As we head toward the CQ WW 160 Meter Contest season, W2FMI shows us how to improve our chances through better matching.

Ununs For Beverage Antennas

BY JERRY SEVICK*, W2FMI

The Beverage antenna[1] is well-known to 160 meter enthusiasts for enhanced signal-to-noise ratios in high levels of interference and atmospheric noise. If they are erected properly, Beverages also have excellent directivity. They are quite inefficient, however, and therefore generally are not suitable as transmitting antennas. Important considerations with Beverages are the terminating resistor (for the more common single-wire version) and the input matching unun (unbalanced-to-unbalanced transformer). The terminating resistor and the impedance ratio of the unun are determined by the characteristic impedance of the antenna acting as a long transmission line with one good conductor and one poor conductor (the earth). It is generally between 400 and 600 ohms and theoretically given by:

$$Z_o = 138 \times \log(4h/d) \qquad (1)$$

where: Z_o = characteristic impedance of the Beverage; h = height of the wire above ground; and d = diameter of the wire.

This article presents low-power and high-power versions† of multimatch ununs designed to match 50 ohm cable to unbalanced loads from 450 ohms to 800 ohms. The low-power unit, which is capable of handling continuous power levels up to 100 watts, is specifically designed for the Beverage antenna when it is performing as a receiving antenna. The high-power unit, which is capable of handling 1 KW of continuous power, can be used with the Beverage or any other traveling-wave antenna when used as a transmitting antenna. Additionally, this article presents high-power designs capable of flat response, including the entire AM broadcast band. These multimatch ununs may be of interest to designers of high-power amplifiers for the broadcast band.

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†*Kits and finished units are available from Amidon Associates, Inc., 2216 East Gladwick Street, Dominguez Hills, CA 90220.*

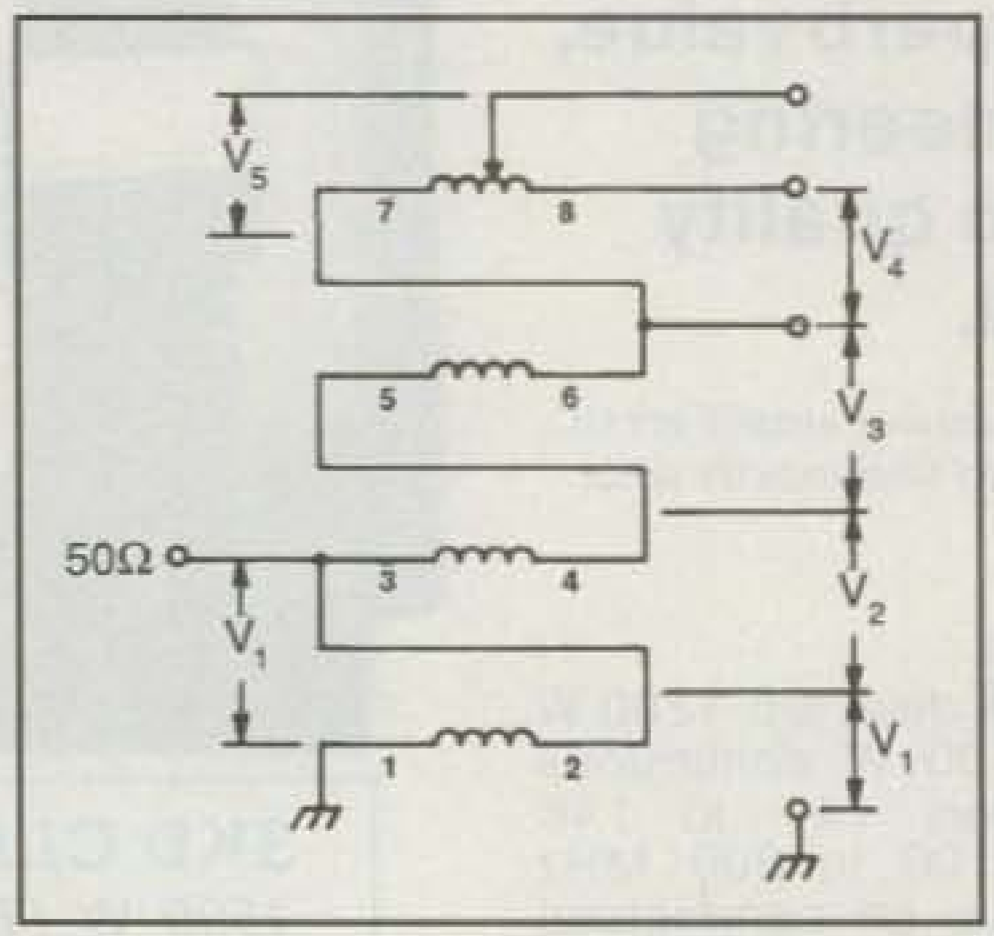

Fig. 1– Schematic diagram of the quadrifilar design using Ruthroff's approach for high-impedance, low-frequency ununs such as the Beverage antenna matching transformer.

A bit of theory on how these devices are designed is presented next.

A Little Theory

Transmission line transformers[2] (the unun being a subset thereof) are known for the greater bandwidths and efficiencies over their counterparts—conventional transformers. It is also known that their design considerations are vastly different. They involve chokes and transmission lines, while conventional transformers involve flux linkages.

High-impedance ununs (and baluns) which match 50 ohms, unbalanced, to impedances as high as 800 ohms are at about the edge of capability of this technology. The reasons are (1) the windings require more turns, since higher reactances are needed for isolating the input from the output, and (2) they require higher characteristic impedances in the transmission lines, since the loads they see are greater. Therefore, one just runs out of space on toroidal cores in trying to satisfy the low-frequency and high-frequency objectives. Incidentally, beaded trans mission lines are not recommended at these impedance levels because of their excessive losses.

There are two methods for obtaining broadband operation at these high-impedance levels. One uses Guanella's 9:1 and 16:1 baluns, which are converted to unun operation.[2] The other uses higher order windings (quadrifilar in this case) on a single core, which is an extension of Ruthroff's approach.[3] The Guanella approach, which uses coiled transmission line connected in series at the high-impedance side and in parallel at the low-impedance side, results in very broad bandwidths, but with difficulty in meeting low-frequency objectives. Low-frequency models[2] show that with ratios above 4:1, some of the coiled windings are connected in parallel, resulting in reduced reactances. However, with the Ruthroff approach all of the inductances (at the low-frequency end) end up mutually-aiding. But Ruthroff's approach suffers at the high-frequency end because a direct voltage is summed with three voltages which traverse various lengths of transmission lines. As a result, Guanella's approach of summing voltages of equal delays is preferred for the higher frequency bands, and Ruthroff's approach is preferred for the lower frequency bands. This article presents designs using Ruthroff's approach.

Fig. 1 shows the schematic diagram of a quadrifilar-wound unun. If the lengths of the transmission lines are very short compared to the wavelength (therefore, phase-delay and standing waves are negligible), then:

$$V_1 = V_2 = V_3 = V_4 \qquad (2)$$

at terminal 6,

$$V_o = V_1 + V_2 + V_3 = 3V_1 \qquad (3)$$

and the impedance ratio becomes

$$g = (V_o/V_1)^2 = 9 \qquad (4)$$

At terminal 8, it becomes

$$g = 16 \qquad (5)$$

The voltage at the tap in winding 7–8 is

$$V_o = 3V_1 + V_5 = 3V_1 + n/NV_1 = V_1(3 + n/N) \qquad (6)$$

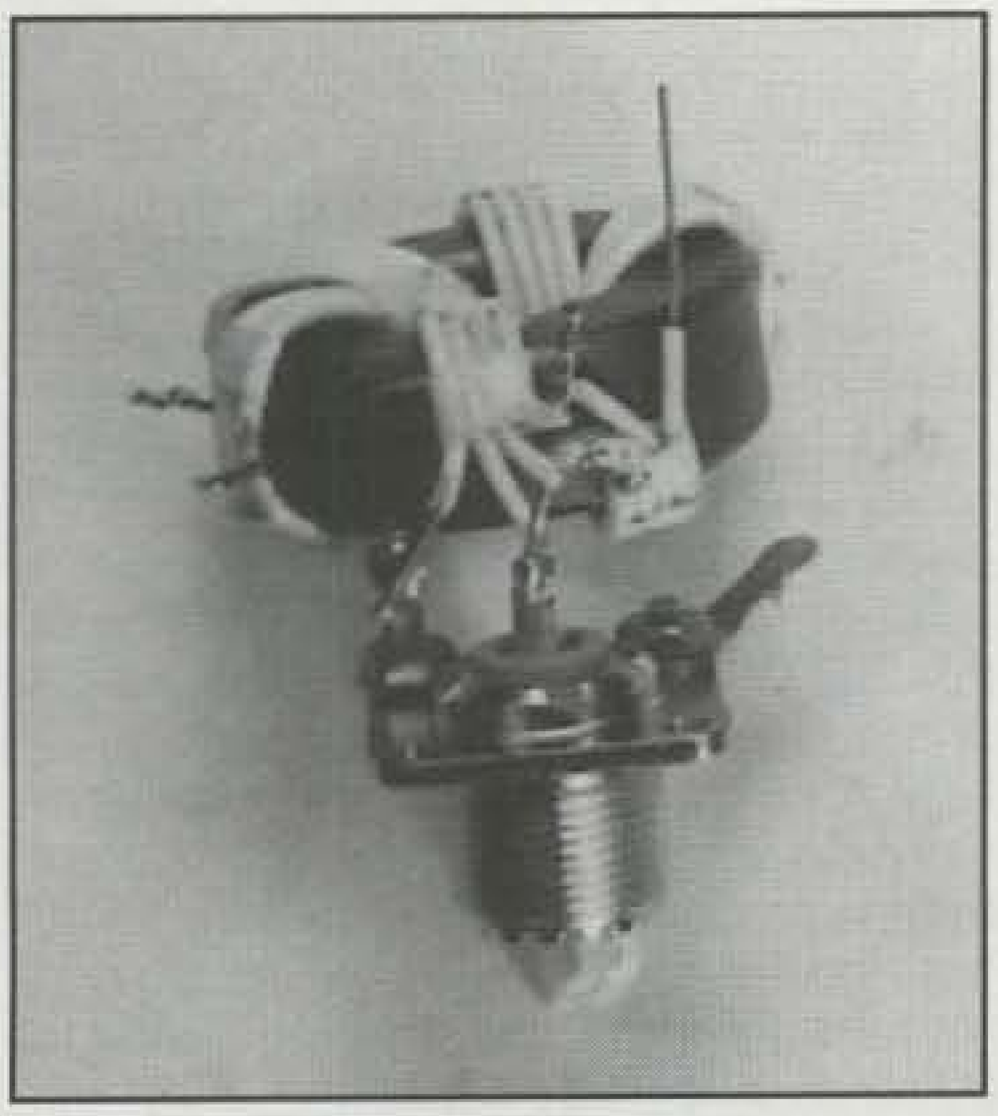

Photo A– The bottom view of the low-power Beverage antenna unun.

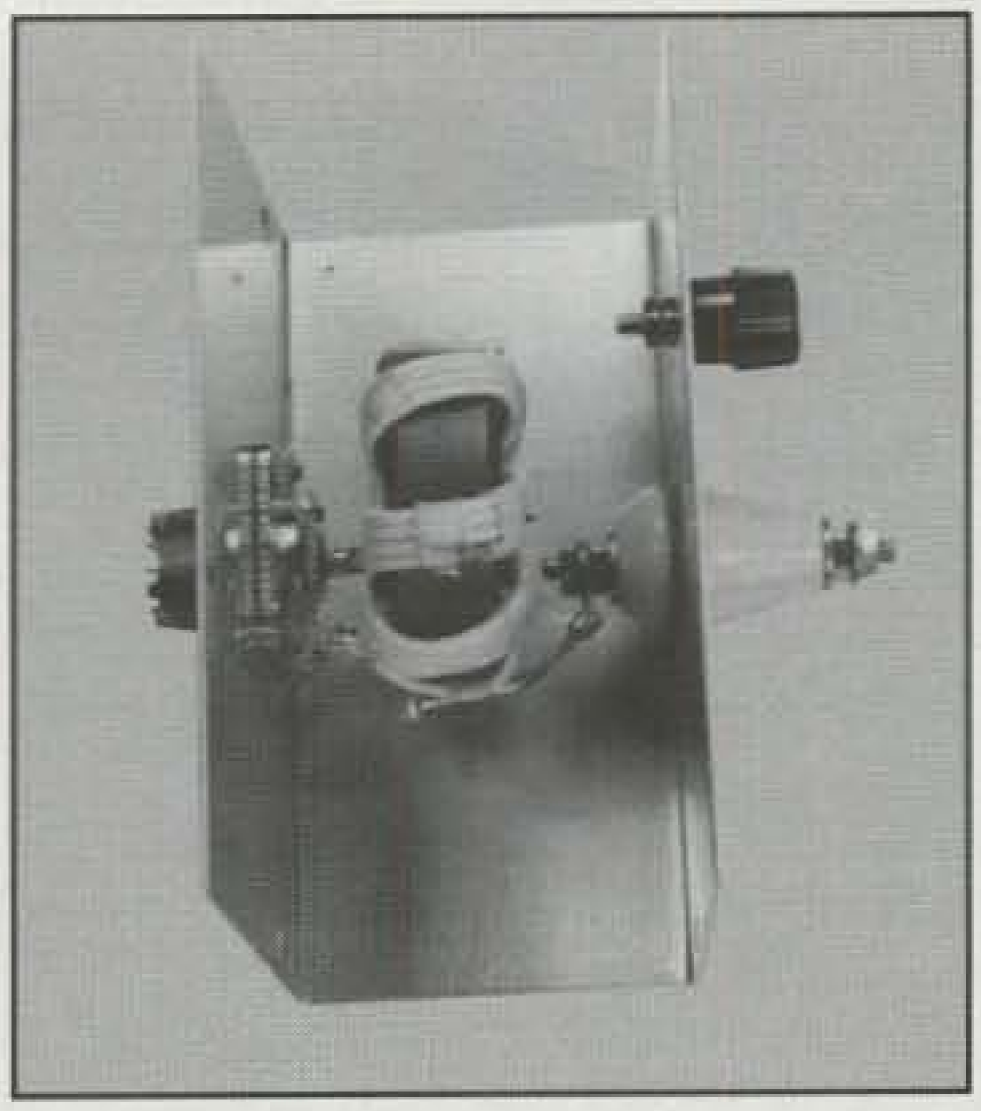

Photo B– The low-power Beverage antenna unun mounted in a 4"L × 2"W × 2.75"H minibox.

where: N = total number of turns; n = number of turns from terminal 7.

The impedance ratio, using the tapped winding, becomes

$$g = (V_o/V_1)^2 = (3 + n/N)^2 \qquad (7)$$

When the lengths of the transmission lines are significant, then important phase delays can occur and reduce the high-frequency response. As can be seen in fig. 1, V_2 travels one transmission line, V_3 travels two transmission lines, and V_4 travels three transmission lines. Additionally, the high-frequency response is further diminished if the characteristic impedances of the transmission lines are not at their optimum values (which is hard to do at these impedances levels). Even with these major flaws, the Ruthroff approach is better for Beverage antenna use, since the greatest advantages are on the lower frequency bands (80 and 160 meters).

A Low-Power Design

Photo A shows the bottom view of an unun designed to handle 100 watts of continuous power with constant ratios from 9:1 to 16:1 on the 80 and 160 meter bands. In fact, since its transmission lines are very short (about 12 inches long), the ratios only increase by 5 percent on the 40 meter band.

The design uses the Ruthroff approach shown in fig. 1. It has 6 quadrifilar turns on a 1.5 inch OD ferrite toroid with a per-

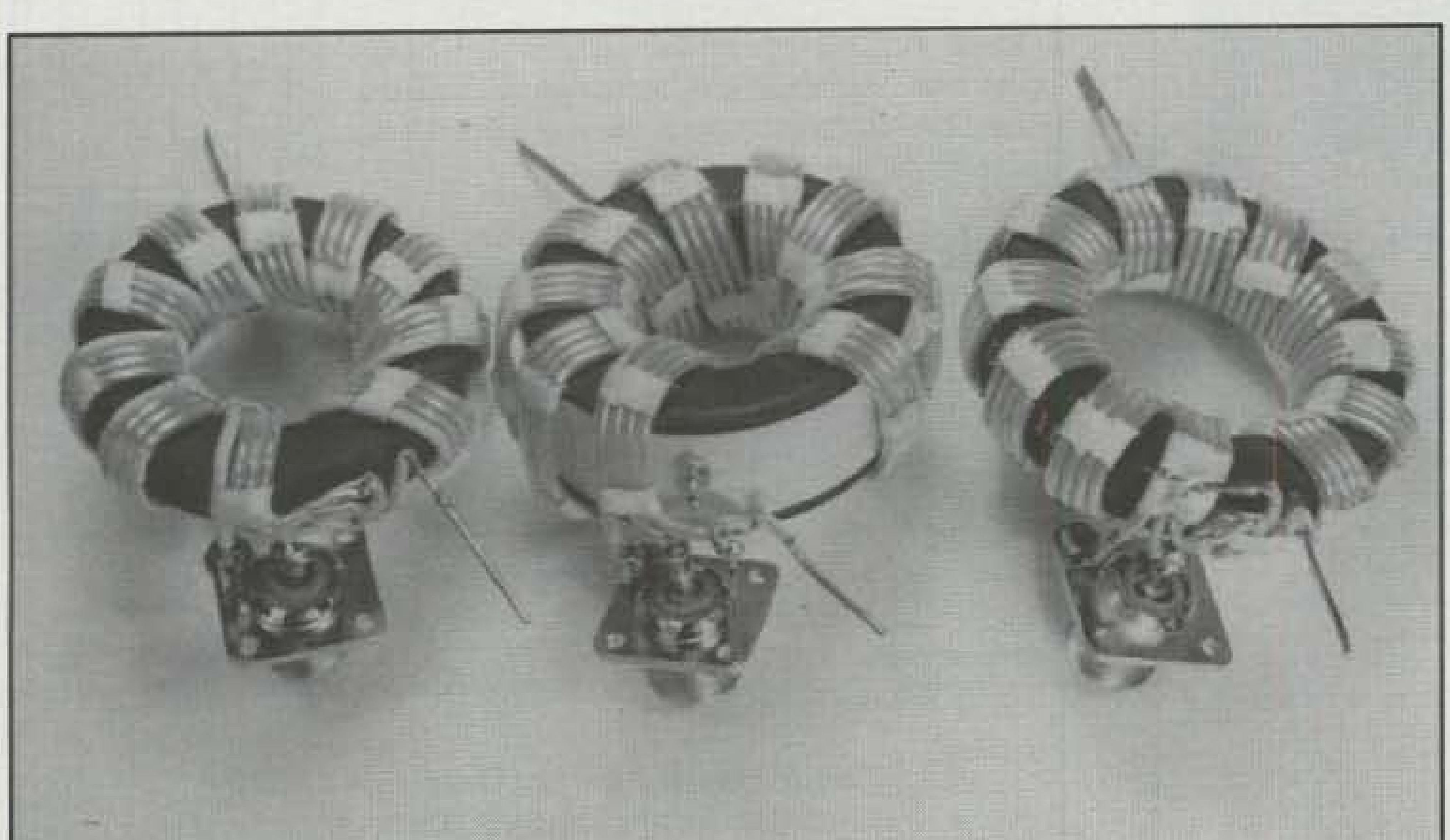

Photo C– Three high-power, low-frequency ununs using a quadrifilar design with Ruthroff's approach. One on the left is designed to cover the 80 and 160 meter bands Other two are designed to cover the 160 meter and AM broadcast bands.

meability of 250. The bottom winding is No. 20 hook-up wire, and the other three are No. 22 hook-up wire. Winding 7–8 is tapped at 2 turns from terminal 7 yielding a 11.11:1 ratio and at 3 turns from terminal 7 yielding a 12.25:1 ratio. Therefore, with outputs also at terminals 6 and 8, this unun matches 50 ohm cable to loads of 450, 555.6, 612.5, and 800 ohms.

Photo B shows the unit mounted in a 4"L × 2"W × 2.75"H minibox. The output (the feed-through insulator) is connected to one of the taps. A grounded binding post is also shown.

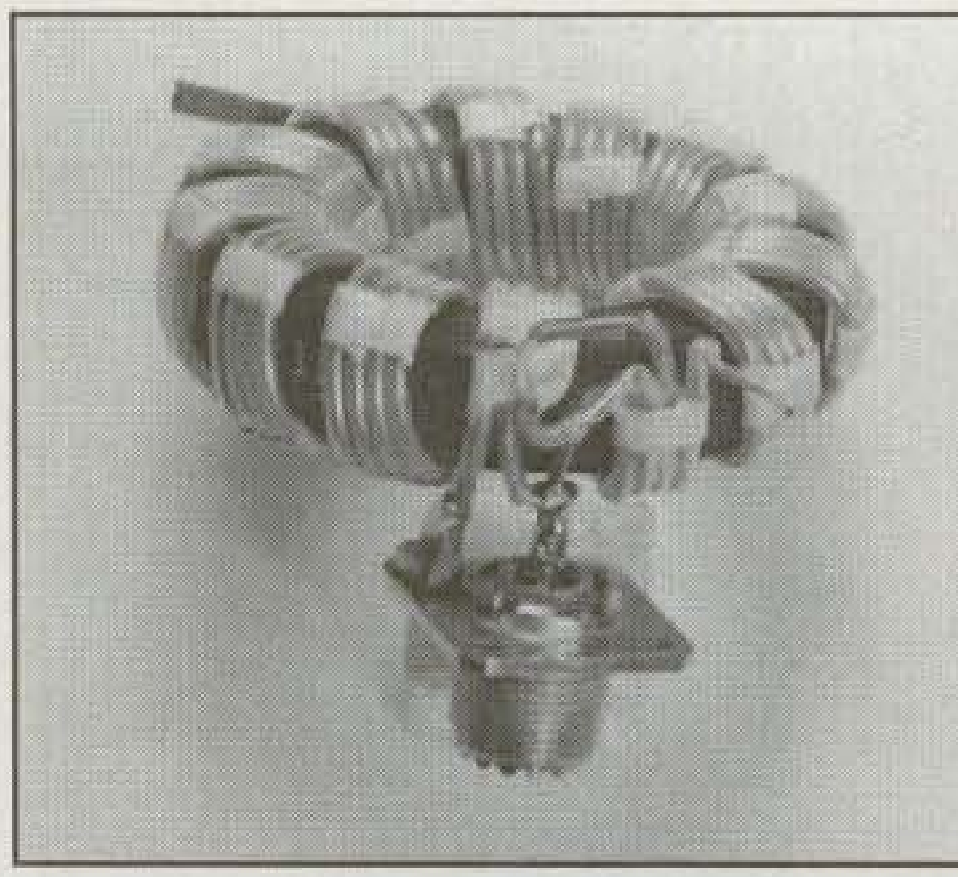

Photo D– Bottom view of the high-power Beverage antenna unun.

High-Power Designs

Photo C shows three high-power designs. The one on the left is specifically designed to cover the frequencies generally used with traveling-wave structures such as the Beverage antenna. It has 10 quadrifilar turns on a 2.4 inch OD ferrite toroid with a permeability of 250. Winding 1–2 is No. 14 tinned copper wire and the other three are No. 16 tinned copper wire. The wires are also covered with Teflon sleeving. Winding 7–8 is tapped at 5 turns from terminal 7, yielding a ratio of 12.25:1. When matching 50 ohm cable to loads of 450 ohms (terminal 6), 612.5 ohms (the tap), and 800 ohms (terminal 8), the variation in response is less than 5 percent from 1.5 MHz to 4 MHz. At 6.5 MHz the variation (which is an increase in the impedance ratio) increases to about 20 percent. Photo D attempts to give a better view of the connections.

The other two high-power ununs in photo D are specifically designed to cover the broadcast and 160 meter bands. The one in the center has 9 quadrifilar turns (of the same wires as above) on a stack of two 2.4 inch OD ferrite toroids with permeabilities of 250. The tap on winding 7–8 is now at 4 turns from terminal 7, yielding a ratio of 11.86:1. When matching 50 ohm cable to 450 ohms (terminal 6), 593 ohms (the tap), or 800 ohms (terminal 8), the response is literally flat from 0.5 MHz to 2 MHz. At 4 MHz the ratios increase by about 6 percent. At 7 MHz they increase by about 20 percent.

The unun on the right in photo C shows another way of obtaining the same performance as above. In this case the design has 12 quadrifilar turns (of the same wires as above) on a 2.68 inch OD ferrite with a permeability of 290. The tap on winding 7–8 is at 6 turns from terminal 7, yielding a 12.25:1 ratio (instead of 11.86:1 as above). Although the performance of this design is practically the same as the one above (using the two 2.4 inch OD cores), it is a much more expensive design, since the 2.68 inch OD core is not nearly as popular. But if a broadband, high-power and high-impedance unun (or balun) is required to cover 1.5 MHz to 30 MHz, then these expensive 2.68 inch OD ferrite cores are very likely the only alternative!

References

1. Gerald (Jerry) Hall, K1TD, *The ARRL Antenna Book,* 18th ed., 1991, Amateur Radio Relay League, Newington, CT, chapter 13, pp. 13–17.

2. Jerry Sevick, W2FMI, *Transmission Line Transformers,* 2nd ed., 1990, Amateur Radio Relay League, Newington, CT, chapters 1 and 8.

3. Jerry Sevick, W2FMI, "The Ultimate Multimatch Unun," *CQ,* August 1993, p. 15.