This is it! You can't get any newer in theory and practice than this matching device you can put together now.

A Multimatch Unun

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Broadband multimatch ununs (unbalanced-to-unbalanced transformers) capable of high-power applications have been the goal of many designers throughout the years. Some have resorted to using conventional autotransformers with tapped windings to obtain the many impedance transformation ratios. These met with little success, however, because of their limited bandwidths and efficiencies. Others (including the author's[1]) have tried tapping a bifilar Ruthroff unun.[2] Although these designs yielded the high efficiencies of transmission-line transformers, they too had limited bandwidths. Furthermore, their best bandwidths (for the various ratios) occurred at odd impedance levels. In other words, they didn't meet the objective of broadband operation with one of the input or output ports being at 50 ohms.

This article describes a design[3] that is capable of broadband operation from 1.7 MHz to 30 MHz with the following five ratios (which are close to): 1.5:1, 2:1, 4:1. 6:1, and 9:1. Since the two lower ratios work well in either direction (that is, stepping up or down from 50 ohms), this design can match 50 ohm cable to impedances as high as 100 ohms (actually, 112.5 ohms) and as low as 5.6 ohms over the frequency range. Furthermore, since this is a transmission-line transformer which cancels out the flux in the core, losses (in a matched condition) of only 0.04 dB to 0.08 dB can be expected.

The novelty in the design is the use of a trifilar winding (with one winding tapped) on a very small ferrite toroid, resulting in the shortest possible lengths of transmission lines. The windings are also connected in such a manner as to optimize the characteristic impedances of the windings from an overall standpoint. Since the transmission-line transformer is a choke (which limits the low-frequency response) and a configuration of transmission lines, the high-frequency response is not limited by leakage inductance or shunting capacitance (as some say), but by *standing* waves.

Therefore, the combination of using small ferrite toroids with the maximum allowable permeability (less than 300) for high efficiency,[1] and with sufficient turns to meet the low-frequency objective, results in the excellent performance exhibited by the designs in this article.

For those interested in the design considerations of this broadband multimatch transformer, a brief review is presented in the first section. It is then followed by a section describing a high-power design capable of handling the full legal limit of amateur radio power. And finally, the last section includes a low-power design capable of handling the output of any HF transceiver. Since transmission-line transformers can be made so efficient in matching 50 ohms to 100 ohms or less, their small sizes will surprise many readers.

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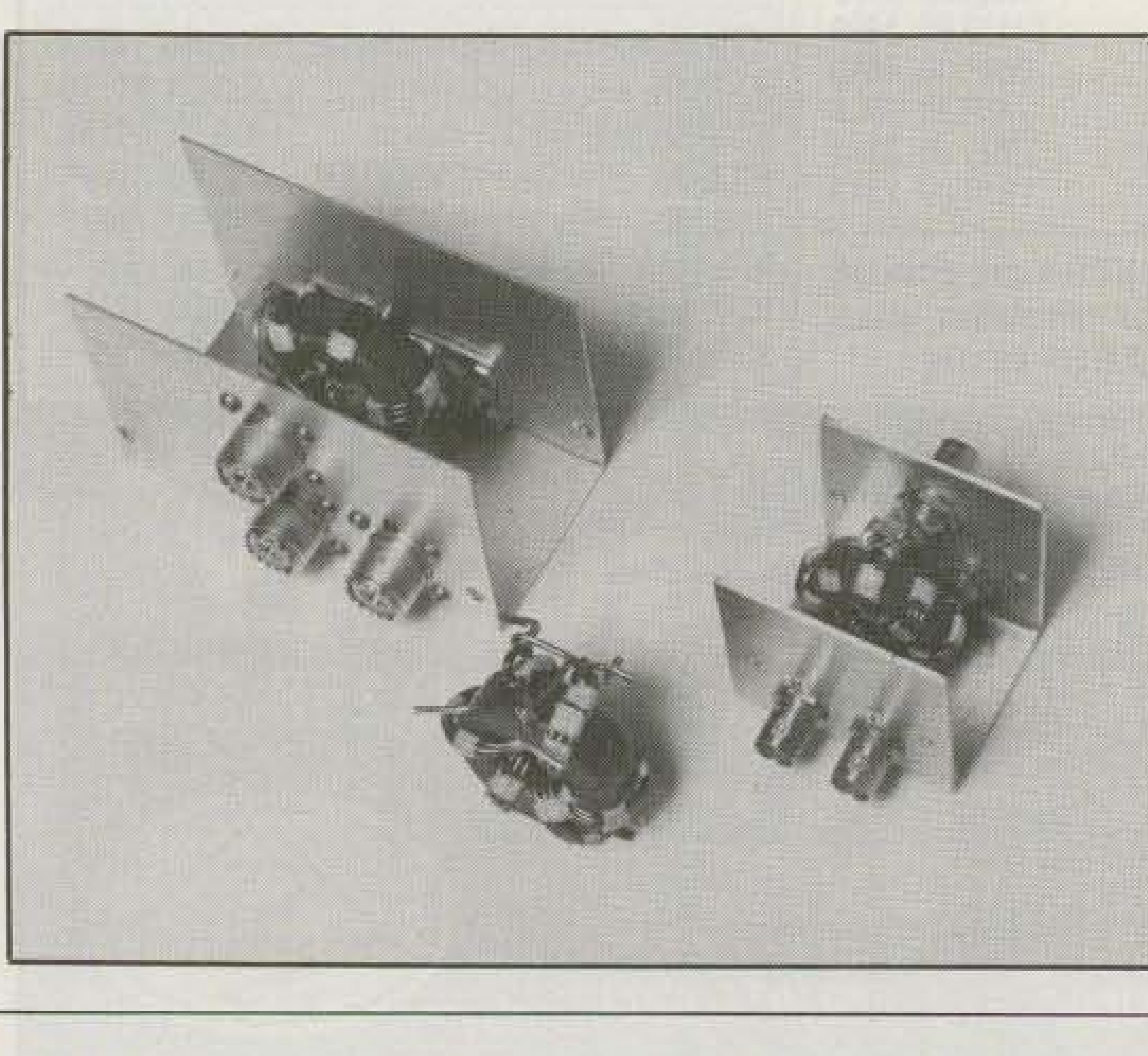
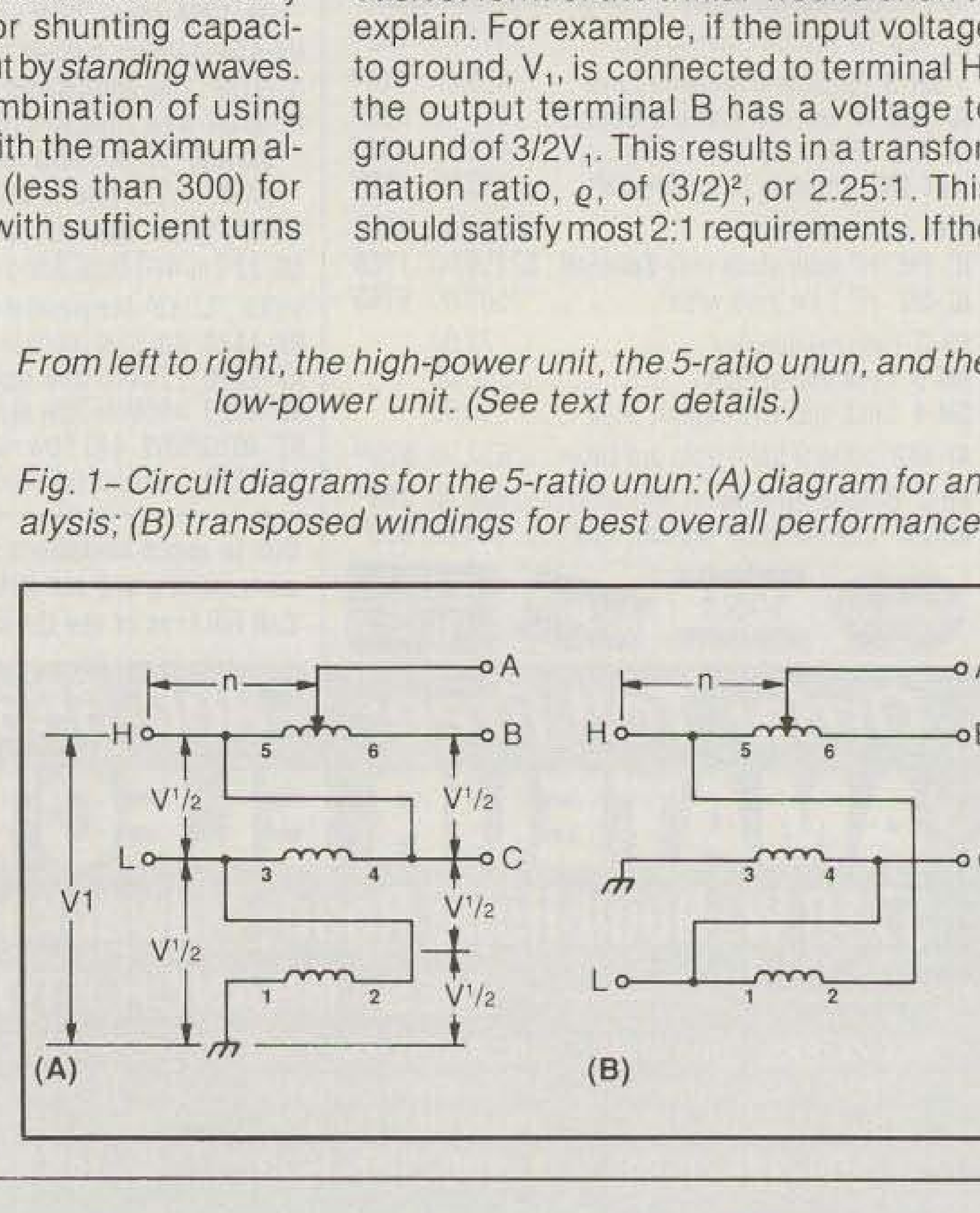
The Circuit

Fig. 1(A) is presented here because it is the easiest form of the trifilar-wound unun to explain. For example, if the input voltage to ground, V_1, is connected to terminal H, the output terminal B has a voltage to ground of $3/2V_1$. This results in a transformation ratio, ϱ, of $(3/2)^2$, or 2.25:1. This should satisfy most 2:1 requirements. If the



From left to right, the high-power unit, the 5-ratio unun, and the low-power unit. (See text for details.)

Fig. 1– Circuit diagrams for the 5-ratio unun: (A) diagram for analysis; (B) transposed windings for best overall performance.



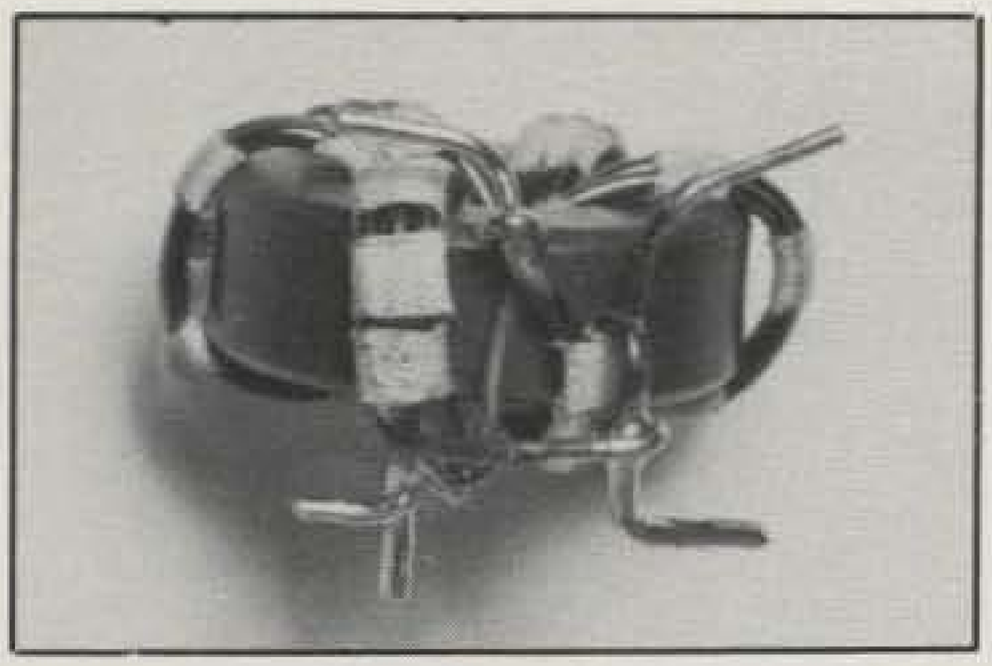


Fig. 2- Bottom view of the 5-ratio unun of fig. 1(B). The upper-left lead is terminal C. The upper-right lead is terminal B. The lower-left lead is terminal H. The straight-downward lead is grounded (terminal 3). The lower-right lead is terminal L.

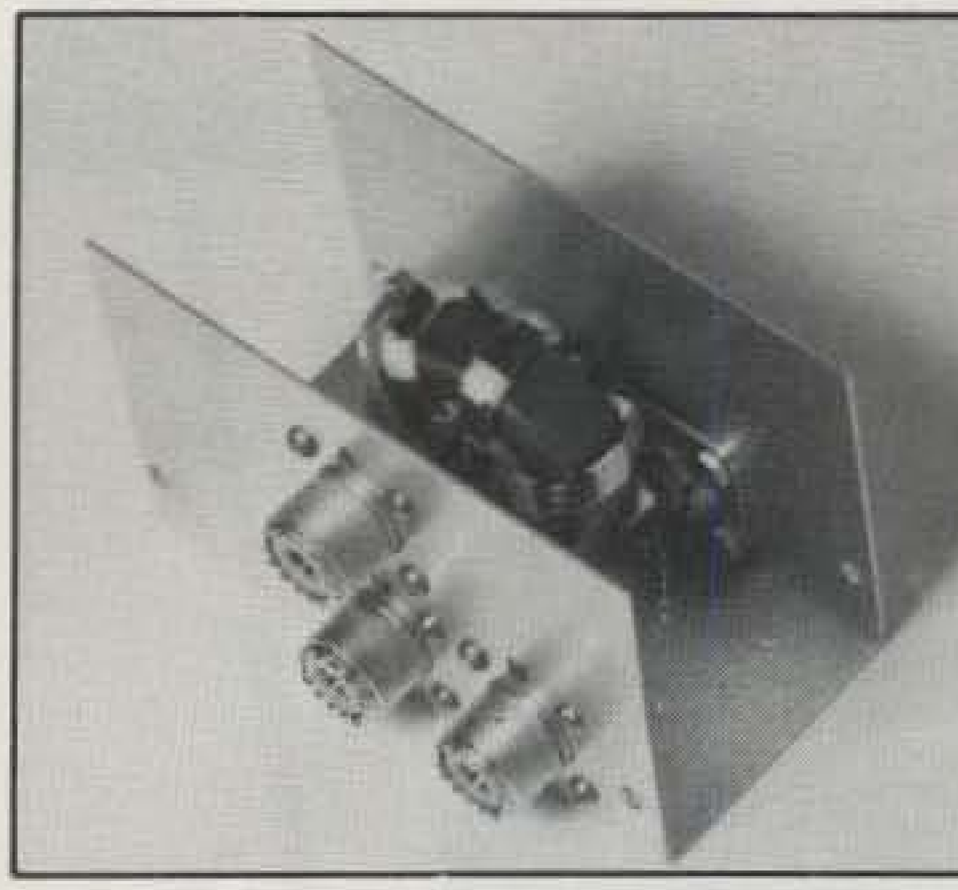


Fig. 3- High-power unit mounted in a 4"L × 2"W × 2.75"H CU-3015A minibox.

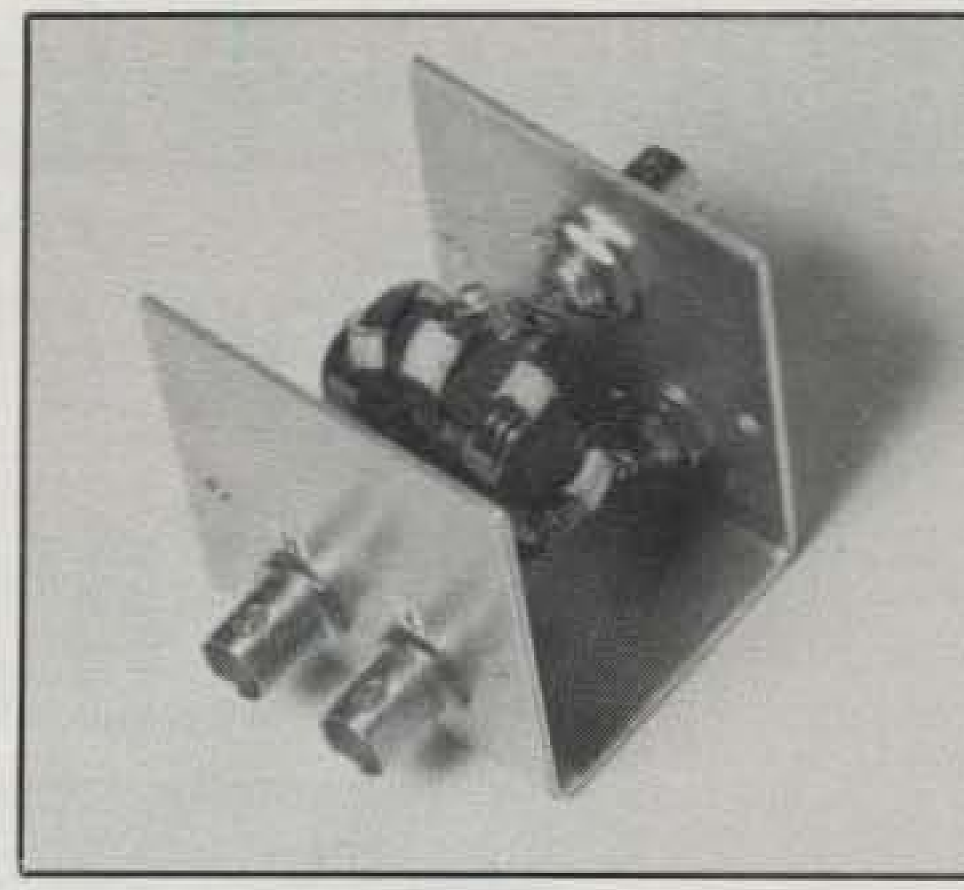


Fig. 4- Low-power unit mounted in a home-made 2"L × 1.5"W × 2.25"H minibox.

output is at terminal A to ground, then the output voltage is

$$V_o = V_1 + V_1(n/2N) = V_1(1 + n/2N) \quad \text{(Eq 1)}$$

where

N = the total number of turns on the winding

n = the number of turns from terminal 5

The transformation ratio, ϱ, then becomes

$$\varrho = (V_o/V_1)^2 = (1 + n/2N)^2 \quad \text{(Eq 2)}$$

If the input voltage to ground, V_1, is connected to terminal L, then terminal C has twice the voltage of V_1, resulting in a 4:1 ratio. Terminal B has three times the voltage, resulting in a 9:1 ratio. With terminal A, the output voltage is

$$V_o = 2V_1 + V_1(n/N) = V_1(2 + n/N) \quad \text{(Eq 3)}$$

The transformation ratio, ϱ, then becomes

$$\varrho = (2 + n/N)^2 \quad \text{(Eq 4)}$$

A High-Power 5-Ratio Unun

After several attempts at rearranging the windings of fig. 1(A) for best overall performance (optimizing the effective characteristic impedances of the windings), fig. 1(B) evolved. Fig. 2 shows the bottom view of an unun, using the circuit of fig. 1(B), capable of handling the full legal limit of amateur radio power. Fig. 3 shows the unit mounted in a CU-3015A minibox. It has five trifilar turns on a 1.5 inch OD ferrite toroid with a permeability of 250. Winding 5-6 is tapped at two turns (n = 2) from terminal 5.

If the 9:1 ratio matching 50 ohms to 5.6 ohms (connection B-L) is to be used at full power, then winding 3-4 should be No. 12 H Thermaleze wire. If not, then all windings can be No. 14 H Thermaleze wire.

A listing of the expected performance across the band from 1.7 MHz to 30 MHz, with the various ratios, is as follows:

9:1 (B-L); 50:5.6 ohms

Ratio is within 1 percent!

5.75:1 (A-L); 50:8.7 ohms
Ratio decreases by 5 percent.

4:1 (C-L); 50:12.5 ohms
Ratio increases by 15 percent (the greatest deviation of all the ratios).

2.25:1
a. (B-H); 50:22.22 ohms
Ratio decreases by 4 percent.
b. (H-B); 50:112.5 ohms
Ratio increases by 8 percent.

1.44:1
a. (A-H); 50:35 ohms
Ratio decreases by 10 percent.
b. (H-A); 50:72 ohms
Ratio increases by 2 percent.

Several comments should be made regarding the expected results shown above. First of all, the greatest deviation from a flat response at any ratio occurs when matching 50 ohms to 12.5 ohms (connection C-L; a 4:1 ratio). If an accurate insertion-loss measurement was made at this ratio and impedance level, the result would show an insignificant difference across the band. Second, the major part of the deviations for all ratios occurs beyond 15 MHz (the effect of standing waves). And finally, the higher ratios should never be used to match 50 ohms to 450 ohms, 288 ohms, and 200 ohms, respectively. The characteristic impedances and choking reactances do not allow for broadband operation under these conditions.

A Low-Power 5-Ratio Unun

Fig. 4 shows a low-power unit mounted in a homemade 2"L × 1.5"W × 2.25"H minibox. It has six trifilar turns of No. 16 H Thermaleze wire on a 1.25 inch OD ferrite toroid with a permeability of 250. The tap on winding 5-6 is at three turns from terminal 5, yielding ratios of 6.25:1 and 1.56:1 instead of the 5.75:1 and 1.44:1 ratios of the high-power unit. In actual use, these differences should be negligible.

Since this unun has shorter transmission lines than its high-power counterpart, the deviations of the ratios across the band are even less. Also, it is interesting to note that if No. 14 H Thermaleze wire was used in winding 3-4, this very small unun could well be rated at 500 watts of continuous power!

Footnotes

1. Sevick, J., *Transmission Line Transformers*, 2nd ed., Newington: ARRL, 1990.
2. Ruthroff, C. L., "Some Broadband Transformers," Proceedings of the IRE, Volume 47, August 1959, pages 1337–1342.
3. Kits and finished units available from Amidon Associates, Inc., 2216 East Gladwick Street, Dominguez Hills, CA 90220.