By Doug DeMaw, W1FB and Lee Aurick, W1SE

From *QST*, October 1984

The Full-Wave Delta Loop at Low Height

You'll be surprised at the results you'll get from a full-wave loop at low heights.

Property size and antenna-support height are ever-present concerns of the urban amateur. Many good antennas are untried because the radio amateur is unable to imagine how a large wire antenna could be squeezed onto a small lot. Certainly, this is typical in the case of full-wave loop antennas. But there is no rule that dictates using a symmetrical loop. It can be distorted rather severely without spoiling the performance. The same philosophy is appropriate with regard to height above ground and the plane in which the antenna is erected. In most instances, a less-than-optimum full-wave loop will outperform a dipole or inverted V antenna that is close to the ground in terms of wavelength. It is possible that such a loop will give comparable or better performance than a vertical antenna that is less than 90 degrees (with respect to ground), or one with a substandard ground screen.

We want to discuss the Practical considerations of loops that can be supported from low supports on small pieces of property. The results we have obtained are noteworthy with respect to all-around "solid" communications within and outside the USA. Perhaps you will be inspired to unroll some wire and try a loop at your QTH.

Some Loop History

Loops were used first as receiving antennas. While single- and multiturn small loops worked well for receiving, they were not satisfactory for transmitting: They were inefficient in terms of gain, and the feed impedance was generally a fraction of an ohm, making them difficult to match. The losses were significant. But, it was possible to use a compact loop (less than 0.5 wavelength) for receiving in place of a fullsize version that could require thousands of feet of conductor. One of us owned a portable broadcast-band receiver in the 1930s. The loop antenna was stored in the lid of the cabinet, and needed to be mounted atop the radio during reception periods! The radio was heavy: it weighed 91 pounds, including the various dry batteries.

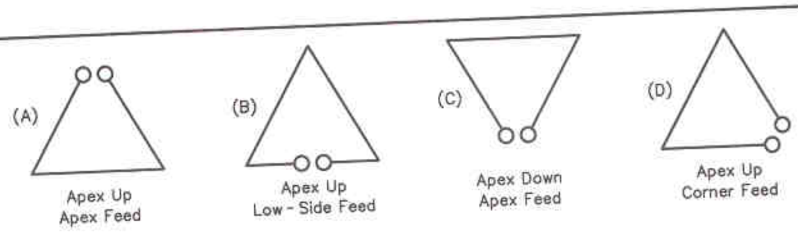
Receiving loops continued to be useful for many years in the commercial services, especially for LF and VLF applications. Amateurs also used them (and continue to do so) for improved reception on 160 and 80 meters. The signal-to-noise ratio of receiving loops is markedly better than that of vertical antennas, and they are directional.[1] Many successful 160-meter DXers owe their success to the use of receiving loops with low-noise preamplifiers. Practically, these loops are the next best thing to Beverage antennas.[2]

Loop Characteristics

What are some of the advantages of a closed, full-wave loop? Perhaps number 1 on the list is the lack of need for a ground screen. The matter of effective height above ground is still a consideration, but we need not lay a ground-radial system as would be the case with a vertical antenna. Consideration number 2 is that a full-wave loop (depending on the shape) has some gain over a dipole. Number 3 relates to noise factor. A closed loop is a much "quieter" receiving antenna than are most vertical and some horizontal antennas.

To illustrate this point, the 160-meter antenna at W1FB is a $^{3}/_{8}$-wavelength inverted-L with twenty $^{3}/_{8}$-wave radials. Since this is essentially a vertically polarized antenna, it is noisy (man-made and atmospheric noise). There are times when an S9 signal is unreadable because of the ambient noise being S9 or greater in strength. Upon switching to the 75-meter Delta loop, the same signal will rise above the noise by 1 or 2 S units, while the noise and signal will drop well below S9. For example, the received signal may drop to S6 on the loop, but the noise will decline to S4.

Feed-point selection will permit the choice of vertical or horizontal polarization. Various angles of radiation will result from assorted feed-point selections. The system is rather flexible when we want to maximize close-in or faraway communications (high angle versus low angle). Figure 1 illustrates various configurations that can be used. The arrangement at C is used at W1SE, and the shape at D is being applied



	Polarization	Radiation Angle
A	Horizontal	Moderately High
B	Horizontal	High
C	Horizontal	Moderately High
D	Vertical	Low

Overall Loop Size in feet $\approx \frac{1005}{1\ \text{MHz}}$

Feed Impedance ≈ 100 Ω

Figure 1—Various configurations for a full-wave Delta loop. Radiation angles and polarization are affected by the feed-point placement and location of the apex.

at W1FB. Both antennas are cut for 80-meter operation. The bandwidth at resonance is on par with that of a dipole. A Transmatch is used for matching the system to the transmitter in those parts of the band (75 and 80 meters) where the SWR is too high to deal with.

Our loops are not deployed in a vertical plane, owing to the lack of tower height. A 60-foot tower and 50-foot tree support the W1SE antenna. A single 50-foot tower is used at W1FB. Both loops are tilted away from the supports at roughly 45 degrees (Figure 2). This shows the present W1FB system. The loop is broadside northeast and southwest for maximum radiation in those directions at 80 meters. More on this later.

When these low-to-the-ground experiments began in the summer of 1983, we were joined by Bill Martinek, W8JUY, near Traverse City, Michigan. Bill experimented with various loop configurations so that he and W1FB could make signal comparisons locally and afar. He finally adopted the W1SE format with the apex down (Figure 1C, with the flat top strung between two 50-foot trees). In order to keep the loop completely vertical (not sloping), he chose a triangle that was not equilateral. The upper side of his triangle is substantially longer than the two downward sides. His signal on 75 meters is consistently 10 to 20 dB stronger than with his inverted V. The point of this discussion is that you need not use an equilateral triangle if it will not fit on your property. Erect whatever you can, then give it a try!

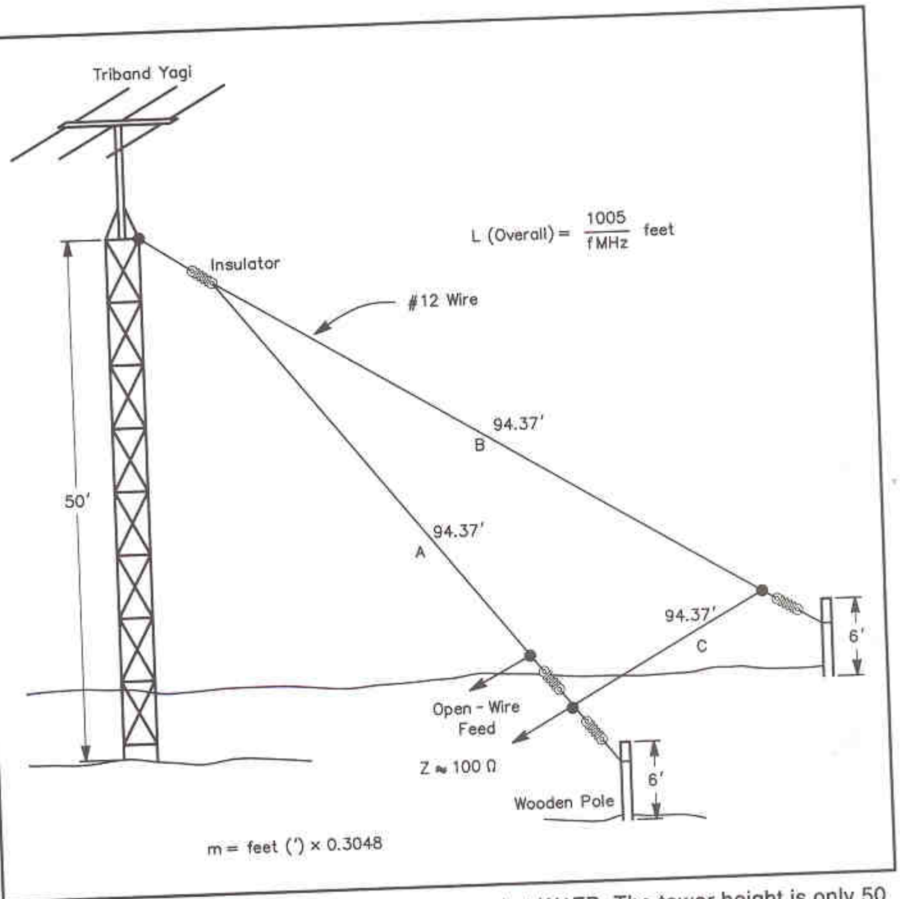


Figure 2—A tilted Delta loop for 80 meters is used at W1FB. The tower height is only 50 feet. Homemade open-wire line is used as the feeder to permit multiband use with vertical polarization and a low radiation angle.

Feed Methods

A Q section is used for feeding the W1SE loop. A Q section is a quarter-wave-length line with an impedance that is somewhere between the antenna feed impedance and that of the feed line. Calculation is a simple matter:

$$Z\ (\text{Q section}) = \sqrt{Z1\ Z2}\ \text{ohms} \qquad \text{(Eq. 1)}$$

where Z1 is the antenna impedance, and Z2 is the feeder impedance in ohms. In this case, assuming approximately 100 ohms for the antenna. feed impedance, we would have $\sqrt{100 \times 50}$ = 70.7 ohms for the Q-section impedance. This represents a close match to 52-ohm coaxial cable. The Q-section length (made from RG-59/U) can be determined from L(feet) = 246 V/f(MHz), where V is the velocity factor of the coaxial line for the matching section. (The length should be verified using a dip meter.) For operation at the W1SE-chosen frequency of 3.825 MHz, the calculation calls for a Q section of 42 feet 5 inches (Figure 3).

Open-wire feed is used at W1FB (Fig 6B) to permit multiband operation through 10 meters. Unfortunately, a short run of RG-8/U was needed to bring the feed line to the ham station–under the driveway. The coaxial cable was buried in the ground for this reason. A homemade 4:1 toroidal balun transformer (two stacked T200-2 Amidon

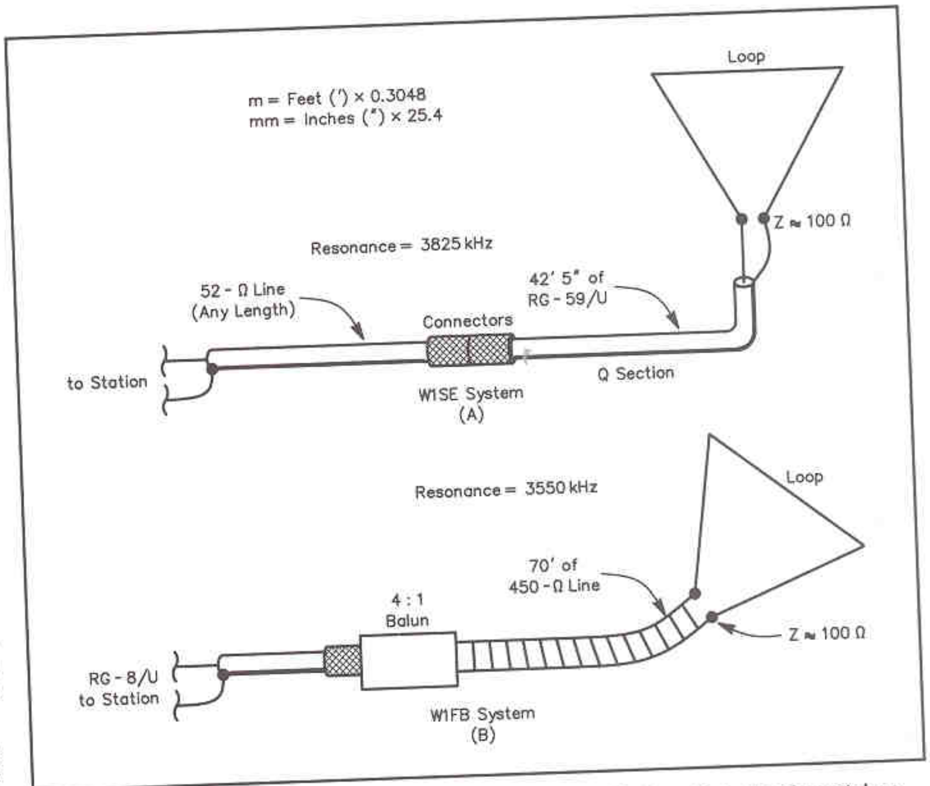


Figure 3—At A is the feed method used at W1SE. A coaxial Q section closely matches the 100-ohm feed impedance to a 52-ohm coaxial line. Illustration B shows the W1FB feed arrangement. Open-wire line, a balun transformer and a short length of RG-8/U cable permit multiband use with a Transmatch. Ideally, the open-wire line would continue all the way to the Transmatch, and the balun transformer would be located at the Transmatch.

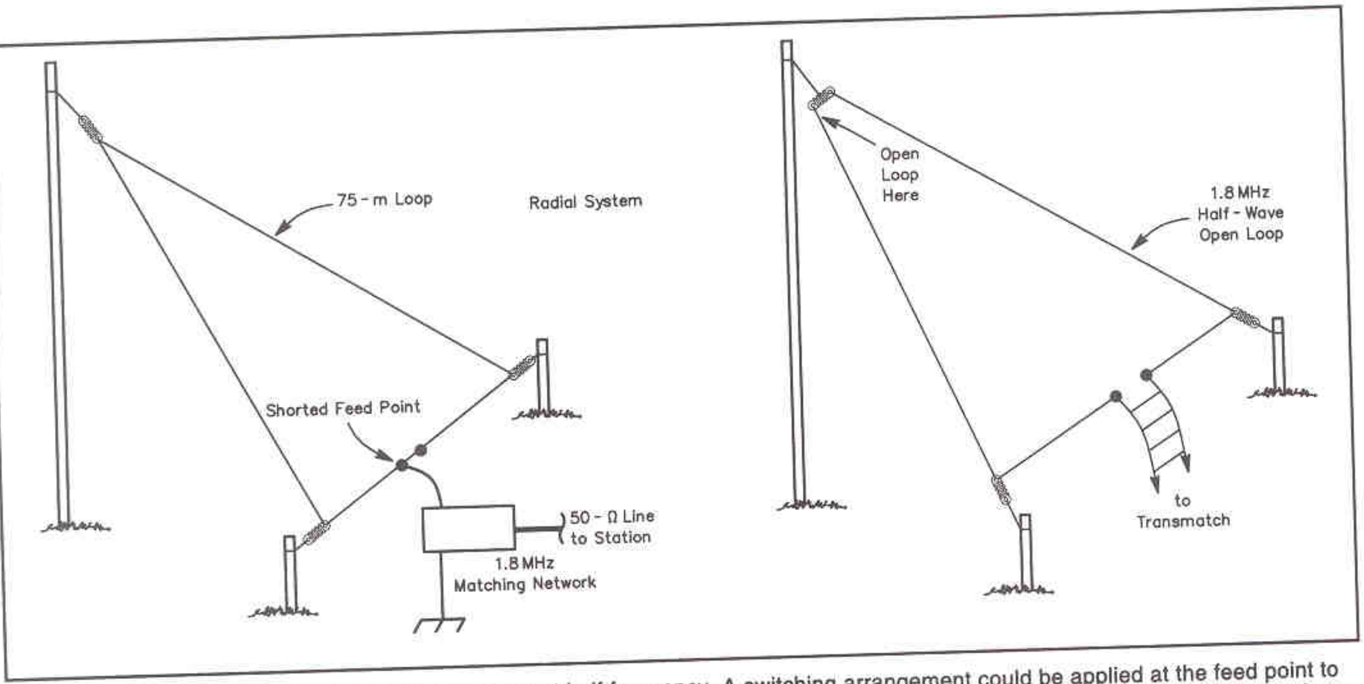


Figure 4 — Two methods for using a full-wave loop at half frequency. A switching arrangement could be applied at the feed point to change from a closed, full-wave loop to the first configuration seen here. The method at A performs as a 1/4-wavelength radiator, but a ground screen is required. Method B is satisfactory as a 1/2-wavelength open loop for half-frequency use. It requires opening the loop at the electrical point opposite the feed point. A relay could be used for this purpose.

cores and Teflon-insulated no. 14 wire) was enclosed in a weatherproof box and mounted on one of the support poles for the 450-ohm open-wire line. The RG-8/U was run underground from that location (about 25 feet). Ideally, the openwire line would have been brought into the house, where it would be matched to the station gear with a Transmatch. Fortunately, the SWR at loop resonance is 1.3:1 without the Transmatch in use.

Performance

This is the part of our article that many of you have been waiting to read. Well, the W1FB results have been entirely gratifying. The loop replaced an inverted V with an apex height of 50 feet. This led to a pronounced improvement in all-around communications on 75 and 80 meters out to 500-600 miles. But, the loop proved to be very effective also for DX communications to Europe on 80 meters. The first version was that of Figure 1B. Although the antenna was outstanding for close-in 75- and 80-meter work, it offered dismal DX performance. The configuration at D of Figure 1 seems to offer a good compromise in performance for local and DX work. The theoretical launch angle to the horizon at the loop fundamental frequency is 10 degrees, as reported by VE2CV in a letter to W1FB. This assumes that the loop is erected vertically and at a reasonable height above ground.

Harmonic operation of the loop, as depicted in Figure 1D, is superb. At times it outperforms the trap tribander atop the tower during DX operation to Europe and Africa. The loop shows an average 6-dB signal increase on 20 and 15 meters in the favored direction, owing to the gain and lower radiation angle of the loop. Radiation at the harmonics is in the plane of the loop rather than broadside to it. This makes it ideal for contacts into Africa. It is perhaps the most effective 40-meter DX antenna that has been used at W1FB from northwest lower Michigan. The Transmatch is required on all harmonic frequencies other than 18.111 MHz, where W1FB has been conducting propagation studies with Bill Orr, W6SAI, Prose Walker W4BW, Bob Haviland, W4MB and Stu Cowan, W2LX, under special experimental/research licenses (KM2XQV). The loop has worked very well on 24.9 MHz as well during these tests. At 18.111 MHz, the SWR is 1.4:1.

The operating results at W1SE also indicate that a tilted loop, close to the ground, functions quite well. With loop resonance at 3825 kHz, the 2:1 SWR points occur at 3734 and 3934 kHz, respectively. This 200-kHz bandwidth spectrum can be shifted up or down the band by lengthening or shortening the loop conductor and Q section accordingly. From the W1SE location in Newington, the loop has delivered impressive performance for local and DX work.

A 40-meter Delta loop was constructed for use at W1SE after noting the fine performance of the 80-meter system. It was cut for resonance at 7016 kHz. This model was erected in a completely vertical format, using 143 feet 3 inches of wire. The Q section is 23 feet 2 inches long. The apex (feed point) is 4 feet above ground. The SWR on 40 meters is less than 2:1 across all of the band. The 80- and 40-meter W1SE loops showed resonance slightly apart from the design frequency, perhaps because of the proximity of the antennas to ground. Resonance on 40 meters was checked as 7050 kHz. Both loops are performing better for local and DX contacts than any of the many antenna types tested at W1SE. We would be even more impressed if we could elevate our Delta loops so the lower portions were a half wavelength or greater above ground.

In Conclusion

There is no rule that dictates the shape of a full-wave loop. The triangular format is convenient for mounting the radiator. If the apex is at the top, only one high support structure is needed. You may have one or more tall trees that can be used as supports. Circular, square or rectangular shapes have been used by many amateurs and the results were good. Certainly, a loop is an impressive receiving antenna, in terms of noise reduction. In some urban locations, that may be more important than transmitting a "death-ray" signal! There is something to be said about the age-old expression, "If you can't hear 'em, You can't work 'em."

An 80-meter Delta loop can be used on 160 meters by adopting one of two simple methods (Figure 4). A closed loop does not, however, offer good results when the overall length is a half wavelength. Either of the techniques in Figure 4 will work, but the method at A requires a ground radial system for best results.

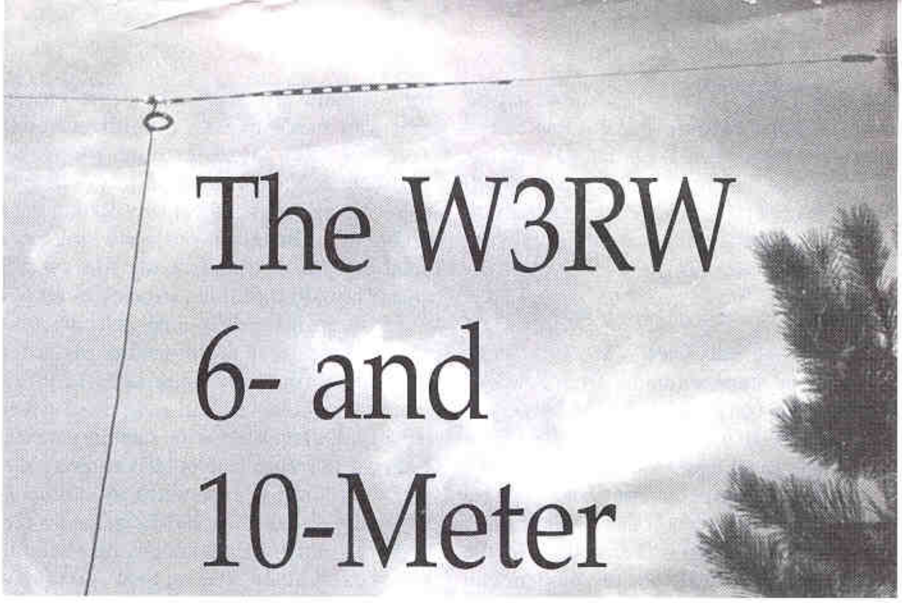
Notes

[1]D. DeMaw, "Beat the Noise with a Scoop Loop," *QST*, July 1977, and "Maverick Trackdown," *QST*, July 1979.

[2]H. H. Beverage and D. DeMaw, "The Classic Beverage, Revisited," *QST*, Jan. 1982.

By Bob Witmer, W3RW

Looking for better-than-dipole performance on 6 and 10 meters without investing in a beam and rotator? Here it is! This novel antenna includes a matching section to deliver a near-50-Ω match on both bands.



The W3RW 6- and 10-Meter Long Wire

& KITE!

I received many inquiries about the antennas described in my article, "Wire Gain Antennas for 6 Meters."[1] My favorite wire antenna—in terms of overall ruggedness, simplicity and pattern coverage—is a 4-λ long wire. In the spring of 1999, with the sunspot cycle improving, I decided I needed an antenna that would also provide some gain over a dipole on 10 meters. With this goal in mind, I investigated how to make a long-wire antenna that works well on 6 *and* 10 meters. Here's what I found.

Why Use a Long-Wire Antenna?

Wire antennas are among the easiest to install and use (and arguably lowest in cost), but most hams don't think of using long-wire antennas on VHF. Long-wire antennas *can* be used on VHF—particularly on 6 meters—as easily as on the HF bands. The following paragraphs describe typical long-wire gain and pattern characteristics; feedpoint characteristics are discussed later.

Gain

Antennas more than a couple of wavelengths long at the operating frequency exhibit gain over a dipole. The maximum lobe of an antenna 4λ long has an estimated *gain over a dipole* of approximately 3 dB (3 dBd); see Figure 1. The estimated gain for other multiple-wavelength wire antennas varies. A 3-λ antenna should have a gain of slightly more than 2 dBd; a 5-λ antenna exhibits a gain of about 4 dBd.

Patterns

With the gain increase comes a change in the antenna's radiation pattern. Along the axis of the wire, there is a narrowing and increase in the amplitude of the gain lobes compared to those of a typical dipole antenna's broadside pattern. Also, there's an increase in the number of lobes (and nulls) that provides somewhat omnidirectional coverage. Figure 2 shows some theoretical pattern comparisons.

Dual-Band Long-Wire Design Constraints

By changing which trees I used to support my wire antenna, I had room (just over 105 feet) to put up an antenna longer than the original 77-foot, 4-λ antenna. After playing with the antenna-length formulas, I found that a 3-λ, 10-meter long wire or a 5-λ, 6-meter long wire would fit. Both antennas provide the gain I was looking for—but I didn't have the room to put up *both*!

Eureka! The Dual-Band Long-Wire Antenna

Like the 4-λ, 6-meter long-wire antenna, I wanted a configuration with its feedpoint at a current loop (1/4 λ from one end of the antenna) to present a low-impedance to the feed line. This approach essentially separates the antenna into a "long" section and a 1/4-λ section. After examining the individual 3- and 5-λ antenna dimensions using 28.35 MHz and 50.15 MHz as frequencies of operation, it became clear that these antennas have one thing in common: The long sections are almost equal in length. With that in mind, I came up with a dual-band long-wire antenna design (see Figure 3) that uses ladder line as part of the 1/4-λ sections for each band and shares a common long section.

Dual-Band Matching Issues

Figure 1 shows the variation of radiation resistance, as measured at a current loop, with wire antenna length. Using this as a guide, the dual-band long-wire antenna has a theoretical feedpoint impedance of about 125 Ω on 10 meters (3λ) and 140 Ω

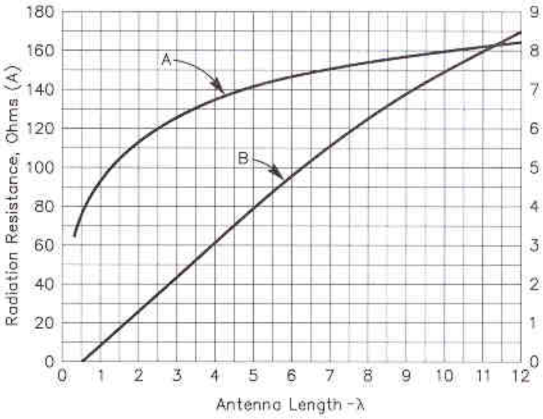


Figure 1—The variation in radiation resistance and power in the major lobe of harmonic (long-wire) antennas. Curve A shows the change in radiation resistance with antenna length, as measured at a current loop, while curve B shows the power gain in the lobes of maximum radiation for long-wire antennas as a ratio to the maximum of a 1/2-λ antenna.

[1]Notes appear on page 48.

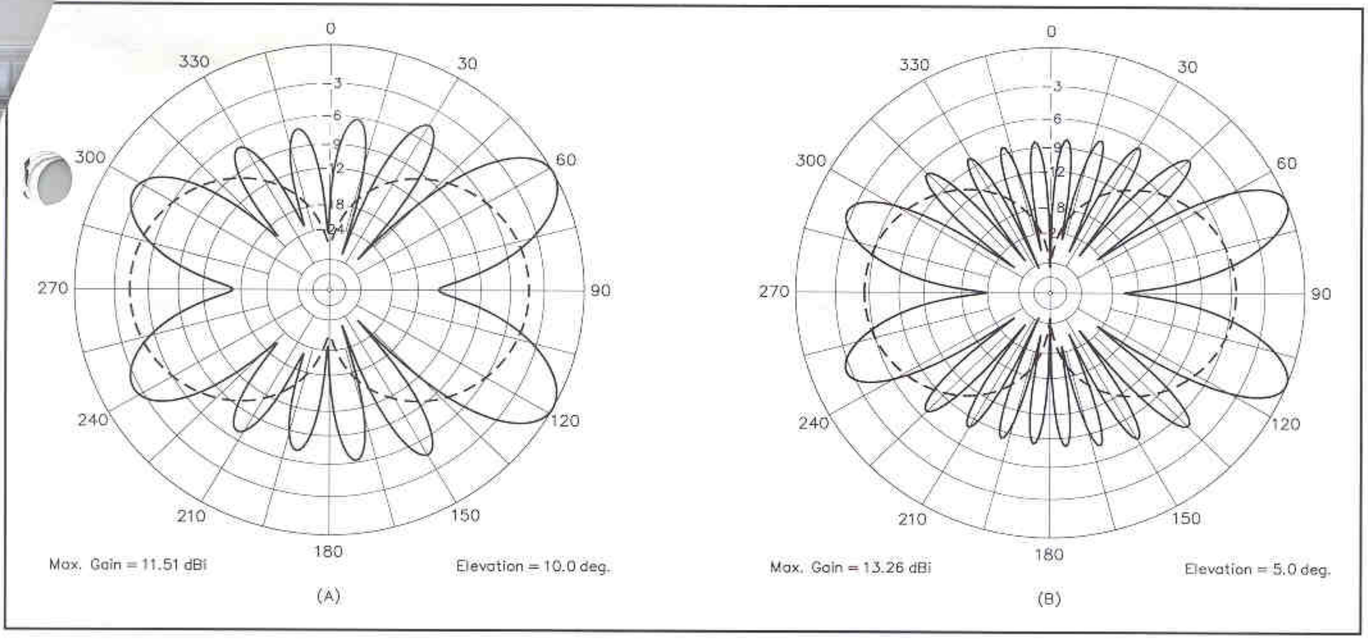


Figure 2—Predicted horizontal radiation patterns of a long-wire antenna as a function of length. At A, pattern of a 50-foot-high 3-λ long-wire antenna (solid lines) compared to that of a dipole (dashed lines). At B, pattern of a 50-foot-high 5-λ long-wire antenna (solid lines) compared to that of a dipole (dashed lines). ***Tnx Dean Straw, N6BV***

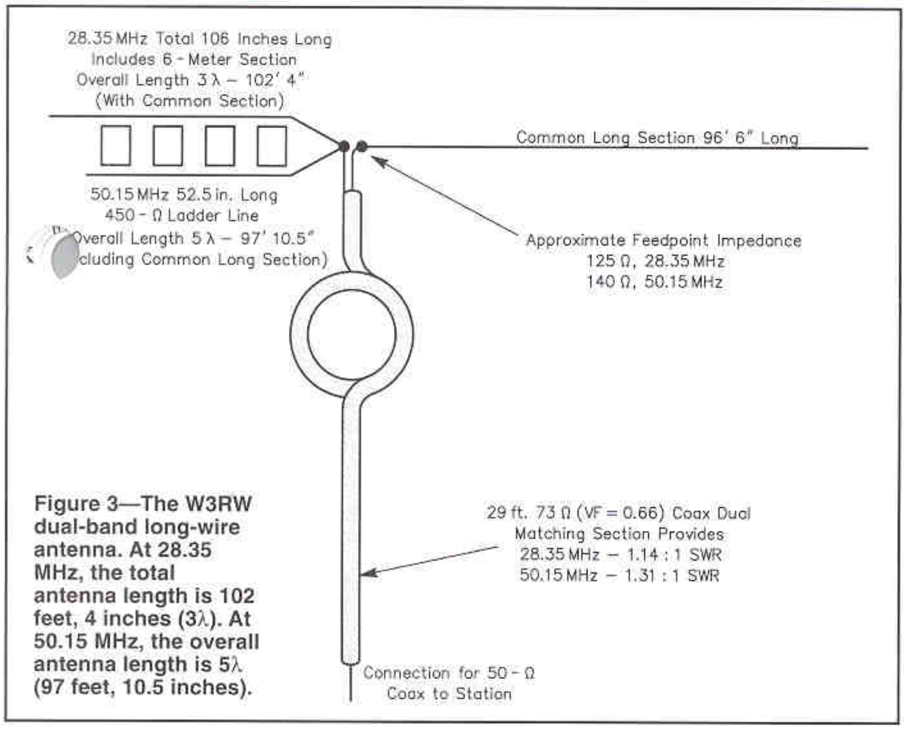


Figure 3—The W3RW dual-band long-wire antenna. At 28.35 MHz, the total antenna length is 102 feet, 4 inches (3λ). At 50.15 MHz, the overall antenna length is 5λ (97 feet, 10.5 inches).

on 6 meters (5λ). Either feedpoint impedance lends itself to using a ¼-λ 75-Ω coax matching section to match a 50-Ω coax feed line, but the typical ¼-λ coax matching section on 10 meters doesn't work on 6 meters and vice-versa. A wideband 4:1 balun could be used for matching, but the resulting impedance transfer would probably not be as close to 50 Ω as the ¼-λ matching technique provides. Also, most 4:1 baluns are relatively heavy, adding to antenna sag. Wideband 4:1 baluns are also expensive compared to the cost of 20 to 30 feet of coax. So, I decided to evaluate other approaches.

Eureka Again! The Dual-Band Coax Matching Section

I thought of the dual-band matching solution when I decided to experiment by adding a number of ½-λ coax sections after the 6- and 10-meter ¼-λ sections. Comparisons showed that there is a combination of ¼-λ and ½-λ transmission-line sections that results in total coax lengths for *each* band that are almost the same. (See Figure 4 and the sidebar "Characteristics of Half-Wavelength Transmission Lines.")

The total lengths of the two coax sections are close enough that the combination match works for the frequency pair of 28.35 and 50.15 MHz, although frequencies of 50 and 29.9 MHz provide an optimum calculated dual match. With the combination of the dual-band matching section and the dual-band long wire, an overall good match to 50-Ω line is obtained over the low-frequency ends of 6 and 10 meters.

On-The-Air Performance: Does it Work?

The system appears to work well—just like individual 6- and 10-meter long wires! With the long-wire antenna's maximum-strength lobes favoring the North/South directions, I use a two-element 6-meter quad in the attic to provide extra gain to the West. Although there are directions in which the quad *is* significantly better than the dual-band long wire, I've found that the long wire can hear everything the quad can hear—*including some signals the quad doesn't.*

My first QSO with the antenna came just after I finished making some adjustments. With my IC-706 connected directly to the end of the coax matching section, I answered a station in upstate New York calling CQ on 50.125 MHz. He came right back to me and we exchanged good signal reports (he was off the slightly weaker major lobe's end of the antenna.) After that, I switched to 10 meters and proceeded to work quite a few South and Central American stations in the main line of the antenna's stronger gain lobes. With the help of a small antenna tuner, I stretched the antenna's 10-meter bandwidth to cover the repeater segment and proceeded

Characteristics of Half-Wavelength Transmission Lines

A key factor in the dual-band matching solution is the $^1/_2$-λ characteristic of transmission lines. Any impedance presented at one end of a $^1/_2$-λ of coax—with coax of *any impedance* (that's the important part)—that same impedance is seen at the opposite end of the cable. For example, if you connect a $^1/_2$-λ (or any multiple of $^1/_2$-λ) of 75-Ω coax to a 50-Ω load, a 50-Ω impedance is seen at the other end—*even though the characteristic impedance of the coax in between is 75 Ω.* (All wavelength references are to *electrical* lengths of coax; this takes into account the velocity factor of the cable.)

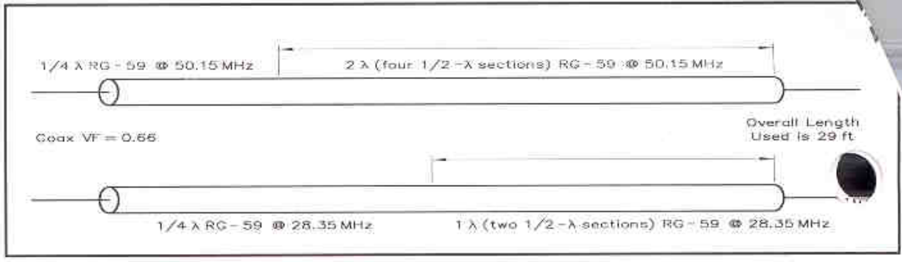


Figure 4—The W3RW dual-band matching section. Lengths shown here are for coax with a velocity factor of 0.66. The upper cable leg consists of a 50.15-MHz $^1/_4$-λ section of RG-59 coax in series with a 50.15-MHz 2-λ (four $^1/_2$λ-lines in series) section of RG-59 coax. The lower leg is a 28.35-MHz $^1/_4$-λ of RG-59 coax in series with a 28.35-MHz 1-λ section (two $^1/_2$λ-lines in series) of RG-59.

to work several additional stations.

As I write this, the September VHF contest and Hurricane Floyd's visit occurred about two months ago. I didn't actively participate in the contest, but I did use it to further check the antenna's 6-meter performance. With a transmitter RF output of 100 W, I found I could work everything I heard, including several sporadic-E contacts late one Sunday, but I did have to use a 400-W amplifier to make an Auroral contact. Ten-meter performance has been great! I've had no trouble working most DX I can hear from all over, including 7X, 9K, JA, ZS, ZL—and even a DS—with just 100 W output.

Construction Tips

Figure 3 shows the antenna details (not to scale). Cut the wire sections of the antenna a little long and wrap the far ends of the extra wire lengths back onto the main wire. This way, if you need to lengthen the antenna, you just unwrap the extra wire; you don't have to worry about adding more wire. If the antenna is too long, simply wrap more wire back onto the main run to reduce the antenna's overall length.

I started out with a little more than 5 feet of 450-Ω #14 stranded copper-clad ladder line for the $^1/_4$-λ antenna section, allowing for connection to the center insulator and the 10-meter wire extension. As shown in Figure 3, one conductor of the 450-Ω line (the upper one) is used on 10 meters. The shorter conductor (lower one) is used on 6 meters. Make the cut for the 6-meter section so that it is *inside* one of the solid-dielectric sections of the line. Cutting the ladder line this way helps maintain the overall physical strength of the 6-meter section. (By the way, the dual-band long wire survived Hurricane Floyd's visit!)

Weatherproof the antenna by sealing the coax-to-wire connections, the connection between the matching-section coax and the 50-Ω feed line, and the connections at the ends of the matching section. Use a low-loss 50-Ω cable between the matching section and your shack.

To properly cut the matching line, you *must know* the velocity factor of the 75-Ω coax! (See Table 1 for estimated coax matching-section lengths versus cable velocity factor.) The matching section I use is made of 0.66 velocity factor RG-59 coax, but cables with other velocity factors can be used as well. (When selecting the matching-section coax, remember that the center conductor in *foam-dielectric* coax has a tendency to migrate, potentially resulting in a short to the shield if the coax provides some structural support or is coiled.) I took the precaution of verifying the coax velocity factor by cutting an approximate $^1/_4$-λ section and checking its length and frequency characteristics using a dip meter. Larger-diameter 75-Ω coax (such as RG-11) can be used if you want lower loss, but the cable is heavier than RG-59, and will likely increase the antenna sag. Interestingly, the data tables for coaxial cable show that the loss of many RG-59 coax types is similar to, or slightly *lower* than, RG-8X coax types at 50 MHz.

Adjustment

To tune the antenna, first adjust the lengths of the $^1/_4$-λ sections, then adjust the long-wire sections to minimize the SWR on both bands. Then check the $^1/_4$-λ-section lengths again. It takes no more than a couple of iterations to achieve the lowest SWR on both bands. The exact length of the dual-band coax matching section doesn't appear to be critical. I cut the matching section a little longer than 29 feet (using 0.66 velocity-factor coax) to provide the extra length needed for the connections to the wire and ladder-line sections and for the end coax connector. The resulting match was close enough to not require adjustment.

Coaxial Choke Balun

To isolate the feed line from the radiating currents of the antenna, I use a choke balun consisting of four feet of the matching-section coax wrapped in four turns just below the antenna feedpoint. This approach may not be as effective as using a traditional balun, but it seems to work; and considering the unbalanced antenna configuration, it may work almost as well. I have had no complaints about RF in the shack or house on either band. I derived this approach from the information in Table 19.4 on page 19.16 of *The 2000 ARRL Handbook for Radio Amateurs.*[2]

Summary

The W3RW 6- and 10-meter long-wire antenna is a resonant multiwavelength antenna that provides gain over a dipole on 6 and 10 meters and integrates a unique coax-cable matching section to provide a close match to 50 Ω on both bands. This is a predominantly horizontally polarized antenna optimized for the SSB portions of the 6- and 10-meter bands. Considering its simplicity and low cost, you ought to give it a try!

Notes

[1]J. Robert Witmer, W3RW, "Wire Gair[illegible]ennas for 6 Meters," *QST*, Feb 1997, p[illegible]67.

[2]ARRL publications are available from your local dealer, or directly from ARRL. See the ARRL Bookcase elsewhere in this issue, or check out the ARRL web site at: **http://www.arrl.org/catalog/**.

[3]Please contact me for price and availability of a partial kit consisting of the dual-band matching-section coax, the $^1/_4$-λ open-wire section and additional assembly information. Bob Witmer, W3RW, 146 Forest Trail Dr, Lansdale, PA 19446-6415; **w3rw@arrl.net**.

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Edward M. Noll, W3FQJ, "A Multiband Long-wire Antenna," *ham radio*, Nov 1969, pp 28-31

ARRL's Wire Antenna Classics, (Newington: ARRL, 1999)

John D. Heys, G3BDQ, ed., "Practical Wire Antennas," (Potters Bar, England: RSGB, 1989)

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