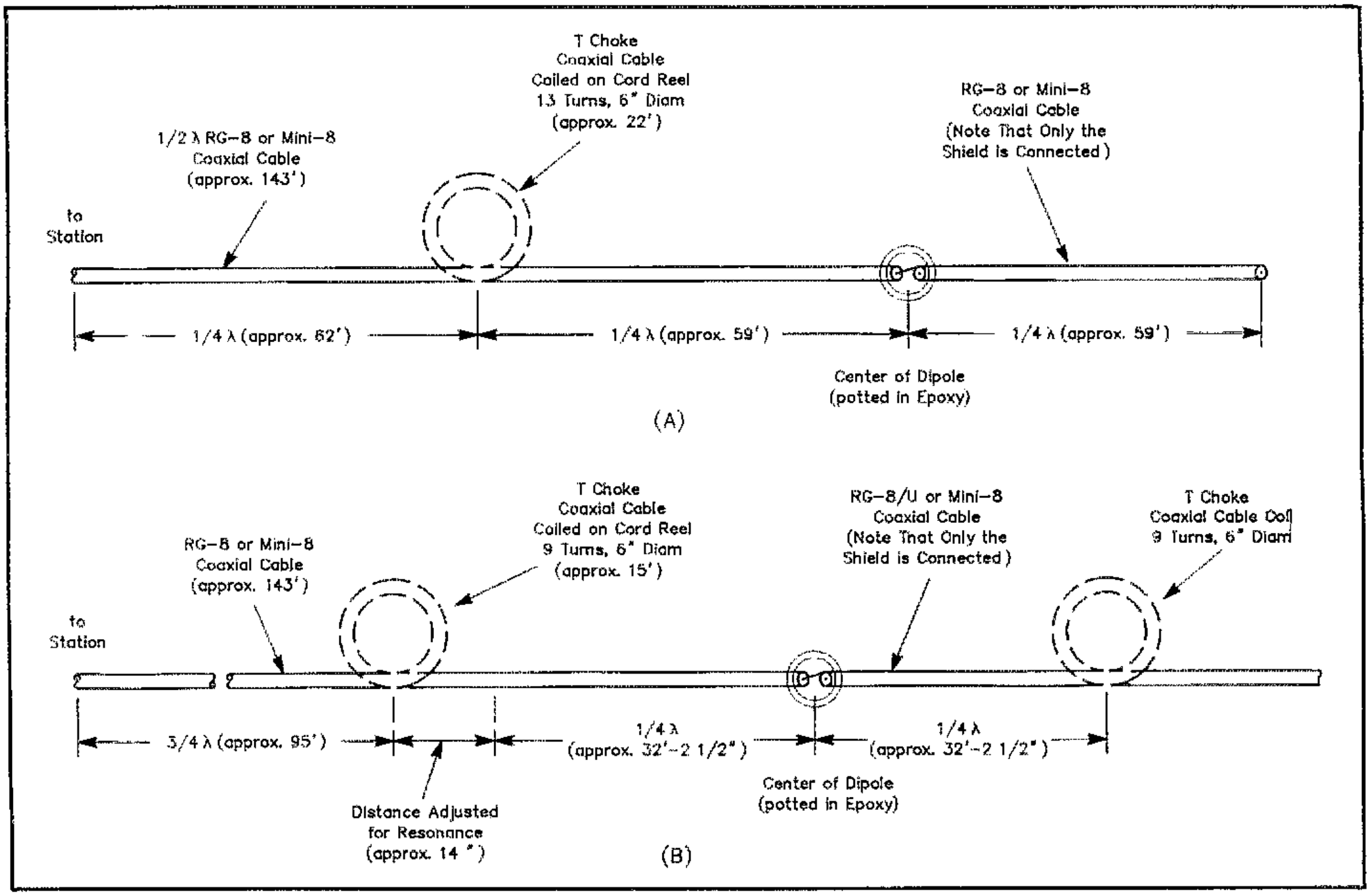

Fig 3—The RFD-2 antenna can be configured for either of two bands. Shown at A is the setup for 80 meters, and at B for 40 meters.

Arrangement and Construction

From Table 2, for the 40-meter band we need to reduce the resonant coil at the input end of the dipole to nine turns, and we need to move the coil along the coax to a point slightly more than 32 feet, 2¼ inches from the center. This is half the dipole length calculated for 7.26 MHz with an allowance for tuning adjustment, using the dipole-length approximation equation, $L = 468/f_{MHz}$. As with the RFD-1, this coil establishes the desired high impedance at the fed end of the dipole.

In addition, we need to establish a high impedance at the far end of the dipole because, in this case, the desired end of the 40-meter dipole does not coincide with the end of the conductor. This is because we want to retain the full length of the conductor measured for the 80-meter band, rather than cutting it. The desired high-impedance reflecting termination is achieved by use of a second, 9-turn, self-resonant coil of coax.

Fig 3B shows the RFD-2 configuration for 40 meters. A cord reel can be used for the second coil, although any suitable insulating 6-inch-diameter form can be used. I wound the coil in two layers using a 1-gallon windshield-washer-fluid bottle. After the windings had been properly adjusted, I taped them in place with duct tape, and slipped the coil off the form so it became self-supporting.

Table 2
Scaling of RFD-1 to Other Bands

Band	*Frequency*	*Turns*
160 m	1.90	19
80 m	3.95	13
40 m	7.26	9
30 m	10.12	8
20 m	14.29	7
17 m	18.14	6
15 m	21.38	6
12 m	24.96	5
10 m	28.65	5

As with the RFD-1, it is desirable to place the antenna as high above ground as possible to reduce ground losses and to help achieve low-angle radiation, if that is desired. The dipole does not have to be installed in a straight line, and if you can gain appreciably greater height by bending it, this may be a desirable compromise.

After the antenna with its two coils is erected, measure the resonant frequency using a noise bridge or an SWR meter. If the construction details have been followed, the resonant frequency should not be far from the nominal value of 7.26 MHz. The resonance point and the input resistance can be shifted moderately by both changing the 14-inch offset distance and changing the inter-turn spacing of the coils. The greatest effect is produced by changing the spacing between the input and the output turns (that is, between coil turns 1 and 9). This is because the voltage difference, and therefore the change in capacitive influence, is greatest there.

Results

My experience in developing antennas is that the good concepts really "want to work," and this antenna was no exception. Noise-bridge measurements with the RFD-1 indicated an input resistance at resonance of 49 ohms, and from a practical standpoint the SWR is 1:1. An H-field antenna probe was used to evaluate the power radiated at the center of the dipole compared with that at the current loop near the feed-point. The current ratio was 5.5 to 1, which corresponds to a power ratio of 30 to 1, or 15 decibels. This indicates that the coil is very effective in attenuating the common-mode current flowing back toward the feed point.

For the RFD-2 with the 40-meter dimensions shown in Fig 3B, the initial resonance point was within the 40-meter phone band and the SWR was essentially 1:1. Slight adjustment brought the resonant frequency up to the desired value, and the input resistance was very close to 50 ohms. A salient characteristic of the RFD antennas

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is the ease with which an impedance match is attained. It appears always to be easy to get a reflected power indication of zero. This is probably because the common-mode current on the shield of the coax is indistinguishable from the desired radiating current—in other words, the common mode is used rather than avoided.

Appendix

When the separate outer braid of the antenna shown in Fig 1 is removed, there must be some way to let the RF "know" when it should stop flowing on the shield of the coax and reflect back toward the center of the radiator. A balun box that I made up for another purpose is one approach: 30 turns of bifilar winding on an Amidon T-200-2 iron-powder toroidal core. The turns formula for such a balun transformer is

$$T = \sqrt{\frac{\text{desired L } (\mu H)}{A_L}}$$

where
- T = no. of turns
- A_L = inductance index (microhenries per 100 turns)

From this, the inductive reactance for unbalanced current is

$$X_L = 2\pi fL = \frac{2\pi f T^2 A_L}{10^4}$$

At a frequency of 4 MHz, this 30-turn coil has an unbalanced reactance of only 270 ohms. We would need about ten of these in series to support the RF field at the end of a dipole antenna!

An alternative method involves placing a toroidal isolation transformer in the coaxial line at the fed end of the linear dipole. I actually wound such a transformer on two stacked T-200-2 cores, to provide a 1-kW power capability. This configuration worked, after a fashion, but the impedance match was less than desired, probably because of excessive capacitance between secondary and primary windings. However, before I took steps to control this, a simpler approach came to mind.

We need to isolate the transceiver from the fed end of the dipole, so why not cut the coaxial feed line to be a quarter wavelength long? (This length is measured in free-space, not in the line.) This serves to transform the high impedance of the fed end of the dipole to the low impedance at the grounded transceiver. Any unused portion of this approximate 60-foot length of coax can be wound in a coil and used for further isolation and, as it turns out, for tuning the system to resonance.

Scaling for a Second Band

For coverage of a second band, we would like to have the same inductive reactance that we had for the 80-meter coil. From handbooks, the inductance of a coil of assumed dimensions is

$$L = AN^2$$

where
- A = a constant determined by the coil geometry
- N = number of turns

Thus, we have for the reactance

$$X_L = 2\pi fL = 2\pi fAN^2$$

For equal reactances, we can calculate N_2, the new number of turns, at frequency f_2, from N_1, the known number of turns at frequency f_1, by the equation

$$N_2 = N_1\sqrt{\frac{f_1}{f_2}}$$

Jim Taylor has been an active ham for "several decades." A retired Xerox research staff manager, Jim's numerous articles in ham journals have concentrated on 80-meter antennas for mobile and fixed applications. Two designs which have attracted some attention are "The 'Mobiloop'" (QST, Nov 1968, pp 18-19) and "An 80m Phased Array" (73, Mar 1975, pp 52-54, 56).

New Books

HAM STUFF

By Walt Garrett, N0MAL. Published by GAI Systems Press, PO Box 5832, St Louis, MO 63134. 1991. Softcover, 8½ × 11 inches, 392 pp. $19.95.

Reviewed By Brian Battles, WS1O

A well-known George Carlin comedy album is entitled *A Place for My Stuff*. If Carlin were a ham, this book would be where his stuff would indeed be listed. *Ham Stuff* is a reference volume that lists nearly every resource imaginable for ham radio information, products and services. (The author estimates he included 80% of the sources available, but I sure can't think of anything that's missing!)

The book is divided into 19 chapters in three main parts: Stuff to Do, Stuff to Buy and the Ham Stuff Directory. There are comprehensive entries for Amateur Radio organizations, museums, public service groups, transceiver and accessory manufacturers, maps, vacation and rental QTHs, Scouting, summer camps, license plates, publications, equipment, hamfests, scholarships, dealers, instruction, examinations, clothing, software, SWLing, equipment collecting, charts, jewelry, kits, modifications, antennas, bumper stickers, towers and just about anything else you can think of. It even lists ARRL officers, Directors and Section Managers as of March 1991.

There are no schematics, tables, charts or lengthy essays, though. *Ham Stuff* is a compendium of comprehensive listings that tells you where to obtain products, services or information. It's set in a pleasant typeface on large pages and is devoid of artwork, except for some manufacturers' logos in the equipment sections.

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The older models 205BA-S and 155BA-S were changed and renamed the 205CA and 155CA, respectively, and feature enhanced front-to-back ratios. The 205CA, with a suggested retail price $762, has a new adjustable beta match with stainless steel hardware and a setting for the 17-meter band. The 155CA, with a suggested list price of $430, has standard settings for CW, mid and phone, and an optional setting for 12 meters. Telex Communications Inc, 9600 Aldrich Ave S, Minneapolis, MN 55420; tel 612-884-4051, fax 612-884-0043.