

THINGS TO LEARN, PROJECTS TO BUILD, AND GEAR TO USE

## The Coax Balun

**H**ave you read the great series of *CQ* articles on ferrite baluns written by Jerry Sevick, W2FMI? If not, better get out your back copies of this magazine and go over this important and interesting information.

Jerry mentions air-core coax baluns in passing, but the main theme of his work deals with ferrite-core devices. However, there is a place in the world for the air-core design, and I'd like to discuss here two interesting, inexpensive baluns of this type.

An advantage of the ferrite-core balun is it has a greater frequency range and is usually more compact than its air-core counterpart. And conversely, the air-core balun is larger and more bulky than the ferrite equivalent, especially if the former is wound with coax as the conductor.

The air-core coax balun, on the other hand, can be made cheaply and is not subject to core saturation, which can cause a number of unpleasant things to happen. The balun core can saturate and overheat with accompanying power loss, causing an increase in harmonic generation and intermodulation.

It is interesting and easy to build an air-core balun, and here are some coax types with which you can experiment and draw your own conclusions as to their utility.

### The 1-to-1 Coax Balun

The first I read of a wideband coax balun was in the 1959 publication *Principles of Single Sideband*, published by the Collins Radio Company. This book discussed baluns in the chapter describing feed systems suited to 52 ohm coax line (which had become the feedline of choice in the 1950s). A simple parallel-conductor balun was described (fig. 1). This device converts an unbalanced line to a balanced load, as any unbalanced currents flowing from A to C due to its direct connection to the antenna will be cancelled at C by the exact counterpart of current flowing from B to C. Thus, there is no current flowing on the outside of the coax beyond point C.

The length of the balun ( $L$ ) need not be a quarter-wavelength for the cancelling

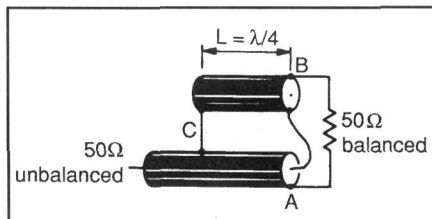


Fig. 1— Parallel-conductor type balun with 1:1 impedance transfer.

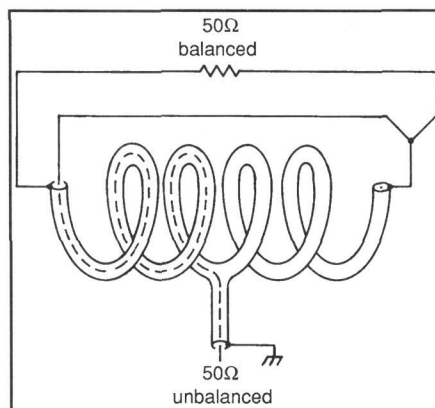


Fig. 2— Broadband coax balun with 1:1 impedance transformation. Center conductor of right-hand coil is unused.

effect to take place, but any departure of magnitude from this length will upset the 1-to-1 ratio of the balun. Unfortunately, this linear balun is not a broadband device. In addition, it is cumbersome, so it was not generally used with amateur antennas.

A form of broadband coax balun which is very useful in amateur service is shown in fig. 2. It may be visualized as the balun of fig. 1 wound into a coil. This physical representation does not cover the real operation of the device, which is somewhat more complex. However, a coiled coax balun is capable of operating over a much wider range of frequencies than is its linear counterpart, shown in fig. 1, without upsetting the impedance at the output termination.

The coax balun is wound to a diameter limited by the bending radius of the coax (about 15 times the cable diameter). The ends of the resulting coil are then symmet-

rically trimmed until resonance is achieved at the desired frequency, which is usually the mean frequency of the range of operation. The trimming is done with the aid of a dip meter with the balun disconnected from the load and the transmission line and with the loop connection open.

No more information of a helpful nature was provided in the Collins book, so it was left to the reader to build up a balun and try out the idea. I proceeded to do this.<sup>1</sup>

### A Practical Coax Balun For 7 to 30 MHz

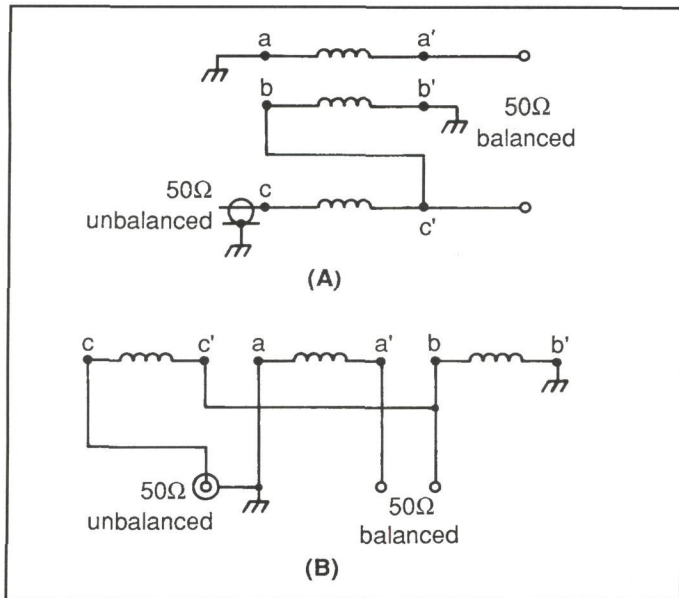
Operation of the broadband coax balun may be seen from the analogy shown in fig. 3. In (A) is a drawing of a balun known as a "ladder transformer" in TV service. This balun can be compared to a multiple-winding inductor (B), with the exciting voltage applied to one winding. Voltage across each coil is equal, and proper polarization of the windings provides output voltage balanced to ground. An equivalent HF balun can consist of three windings, two of which may be made of coax, and the third winding a single section of wire. In most cases, for symmetry and ease of construction, it is made of a matching length of coax cable. In this case, the inner and outer conductors of this section are shorted together.

The input and output terminations of the balun may be transposed, if desired, for easier physical attachment to the antenna (fig. 4). Operation of the balun is the same in either case.

I made up a balun consisting of a length of RG-213/U coax 16 ft. 6 in. long, wound into a single-layer coil the inside diameter of which was  $6\frac{3}{4}$  inches. This resulted in a 9-turn coil, with a couple of inches left at each end for connections. I used a section of gray PVC water pipe as the coil form.

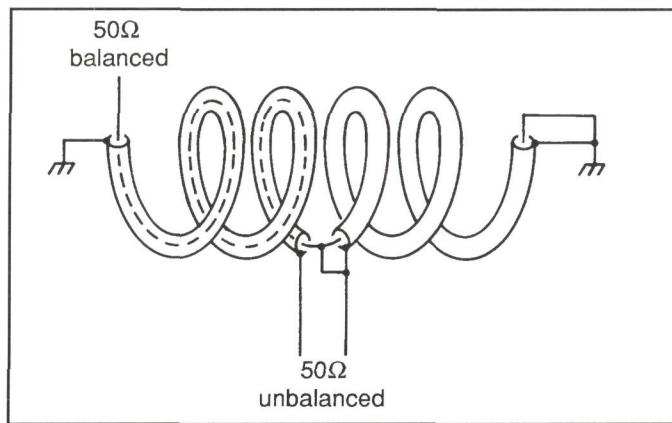
I wound the coil on the form temporarily and marked the points on the PVC corresponding to the ends of the winding. I then removed the winding and drilled small holes through the wall of the form at each spot previously marked with the pencil. The coil was then rewound on the form and held in place temporarily with plastic wire wraps passed through the holes I had just drilled. The center junction of the winding is exactly  $4\frac{1}{2}$  turns

<sup>1</sup>48 Campbell Lane, Menlo Park, CA 94025



← Fig. 3—“Ladder balun” shown at (A) redrawn as a transformer with identical windings (B).

Fig. 4—Reverse-connected 1:1 balun. Inner and outer conductors of right-hand coil are connected to preserve symmetry. ↓



from each end of the coil. I next carefully marked the center point, unwound the coil, and made the center connections shown in fig. 5. Once these were made, I sealed the joint with Coax-seal® tape and rewound the coax on the coil, then fastening it permanently in place with new wire wraps. Additional holes may be drilled near the center of the winding to

allow additional wraps to be placed at this point.

The range over which the balun provides good isolation is approximately 6 to 30 MHz.

#### The 4:1 Coax Balun

This design may be converted into a 4:1

transformer by a change in the configuration. The balun of fig. 4 is connected to place the input terminations in parallel and the output terminations in series (see fig. 6).

A variation of this type of balun was described by Dick Rollema, PAØSE, in *Electron*, a Netherlands publication. It was translated into English and reprinted in the August 1992 issue of *Radio Communication*,

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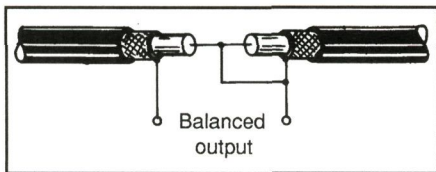


Fig. 5—Close-up of center connection of the balun.

a publication of the Radio Society of Great Britain.

The 4:1 design uses small-diameter 75 ohm coax (RG-59/U, or equivalent). This particular coax is chosen, even though the optimum impedance value for the winding should be about half the value of the terminating load—in this case 200 ohms. Not having any 100 ohm coax at hand, the RG-59 was substituted. The balun consists of 16 turns, split at the center, wound on a PVC form 3½ inches in diameter and about 6 inches long. Instead of making the balun of a single, tapped length of coax, two separate pieces were used, making in effect, two adjacent coils, each with eight turns of coax.

The balun windings are cross-connected at the ends (A to A and C to C). I used short pieces of No. 12 stranded hookup wire to do the job.

I built up a balun and it worked okay, but I felt that I could obtain a more con-

stant transformation ratio across the HF bands if I used a higher impedance coax for the winding. After snooping around, I found that The Wireman<sup>2</sup> listed RG-62A/U (95 ohm) coax in their catalog (stock number 141). I ordered 20 feet of this line and rewound the balun. As I expected, the balance and transformation ratio was much better than that achieved in the RG-59/U configuration, the new winding providing an operating range of 3.5 to 30 MHz. Performance dropped off above 29 MHz, but I think this was probably due to my relatively long interconnecting leads.

The maximum power level of the 4:1 balun is unknown. The RG-62A/U coax is rather fragile stuff, so I limited the applied power to 150 watts. At this power it performed in a satisfactory manner with no sign of heating or deterioration.

### Balun Construction

The ends of the coax windings are the weak points of the coax baluns. The outer conductor must be tinned, and the inner conductor protected from physical strain. After the terminating leads are attached, the coax ends must be protected from the weather with Coax-seal®, or the equivalent. Balun mounting will depend upon the individual installation.

I found that black ABS plastic pipe

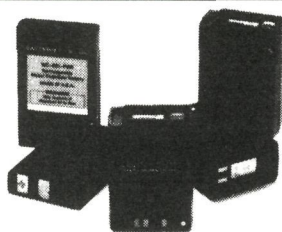
used for drain lines was equally as good as the PVC pipe and easier to cut and handle. ABS end caps can be obtained and epoxied in position when the balun is complete. An outline of my low-power balun, designed for use with an off-center fed, multiband antenna is shown in fig. 7. I didn't epoxy the end caps on; rather I fastened them to the coil form by means of sheet-metal screws. In that way I could dismantle the balun if I wished to make any changes.

### Telephone Interference The Ultimate Solution

My friend Tiff, W6GNX, has been plagued off and on over the years with bad telephone interference. Once he discovered that an unused phone sitting in the corner of the room picked up his 40 meter signal even when it was disconnected from the line! And the telephone answering machine was a puzzlement. Interference on it varied, depending on where it was placed in the house, and moving some telephones from room to room created different levels of interference in them. Line filters, such as described in my past columns, helped some phones, but there were other phones, Tiff found, that even the best line filter could not completely help.

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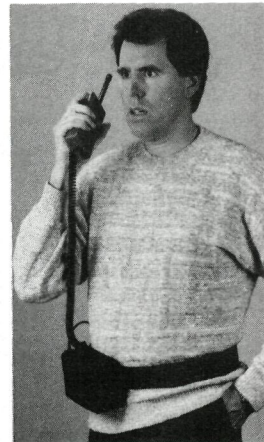
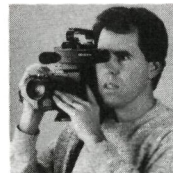
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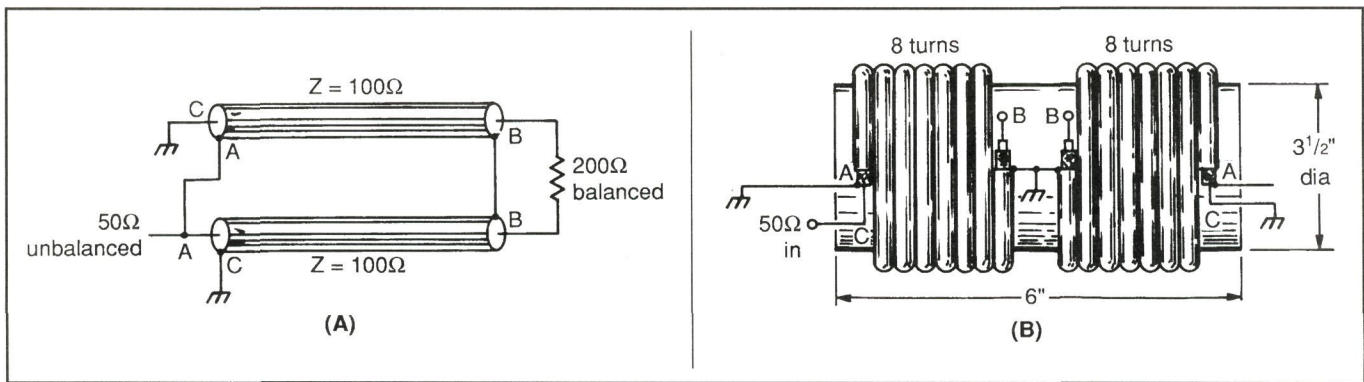


Fig. 6- (A) 4:1 linear balun. Short-circuit between A and B is remedied by the self-inductance created by coiling the coax as in illustration (B). Balanced antenna load connects to B-B.

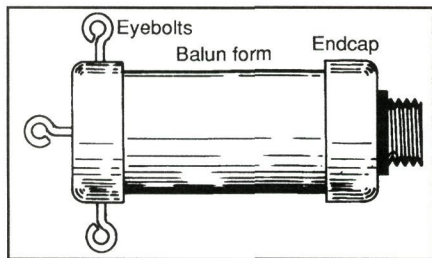


Fig. 7- Physical layout of balun. Side eyebolts are for antenna connections.

Tiff's conclusion was that interference could come from telephone line pickup of the signal, and also from direct pickup by the electronic circuitry of the phone itself. This resolves the interference problem into two parts: cleaning up the telephone lines and cleaning up RFI-sensitive instruments. A lot of thought has been given to the second part of the problem, but not much attention has been paid to the first part.

Most telephones could be cleaned up on a one-by-one basis, but what about pickup by the telephone line itself? A "clean" phone connected to a line that acts as an antenna is self-defeating. The phone line must be decoupled from the

antenna to set things right.

One solution is to move the transmitting antenna farther away from the telephone system. But this is not always possible, especially in an urban neighborhood.

The W6GNX 40 meter antenna is a dipole about 45 feet high, strung between the main tower and a pole at the opposite end of the yard. Unfortunately, the dipole runs parallel to the phone line in the house. At one end of the house the line runs from a junction box out to a nearby telephone pole.

Tiff verified this by crawling up into the attic space to locate the phone line. Sure enough, it ran along the underside of the roof rafters, parallel to the 40 meter antenna. Worst of all, at each telephone jack the wire doubled down the inside of the wall to the jack and came up again to the attic space to run to the next jack! There was over 400 feet of telephone wire running inside the house from one end to the other (fig. 8)!

A quick check with a friend of mine who was a building contractor confirmed that this is a common way of wiring homes today. It is called a "daisy chain." If the electrician installed the line before the framing was completed, the chain ran along below the floor joists. If, however,

the framing was complete, it was easier and quicker to run the chain through the area between the ceiling and the roof. After all, with high labor costs, the quickest way is the cheapest way, and man hours are a lot more expensive than wire!

### Rip It Out And Start Over!

Tiff reasoned it was useless to try to clean up the telephone lines running all through the attic area. He could possibly put RF chokes in the wires, but at which points would they be effective? It was obvious the wires were "hot" and reradiating his 40 meter signal all through the house.

With his characteristic energy, Tiff decided to bite the bullet and rewire his house telephone circuitry, eliminating the wires in the attic area completely. His solution was simple. He bought several hundred feet of two-conductor, shielded computer cable. This was specified as "Multi-conductor, Foil Shield, UL2464 CSA T-1 or T-2 NEC Type CL2 and CM." It consisted of two insulated #22 stranded wires plus a foil shield wrap and a drain wire, all incased in a gray PVC jacket, about 0.175 inch in diameter. The manufacturer of this particular cable coded it "Carol C-0760."

He ran the new cable around the lower outside perimeter of the house, encasing it in 1/2 inch PVC pipe for physical protection. Plastic outlet boxes were attached to the outer wall at the appropriate cut-outs, and a short stub was run through the wall to a terminal box located within the house. The shielded cable was run through the PVC pipe as the work progressed.

At each outlet box the drain wire (the shield) was continued to the next wire section, providing a continuous shield running the length of the telephone line. Tiff reasoned that the shielding, plus the close proximity to ground of the chain, would do away with the annoying interference.

The next question was the drop-cord

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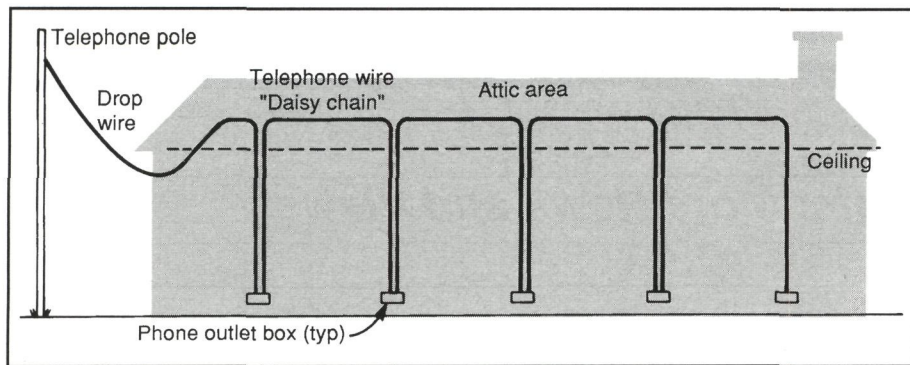


Fig. 8—Telephones wired in "daisy chain" running through attic area and down inside of walls to floor-level jacks. New shielded telephone line runs close to ground level.

from the telephone pole to the house. This was telephone company property and not to be touched. Tiff therefore put an RF filter (such as described in my earlier columns) at the point his new wiring met the drop cord.

The remaining problem was where to ground the shield of the coax line. At the drop cord? At the transmitter? Tiff had a good ground at the transmitter, so he chose that spot. The drain line was connected to the station ground, which was at the base of his tower, just outside the shack window.

Once the job was done, Tiff connected all the phones and gave the system a "smoke test." When 40 meters was relatively quiet, he picked a clear spot and went on the air, modulating his transmitter with an audio tone. No sound could be heard in any telephone—except a weak signal in the telephone answering machine on his operating desk.

This was a lot better than before, as the phone system had been nearly unusable when Tiff was on 40 meters. Now all he had to do was clean up the answering machine. A peek at the innards revealed an unshielded circuit board full of ICs, diodes, various components, and a lot of long, interconnecting leads. In brief, it functioned as an efficient radio receiver!

What to do? The daisy chain was clean, all other phones were clean, but this pesky device was still able to pick up his 40 meter signal and pump it (weakly) into the phone system. As Tiff said, all it needed was a beat-oscillator to be a good SSB receiver! Tune in next month and I'll tell you how Tiff solved this vexing problem.

As a final note, he observed that the SWR response curve of the 40 meter dipole now indicated resonance at the frequency to which he had cut the flat-top! When the phone wires were in the attic, the SWR resonance frequency had been offset over 100 kHz! Obviously, there had been tight coupling between the attic wires and the dipole antenna.

The moral of this story is that telephone filters by themselves often won't completely clean up a tough case of interference. The telephone wiring through the house may be picking up such a high RF

signal level that the filter can't do its job. Rerouting the telephone line to lessen the pickup may be required. Use a shielded line and keep it close to the ground.

Before you rip out any house wiring, make a schematic drawing of the system, showing any color coding of the wires or other identification that will help you reassemble the system in its proper order. For a two-wire installation, it's not hard at all!

## The Dead Band Quiz

Many thanks to the following who have sent me personal notes: W2OQI, W9PVD, AA4GR, N4UZ, WB8SFT, and K1KLO. I'm sorry I don't have the time to reply to each of you, but rest assured, your input is appreciated.

The Dead Band Quiz concerned three switches that operate three light bulbs in a closed room. One switch for each bulb? You can only go in the room once. Can you determine which switch operates which bulb?

There are several solutions. Here is one. All switches are initially off. Turn on switch #1 for a few minutes, allowing bulb #1 to get warm. Turn off switch #1 and turn on switch #2. Immediately enter the room and feel the unlit bulbs. The warm unlit bulb is controlled by switch #1, the lit bulb by switch #2, and the cold bulb by switch #3. Got it? Good.

Congratulations to the following who immediately solved this little puzzle: KD4VAU, W5IKB, WN2SQC, W6GPM, WA5JCI, W2LCV, WD9DDO, K2PF, K5RA, KZ1R, AA9DH, W2ZPL, KL7DN, W4GRY, W4GJG, AE5E, W6OK, KB7WJQ, KE4ARH, W6JJZ, W4EHU, NH6ZF, KA3VVC, WA2DWV, WB6BYU, N8SJP, and WB6IYM. And more calls in my next column! 73, Bill, W6SAI

## Footnotes

1. Orr, William, W6SAI, "A Broadband Balun for A Buck," *CQ*, February 1966, pp. 42-44.

2. The Wireman, Inc., 261 Pittman Rd., Landrum, SC 29356.

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