A Simple Broadband Dipole for 80 Meters

Turn your existing 80-meter dipole into a broadband antenna by simply modifying the feed line. Multiband operation is an option.

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A conventional coax-fed, half-wave dipole doesn't provide a low SWR over the entire 80-meter band—an inconvenience for those of us who like to operate phone and CW on that band. Several approaches to overcoming this limitation, short of an antenna tuner in the station, have been described.[1,2] The antenna system described here is simpler than any of its predecessors and has the following features:

- A 2:1 SWR or better is achieved over all or most of the 80-meter band.
- Antenna length and appearance are the same as those of a conventional half-wave dipole. Consequently, it's lightweight and has small wind and ice loading.
- The antenna configuration permits multiband operation with a single feed line.
- The losses due to broadband matching are acceptable.
- The cost is about the same as a conventional half-wave dipole.

All the SWR data given in this article were measured at the transmitter end of the feed line. The reference impedance is 50 Ω, since most equipment is designed for this impedance. The term *antenna system* as used throughout this article includes not only the radiating wire, but also the feed line, balun (if used), any lightning-protection measures, antenna tuner and so forth.

The dipole antenna itself is not broadband; the system uses a broadband *match*. The key broadbanding element of this antenna system is the *transmission-line resonator*: Part of the transmission line compensates for the reactance presented by the dipole away from its resonant frequency. This part of the line is a multiple of an electrical half wavelength. Another part of the line presents an appropriate source impedance to the transmission-line resonator (TLR).

First I'll describe a version of the broadband antenna system, along with some practical results. Then I'll cover the important matter of antenna-system loss. Following that are some variations to suit specific requirements, and a method for using the antenna for several bands. I'll also compare transmission-line-resonator broadbanding to other broadbanding methods.

[1]Notes appear on page 30.

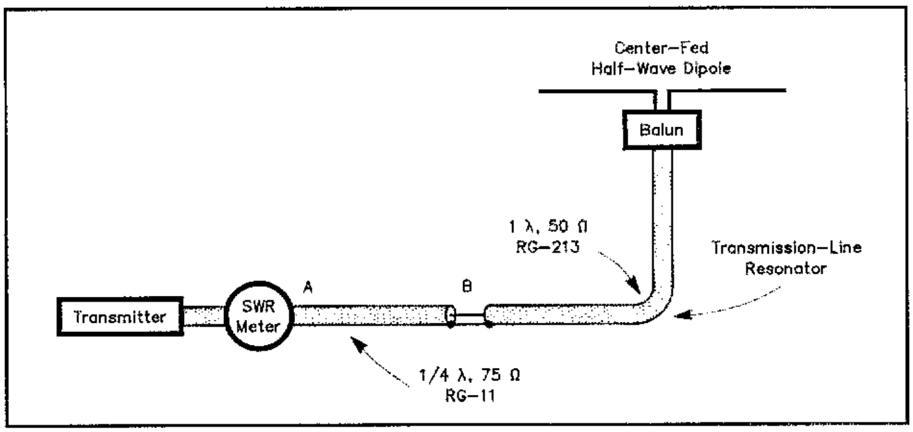

Fig 1—One form of the simple broadband antenna system. It resembles a conventional dipole except for the ¼-wavelength, 75-Ω segment. Points A and B are discussed in the text.

Table 1
Calculated and Actual Lengths of the Broadband Dipole Antenna at AI1H

	Calculated	*Actual*
¼-λ Coax	43.3 feet	43.3 feet
1-λ Coax	173.1 feet	170.5 feet*
Dipole	124.5 feet	122.7 feet

*Includes 11 inches for balun.

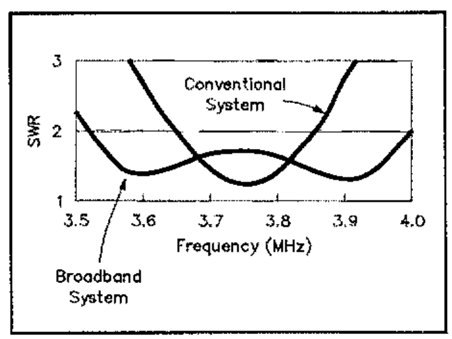

Fig 2—Measured SWR versus frequency for the broadband and conventional antenna systems.

The 80-Meter Broadband Antenna System

Fig 1 shows the simple broadband antenna system as used at my station. The antenna proper is a center-fed half-wavelength dipole. The transmission line is segmented into one electrical wavelength of 50-Ω coax and an electrical quarter wavelength of 75-Ω coax. The calculated and actual lengths are shown in Table 1. Lengths were calculated using the formulas given later in this article, using a center frequency (F_0) of 3.75 MHz and VF (velocity factor) of 0.66. The actual lengths resulted after I performed the tuning procedure described later. Manufacturing variations from the published cable velocity factors, and some stretching of the coax, contributed to the differences between actual and measured values. (The actual lengths were measured on untensioned cable.) The antenna is installed as an inverted **V** with a 140° included angle and an apex height of 60 feet. The wire size is #14, but is not critical.

This system's SWR (at the transmitter) as a function of frequency is shown in Fig 2. For comparison, the SWR for the same dipole fed with about ¾ wavelengths (214

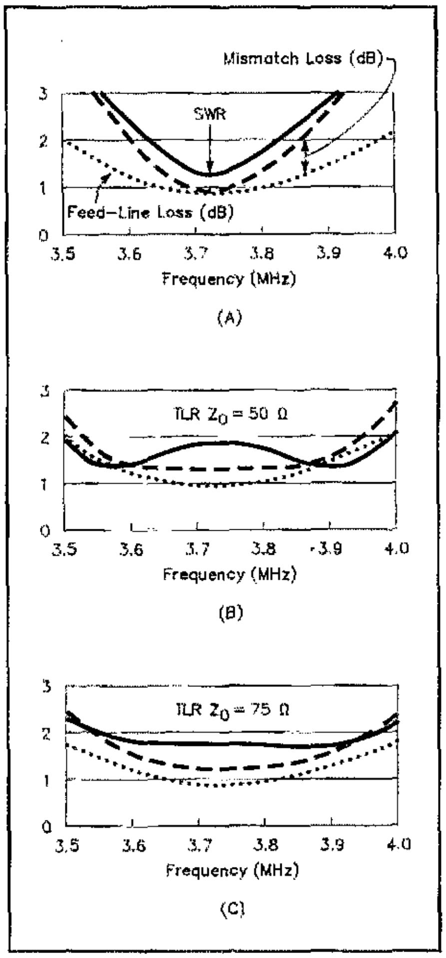

Fig 3—Antenna-system configurations for long feed-line runs. The solid lines are SWR; the dotted lines are feed-line loss; and the dashed lines are feed-line loss plus mismatch loss. At A, a conventional system using an RG-213 feed line; at B, the feed line is a ¼-λ section of RG-11 (75 Ω) followed by 1 λ of RG-213; and at C, a ¼-λ segment of RG-11 is followed by 1 λ of RG-11 (one 5/4-λ piece of RG-11). The total feed-line length in each case is 216.4 feet.

feet) of RG-213 coax is also shown. (This is the same total length as the RG-213 and RG-11 segments used in the broadband system.) The broadband system's 2:1 SWR bandwidth is 2.2 times that of the conventional system—and the *only* difference is the feed-line configuration!

The radiating properties of the broadband antenna over the 80-meter band are essentially identical to those of a dipole cut for any specific frequency in the band. Also, since the antenna system is designed for a 50-Ω transmitter, the feed-line length may be extended by adding the required length of 50-Ω coax between the transmitter and the quarter-wave segment (point A in Fig 1).

A 1:1 current balun should be installed at the antenna's feed point. I use the balun on general principles. Often, it provides no visible difference in operation, but the balun does minimize feed-line radiation. You can determine whether your antenna needs a balun by measuring the SWR versus frequency with and without a balun installed. If the balun is not needed, the two sets of data will be identical.

Antenna-System Losses

It's important to know the losses in any antenna system. This is especially true for broadband antennas, because loss alone can broadband an antenna system. As the next section shows, the configurations presented in this article do not yield a significant loss penalty. Although other loss contributors exist in antenna systems, we will focus on the primary ones: *feed-line loss* and *mismatch loss*. Other losses, such as ohmic loss in the antenna wire, are the same for both the conventional and broadband systems described here.

Feed-line loss is the easiest to understand. It is unavoidable, and is lowest when the feed line is *flat* (when the line SWR is close to 1:1). At HF, feed-line loss results primarily from ohmic losses in the copper conductors.

Mismatch loss occurs when the impedance seen by the transmitter is not the complex conjugate of the transmitter's impedance (when the line SWR at the transmitter is not 1:1). For a 50-Ω transmitter, the mismatch loss is 0 dB when the load impedance is 50 Ω. When the load impedance is not 50 Ω, the mismatch loss can be made to be 0 dB if a transmitter with a tunable output stage (such as a conventional tube-type linear amplifier) is tuned for a conjugate match. An antenna tuner can also provide this match. In this case, however, the antenna-tuner loss (perhaps as much as 1 dB) replaces the mismatch loss in the total-loss equation. That subject isn't discussed here.

If you don't use an antenna tuner and the transmitter has a fixed-tuned 50-Ω output, loads that present the transmitter with an SWR under 2:1 are highly desirable. The impact of high SWR on mismatch loss will become clear in the next section.

Loss must be kept in perspective. All of the broadband antenna systems described here have a worst-case total loss of less than 3 dB—not enough to notice in many 80-meter QSOs. (If the loss is 3 dB, half of the transmitter's output power is radiated and half is lost elsewhere.) The main effect of loss is stress on system components: that on the transmitter due to the mismatched load, and that on the transmission line due to heating.

Variations

The broadband antenna system described above is well-suited for the installation at my station, where the distance between the shack and the antenna is relatively long (more than 200 feet) and because I use a 1-kW amplifier. Other feed-line combinations are better suited to other installations. Some of these are shown in Figs 3 through 5, along with calculated SWR and loss data. From this information, you can select an appropriate feed-line combination for your needs.

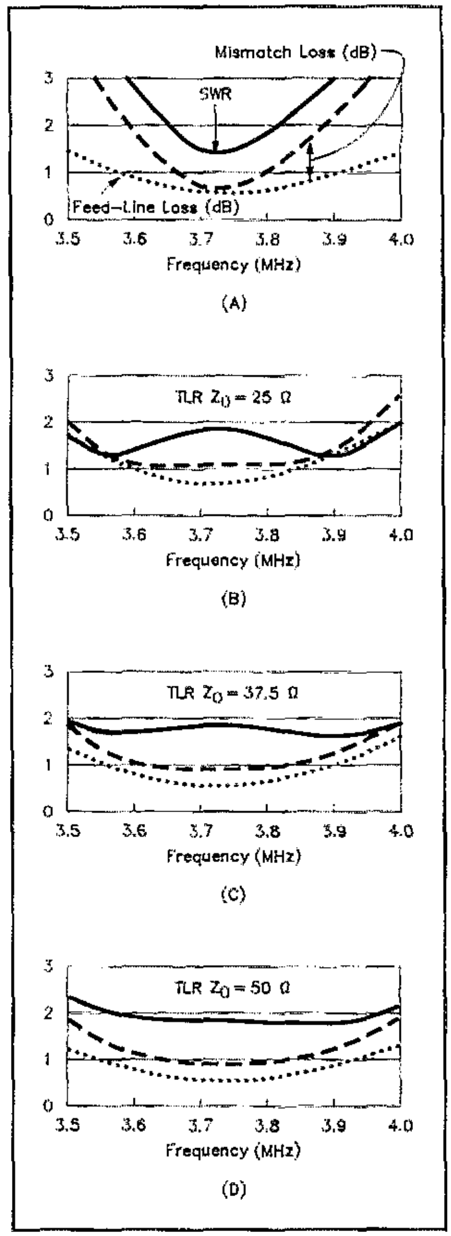

Fig 4—Antenna systems for high power and shorter feed-line runs. The solid lines show SWR; the dotted lines represent feed-line loss; and the dashed lines show feed-line loss plus mismatch loss. At A, the feed line is RG-213; at B, it's a ¼-λ section of RG-11 followed by two paralleled ½-λ lengths of RG-213; at C, a ¼-λ segment of RG-11 is followed by two paralleled ½-λ lengths of RG-11; and at D, ¼ λ of RG-11 is followed by ½ λ of RG-213. The total feed-line length in each case is 129.8 feet.

The figures also show the characteristics of conventional dipole antenna systems. If you compare them, you'll see that the transmission-line resonator provides broadbanding without a significant loss penalty. I haven't tried all these combinations, but based on my experience, they should perform as predicted in most situations if the radiator doesn't deviate significantly from the model I used in my calculations: a dipole 125 feet long, 40 feet high, and made of #14 wire. This model is based on data provided by Walt Maxwell, W2DU, in his book, *Reflections*.[3] I chose his data since it is typical of many 80-meter installations.

All of the broadband antenna systems use a ¼-wave section and either a ½- or 1-wavelength section. Fig 3 illustrates a system for long feed-line runs. It uses RG-11 and RG-213 cable and should be considered for all power levels. Fig 3B covers the case shown in Fig 1 and used at my station. The feed line of Fig 3C is a continuous length of RG-11 cable 5/4 wavelengths long. The transmission-line resonator is the 1-wavelength section of the cable nearest the antenna.

This approach would also work with surplus 75-Ω CATV Hardline. A ¾, 5/4 or 7/4-λ section of ½-inch Hardline yields less than 2 dB feed-line loss plus mismatch loss over the entire band, and less than 1 dB total loss over any 300 kHz of the band. This configuration is particularly attractive to contesters and DXers, because even a fairly long line—7/4 λ is 372 feet of ½-inch CATV Hardline—gives low loss and a very good match over, say, the 3.5- to 3.8-MHz range.

Three broadband antenna systems are shown in Fig 4. All of these are candidates for applications requiring shorter feed-line lengths. Figs 4B and 4C show the performance realized when coax cables are paralleled to achieve a low equivalent characteristic impedance. Fig 3B, which results from a 1-wavelength RG-213 transmission-line resonator, and Fig 4B, are very similar. The latter system uses the same amount of cable, but it's cut in half and parallel-connected. This will become clear in the sidebar, "How It Works." The configuration in Fig 4D is attractive because of its simplicity.

Lower-power applications without long feed-line runs can use RG-58 and RG-59 coax. Fig 5B shows how excellent broadbanding is achieved with a remarkably simple feed line. Again, no loss penalty results from the broadbanding.

Adjusting the Broadband Antenna System

The antenna system is easy to build and adjust. First calculate the lengths (in feet) of the transmission-line segments:

$$L_{quarter} = \frac{245.9\ VF}{F_0} \qquad \text{(Eq 1)}$$

$$L_{half} = \frac{491.8\ VF}{F_0} \qquad \text{(Eq 2)}$$

$$L_{full} = \frac{983.6\ VF}{F_0} \qquad \text{(Eq 3)}$$

where

$L_{quarter}$ = length of quarter-wave segment
L_{half} = length of half-wave segment
L_{full} = length of full-wave segment
VF = velocity factor
F_0 = center frequency in MHz

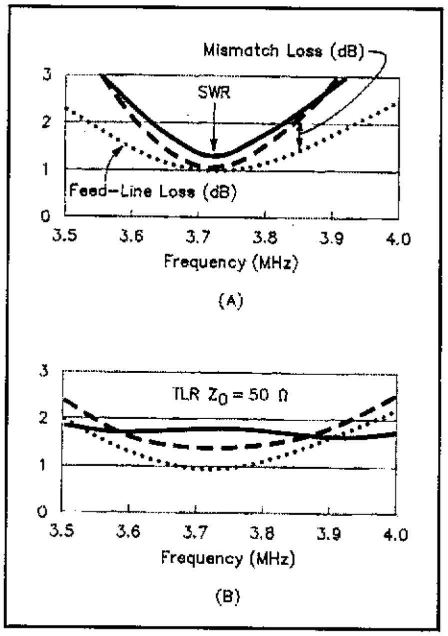

Fig 5—Antenna systems for low power and shorter feed-line runs. The solid lines show SWR; the dotted lines represent feed-line loss; and the dashed lines show feed-line loss plus mismatch loss. At A, the feed line is RG-58; at B, it's a ¼-λ section of RG-59 followed by ½ λ of RG-58. The total feed-line length in each case is 129.8 feet.

A good starting point for the dipole wire length (in feet) is:

$$L_{dipole} = \frac{467}{F_0} \qquad \text{(Eq 4)}$$

For the 80-meter application, I suggest using an F_0 of 3.75 MHz. It's a good idea to cut the wires so that the overall length is 4 feet longer than necessary, in case you need to lengthen the wire during tuning. Pass 2 feet of the extra wire through each end insulator and wrap it back around the antenna wire.

To tune the antenna system, you'll change only the dipole and transmission-line-resonator lengths. The best approach is to build the antenna system as I have outlined here and to measure the SWR at the transmitter end of the system. Any tilt or frequency offset in the SWR characteristic can be removed by increasing or decreasing the dipole or transmission-line-resonator length. Start by changing the length of the dipole. To improve the SWR at the high end of the band, the dipole must be shortened; to improve the SWR at the low end of the band, the dipole must be lengthened. Progressively add or subtract 6 inches from both legs of the dipole until the SWR curve is symmetrical about the center frequency.

Frequency offset may be required to center the SWR characteristic in the 80-meter band. You can move the entire curve along the frequency axis without causing asymmetry by changing both the dipole and transmission-line resonator lengths using the following equation:

$$L_{New} = L_{Old}\left(\frac{3750 - \Delta F}{3750}\right) \qquad \text{(Eq 5)}$$

ΔF is the required frequency offset in kilohertz. Shortening the dipole and resonator moves the curve center up in frequency, and lengthening them moves the center down. The length of the quarter-wave segment need not be changed, since the SWR characteristic is not very sensitive to its length.

Lightning Protection

Every antenna system should be designed to minimize the likelihood of a lightning strike. One part of this is keeping all parts of the antenna proper at ground potential. The grounding should be done *outside the shack*, by means of a good ground rod.

I recommend that you install a coaxial lightning protector, which bleeds any static charge from the center conductor, at point B of Fig 1. The protector (and therefore the feed-line shield) should be connected to a high-quality ground rod (the kind electricians use) driven 8 feet into the ground.

Conversion of Existing 80-Meter Dipoles

A study of the cases shown in Figs 3B, 4D and 5B suggests that it's possible to easily convert many existing 80-meter half-wave dipole antennas. Because the most popular way to feed an 80-meter dipole is with a 50-Ω coaxial feed line, the conversion to a broadband antenna system is straightforward. First trim the dipole for resonance at about 3.75 MHz. Then cut the 50-Ω feed line at a multiple of an electrical half-wavelength (at 3.75 MHz) from the antenna. Calculate this length using Eq 2 or Eq 3. Add the 75-Ω quarter-wave section, then complete the run to the shack (if necessary) with 50-Ω coax. Then use the tuning procedure described earlier to optimize the system.

Multiband Operation

Most broadband 80-meter antenna systems are usable only on the 80-meter band, because the broadbanding elements do not allow efficient power transfer on other bands. This is not true with the approach described here, since the structure consists only of a center-fed dipole and a transmission line. Moreover, the transmission-line segments are close to multiples of an electrical half-wavelength near 40 meters and other bands. This opens the possibility for paralleling other half-wave dipoles with the 80-meter dipole and sharing the feed line.

To minimize their interaction, the various dipoles should be spaced from each other away from the feed point. Of course, some interaction will occur and you must tune the multiband system to meet your requirements. I recommend first tuning the 80-meter

How It Works

A fundamental way of achieving a broadband match to a resonant dipole antenna involves a parallel-tuned LC network and an appropriate source resistance. In an *RF Design* article,* I described the method for designing such networks, even with lossy resonators. The top of Fig A shows the equivalent circuits of the antenna and matching network. The bottom of Fig A illustrates the corresponding elements in the antenna system.

The role of the resonator is played by the transmission-line segment nearest the antenna. It must be a multiple of an electrical half-wavelength. The quarter-wavelength "Q"-section, made from 75-Ω coax, transforms the 50-Ω transmitter resistance to 112.5 Ω ($75^2/50 = 112.5$). I won't go into the design details here; they're the subject of another article, "Broadband Matching Using the Transmission-Line Resonator," in preparation for *The ARRL Antenna Compendium, Volume 4.*

For the structure of Fig A to yield a broadband match, the characteristic impedance of the transmission-line resonator and the transmitter resistance must be within a range of values. Fortunately, commonly used transmission lines, which are available in 50- and 75-Ω characteristic impedances, work well in this application. The broadband systems of Figs 3 through 5 show the usefulness of this approach.

Fig B makes another significant point. For this application, the network parameters of a one-wavelength transmission-line resonator (top) are similar to those of a half-wavelength resonator (bottom) with half the characteristic impedance of the upper resonator. Parallel-connecting two identical cables is a convenient way of achieving lower characteristic impedances. This explains the similarity of Figs 3B and 4B and the similarity of Figs 3C and 4C.—*AI1H*

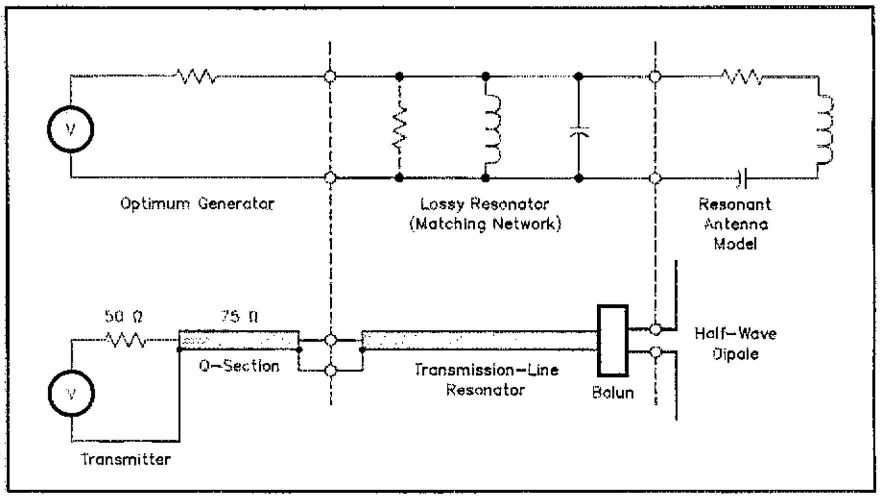

Fig A—Lossy broadband-matching-network equivalent circuit (top), and corresponding simple broadband antenna system elements (bottom).

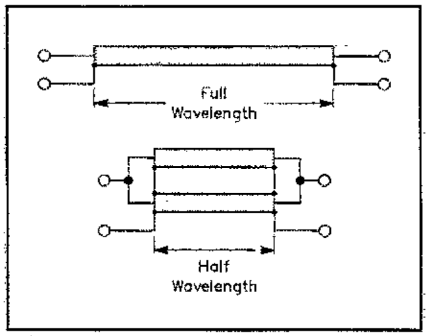

Fig B—These two transmission-line resonators behave essentially the same in this application. The characteristic impedance of each cable segment is the same, making the characteristic impedance of the lower resonator half that of the upper one.

*F. Witt, "Optimum Lossy Broadband Matching Networks for Resonant Antennas," *RF Design*, Apr 1990, pp 44-51, and Jul 1990, p 10.

broadband system and then the next-highest-frequency dipole, and so forth. Only the 80-meter antenna will be broadband, but such broadbanding is not required on the other bands. Fig 6 shows the result of adding a 40-meter dipole to the Fig 1 antenna. Each dipole leg is 34.4 feet long. Note that the SWR on 80 meters changes very little compared to Fig 2. No change was made to the 80-meter dipole or the transmission line.

The multiple-dipole approach described above achieves resonance on several bands and eliminates the need for an antenna tuner on those bands. Of course, if you use an antenna tuner, operation on all HF bands should be possible, but this arrangement is usually not as effective as the multiple-resonance antenna system described here because the feed-line loss is much higher.

Comparison with the Coaxial-Resonator Match

How does the simple broadband dipole described here stack up against other approaches for achieving a good match over the entire 80-meter band? The coaxial-resonator match broadband dipole[4,5] represents one of the more efficient designs published to date. It achieves broadband matching at the antenna by the integration of ¼ wavelength of coaxial cable as a part of the antenna.

Since the coaxial-resonator match achieves a good match at the antenna, the SWR on the feed line is low and the feed-line loss is about the same as its matched loss. However, the coaxial cable in the match itself increases the system loss. The net result is that the total loss is about the same with the coaxial-resonator match, but the SWR at the transmitter is lower, never exceeding about 1.6:1 between 3.5 and 4 MHz. Once the SWR is less than 2:1, however, a lower SWR has little value unless you're using a transmitter that significantly reduces power at such SWRs.

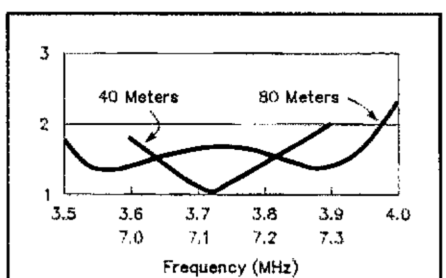

Fig 6—Measured SWR for the 80- and 40-meter multiband antenna system.

Note that the approach described in this article uses a thin wire for the antenna. Most other broadbanding approaches use additional wires or radiators made partly from coaxial cable and are vulnerable to damage from wind and ice loading. Their additional weight and complexity are also limitations.

From the above comparison, the simple broadband antenna system has, by its very simplicity, an edge over the coaxial-resonator match, at least in applications where the simpler approach is feasible. Because of the limitations of available coaxial cables, the opportunity for a satisfactory design is constrained. On the other hand, the coaxial-resonator match has more adjustment para-

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contrast to the performance of my vertical groundplane antenna!

The next big test was the June VHF QSO Party. Last year I used my groundplane and made all of three contacts on SSB—and those contacts required a major struggle. Surely the Eggbeater would provide an improvement.

Improvement is an understatement! During the first 30 minutes of the contest, I worked 20 stations throughout the New England and mid-Atlantic states. I received a solid 59 report from a station in Maine, 165 miles away. Soon thereafter, I made a CW contact with a ham at the southern tip of New Jersey—195 miles south of my location. Many of my contacts were surprised to learn that I was using a roof-mounted, omnidirectional antenna.

This is not to say that the Eggbeater is an optimized contest antenna. Serious VHF contesters use directional, rotatable antennas. Even so, a contest is the perfect environment to test a new antenna such as the Eggbeater. If the reports I received are any indication, the EB-144 does an outstanding job.

Then came my FM testing. With the Eggbeater's horizontal polarization at the horizon, I expected performance to suffer. The only question was, how much?

Out to a range of about 10 miles, my signal is full quieting into voice repeaters. My connections with local packet nodes and PBBSs are also reliable over the same distance. Beyond 10 miles, the differences between the Eggbeater and the vertical become apparent. Because of the mismatched polarization, distant repeaters and packet systems previously accessible with the vertical are now out of reach. Since essentially all of my FM voice and packet communications take place within a 10-mile radius, however, this doesn't pose a problem for me.

Summary

If you don't have the room or the budget for a steerable beam antenna for 2 meters, the Eggbeater offers an attractive alternative. Depending your local terrain, antenna height and output power, you can expect to enjoy reliable 2-meter CW and SSB conversations over considerable distances—perhaps a few hundred miles under good conditions. You should also be able to maintain good communications with local FM repeaters and packet stations.

The Eggbeater is tough to beat for satellite operating, too. It's the ideal antenna for the satellite beginner, offering good performance without the complications of multielement beams and azimuth/elevation rotators. M² Enterprises makes Eggbeater antennas for other bands, including 70 cm (420-450 MHz). With 2-meter and 70-cm Eggbeaters, you'd have a fine antenna system for the low-orbiting Pacsats such as OSCARs 16, 19, and 20-23.

If the Eggbeater's price seems a bit tough to swallow, don't forget that it's constructed of high-quality components. The Eggbeater is not only a good performer, it's built to last.

Manufacturer: M² Enterprises, 7560 N Del Mar, Fresno, CA 93711, tel 209-432-8873, fax 209-432-3059. Manufacturer's suggested retail price: $119.

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The ARRL-purchased Product Review equipment listed below is for sale to the highest bidder. Prices quoted are minimum acceptable bids, and are discounted from the purchase prices.

ICOM IC-737 MF/HF transceiver with internal antenna tuner and optional FL-100 and FL-252A 500-Hz CW filters (see Product Review, August 1993 *QST*). Sold as a package only. Minimum bid: $1020.

Lowe HF-150 LF/MF/HF receiver with optional frequency-entry keypad (see Product Review, August 1993 *QST*). Sold as a package only. Minimum bid: $488.

MFJ 9017 18-MHz QRP CW transceiver (see Product Review, July 1993 *QST*). Minimum bid, $110.

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Alinco DR-600T. Minimum bid, $459.

ICOM IC-2410H. Minimum bid, $544.

ICOM IC-3230H. Minimum bid, $495.

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Standard C5608DA. Minimum bid, $544.

Yaesu FT-5100. Minimum bid, $396.

Sealed bids must be submitted by mail and must be postmarked on or before September 27, 1993. Bids postmarked after the closing date will not be considered. Bids will be opened seven days after the closing postmark date. In the case of equal high bids, the high bid bearing the earliest postmark will be declared the successful bidder.

In your bid, clearly identify the item you are bidding on, using the manufacturer's name and model number, or other identification number, if specified. Each item requires a separate bid and envelope. Shipping charges will be paid by ARRL. The successful bidder will be advised by mail. No other notifications will be made, and no information will be given to anyone other than successful bidders regarding final price or identity of the successful bidder. If you include a self-addressed, stamped postcard with your bid and you are not the high bidder on that item, we will return the postcard to you when the unit has been shipped to the successful bidder.

Please send bids to Bob Boucher, Product Review Bids, ARRL, 225 Main St, Newington, CT 06111.

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meters, is useful over a much broader range of applications and yields the lowest SWR over the band.

Summary

The simple broadbanding technique I've described here capitalizes on the common availability of coaxial cables that fit the application. It overcomes the narrow-bandwidth limitations of a conventional 80-meter, half-wave dipole without significant disadvantages. Even parallel dipoles for other bands may be fed with the same feed line.

The limitation of available coaxial cable parameters can be overcome by using the transmission-line resonator as a resonant transformer. Applying this technique is described in an upcoming *ARRL Antenna Compendium* article, "Broadband Matching Using the Transmission-Line Resonator."

This work has benefited from the support and encouragement of my wife, Barbara, N1DIS. Also, I must credit Andrew Griffith, W4ULD, for helping to turn my attention to the approach described here. After reading my *QST* article on match bandwidth of resonant antenna systems,[6] Andy noted that antenna systems should be viewed from their match to a 50-Ω transmitter, even if the feed line does not have a 50-Ω characteristic impedance. He showed examples of the narrowing of match bandwidth to make his point. In my response, published with Andy's letter in *QST*,[7] I pointed out that match bandwidth of an antenna system may actually be *increased* by selecting the right cable length and characteristic impedance. As an example, I showed in Fig 3 of that correspondence the large match bandwidth of a dipole fed with a ¾-wavelength, 75-Ω RG-11 cable. Note that this is the same case shown in Fig 3C of this article. Thank you, Andy!

Notes

[1]G. Hall, ed, *The ARRL Antenna Book*, 16th ed (Newington: ARRL, 1991), pp 9-1 through 9-12.

[2]M. W. Maxwell, *Reflections: Transmission Lines and Antennas* (Newington: ARRL, 1990), pp 18-1 through 18-6.

[3]See Note 2, p 15-19. I frequency-scaled Walt's data, which is equivalent to changing the wire length. This antenna has a Q of 13 and a resonant resistance of 65 Ω. I took into account the fact that the antenna's radiation resistance increases with frequency.

[4]F. Witt, "The Coaxial Resonator Match and the Broadband Dipole," *QST*, Apr 1989, pp 22-27.

[5]F. Witt, "The Coaxial Resonator Match," *The ARRL Antenna Compendium, Volume 2* (Newington: ARRL, 1989), pp 110-118.

[6]F. Witt, "Match Bandwidth of Resonant Antenna Systems," *QST*, Oct 1991, pp 21-25.

[7]A. Griffith and F. Witt, "Match Bandwidth Revisited," *QST*, Technical Correspondence, Jun 1992, pp 71-72.