Can coaxial cable carrying RF energy also be turned into a choke to block RF energy? Yes, and KA4LBE shows us how to design and build one to meet individual needs.

(Yes, You Can) Design and Build Your Own Coax RF Choke & Balun

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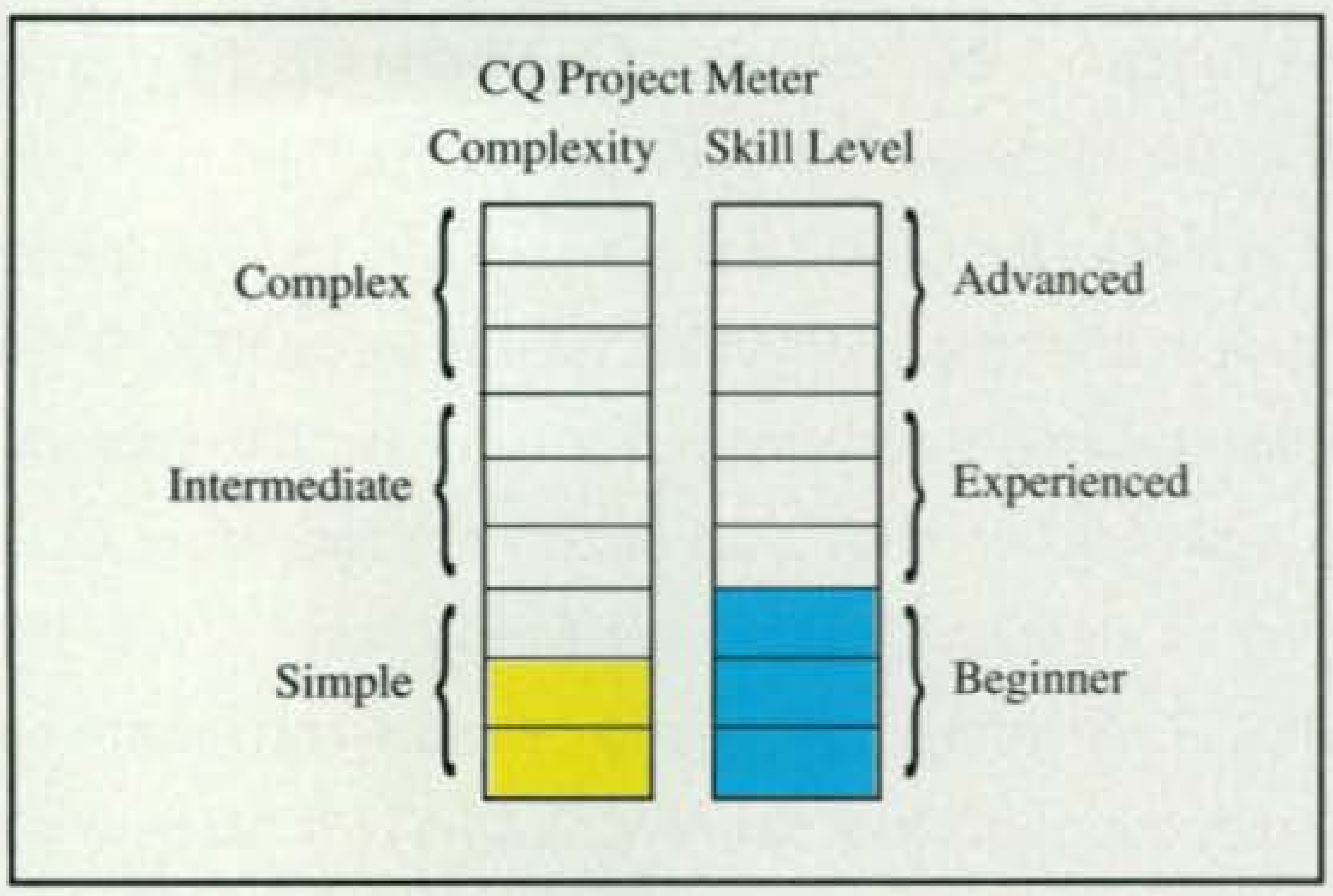

If you're new to antenna building, you might come across certain unfamiliar terms. For example, what is a *balanced feed*? What is a *balun*? Why is it that a balun may be required? What is a *current balun*?

It turns out that many antennas are balanced-feed types. Some balanced-feed types are quite evident. Draw or look at a schematic sketch of a center-fed dipole. Notice that from the center-feed terminals there are two sides that look like mirror images. This is a *balanced antenna,* which works best with a balanced feedline or transmission line, such as twinlead. However, a more typical transmission line is a length of coaxial cable. Coax is an *unbalanced* transmission line. To properly transfer the RF from the unbalanced coax to a balanced antenna, what is needed is a device called a *balun.* The term *balun* refers to a device used to connect a *balanced* load (antenna) to an *unbalanced* line. Fig. 1 shows how a balun is used to connect a balanced load, the antenna, with an unbalanced feedline, the coax.

Impedance Matching, Too

Baluns are sometimes made so that an additional transfer can be made. That transfer is from the source impedance to different impedance. When 50-ohm coax is to be connected to a 200-ohm antenna, the balun required is a 1:4 or 4:1 type. For this article, though, we will consider a 1:1 balun, used when the antenna has input impedance of about 50 ohms, very similar to that of the coax. That means a coax feed of 50 ohms directly matches the antenna as far as impedance is concerned.

If used correctly, coax is a great transmission line. It is easy to use and has easy connector systems. The RF current flows internally on the outer surface of the inner conductor and on the inner surface of the outer conductor or shield. *There is no reason for any RF current on the outside of the coax shield.* However, that is not an uncommon situation when things aren't just right. Some causes of these currents may be improper matching or feeding of transmission line to load or inductive coupling between the antenna and the transmission line.[1] These currents cause problems—some of which may not even have been noticed—and should be eliminated if possible.

If an RF choke could be inserted in the outer surface of the coax shield, the problem would be solved. At first glance it seems this is not possible. Or is it? By simply making a coil of a few turns of the coax feedline, an RF choke is made out of the outside of the shield braid itself.[2] This choke, properly designed, will reduce the RF current on the shield.

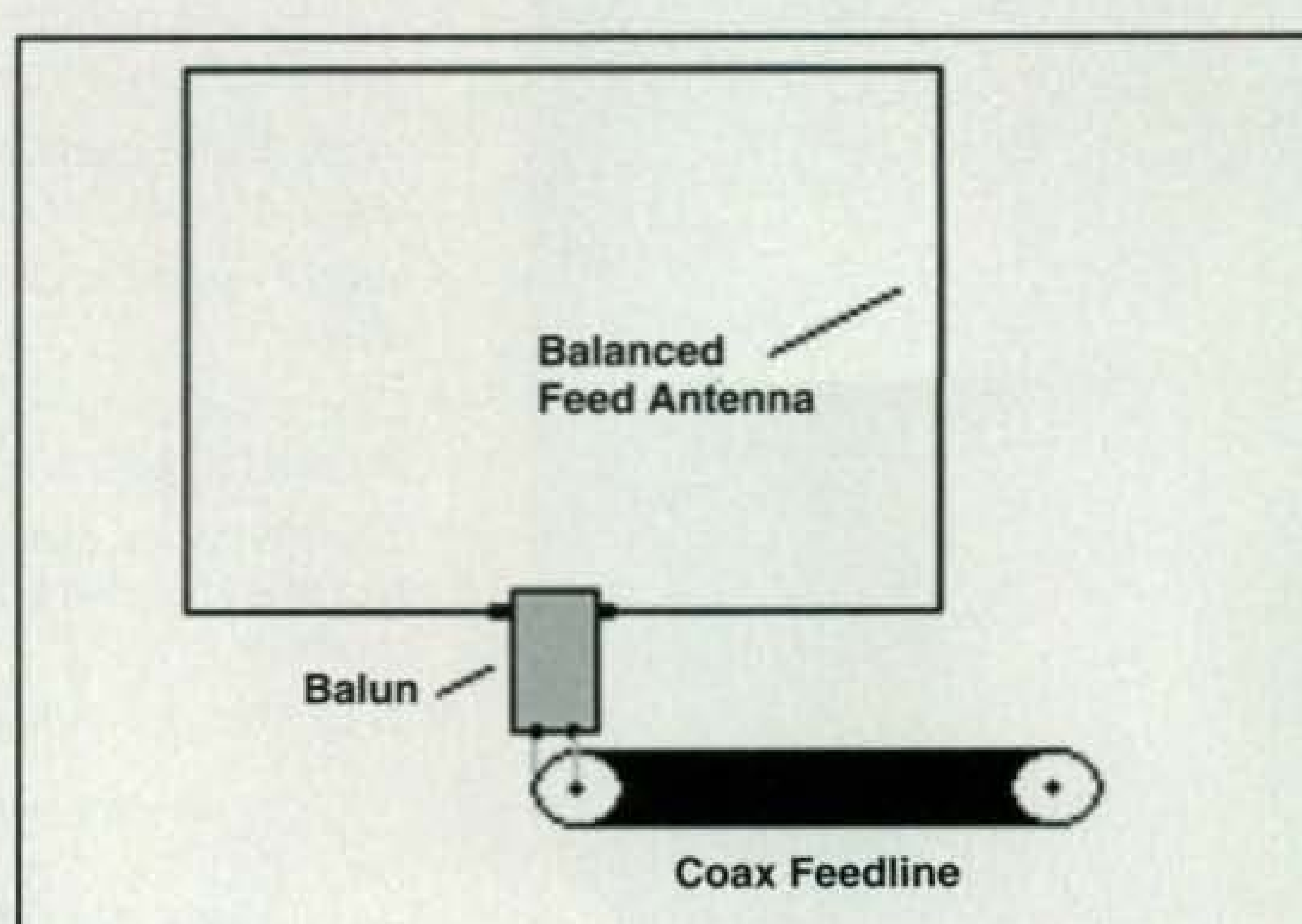

Fig. 1– The balun used to connect unbalanced feedline to a balanced antenna.

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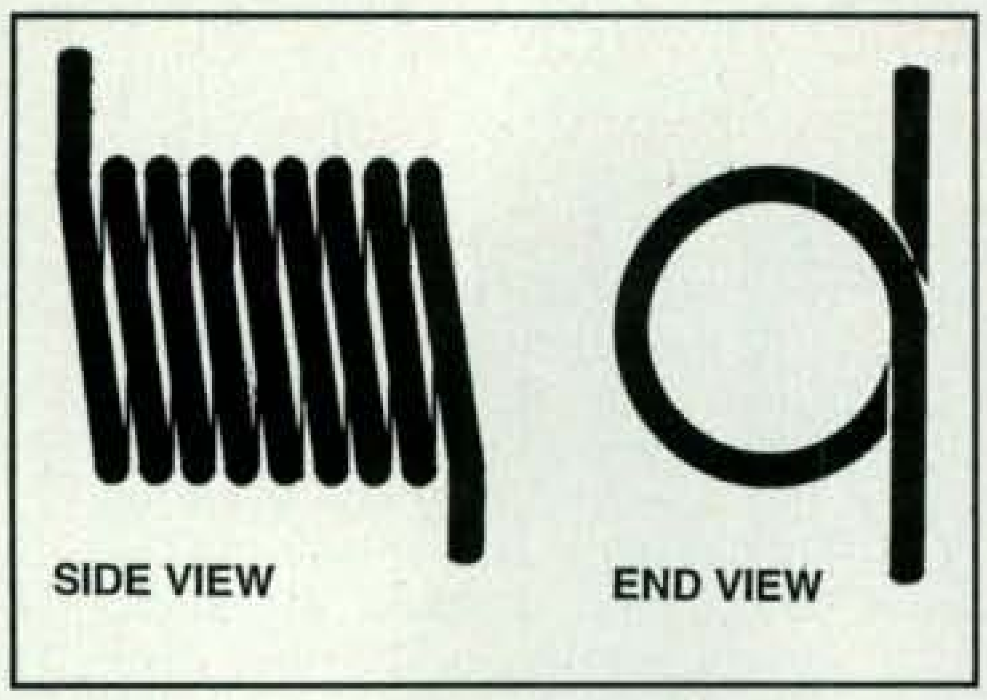

Fig. 2– Side and end views of what the finished choke/balun should look like.

feed is required by many antennas and is not necessarily furnished by all 1:1 baluns. A RF choke balun performs this function.

A coax RF choke has features including the following:

1. Once designed, it is rather **easy** to build.
2. **Very good performance.**
3. **Low loss.** Loss is that of the required coax.
4. It is a *current balun* since it furnishes **balanced feed current.**

Rolling Your Own

The proposed design of a coil is to wind it as a single-layer solenoid. This design allows the values of inductance, hence reactance of a coil, to accurately be predicted. A single-layer coil takes the form shown in fig. 2.[4]

The target of coil reactance is to set the reactance to be at or slightly greater than ten times the characteristic impedance of the coax. For example, if the coax is 50-ohm type, then the coil reactance should then be at least 500 ohms.

The formulas to use in solving our design problem can be found in chapter 4 of the 2005 edition of *The ARRL Handbook for Radio Amateurs.* [5]

Photo B– Finished coil removed from the form. See Table I for numbers of turns needed for different bands, based on the size and impedance of the coax and the diameter of the coil form.

The first formula is to determine reactance:

$$XL = 2\pi fL$$

Rearranging for inductance, we get:

$$L = XL / (2\pi fL) \qquad \text{eq. 1}$$

In the above, **XL** is inductive reactance (ohms), π is pi (3.1416), **f** is frequency (Hz), and **L** is inductance of the coil.

The second formula is to determine the coil inductance:

$$L = (d^2n^2) / (18d + 40lng)$$

Rearranging for the number of turns, we then get:

$$n^2 = (L \times (18d + 40lng)) / d^2$$

$$n = \quad (L \times (18d + 40lng)) / d^2 \qquad \text{eq. 2}$$

In this formula, **L** is inductance in microHenrys, **d** is coil diameter (inches), **lng** is coil length (inches), and **n** is number of turns in the coil.

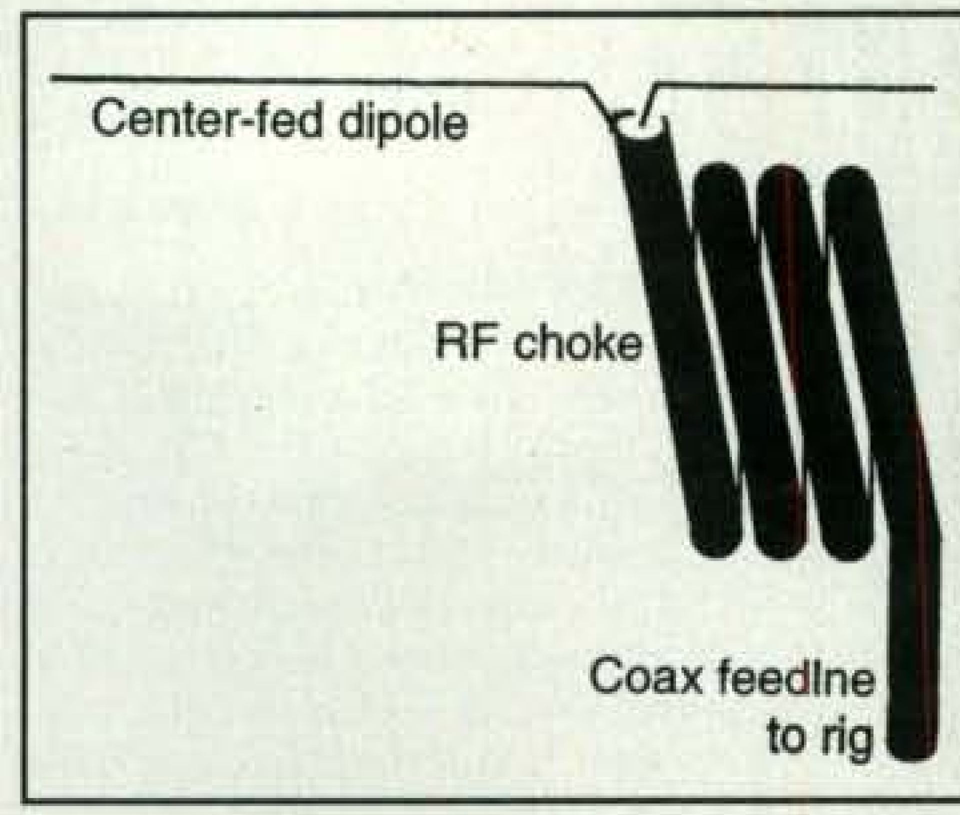

Fig. 3– Connection of the choke/balun to a typical dipole antenna.

The first step is to use equation 1 to determine the inductance required in the coil and then input the value of ten times our coax impedance as XL. Calculating this, the next step is to use equation 2 to determine the required number of turns in the coil. Here a problem is found. Note that the term **lng** is composed of diameter of the coax times the number of turns of coax (n × dc), giving the length. The finished coil length is required, but the number of

		50-ohm Coax			
		0.5 in. Diameter Coax		0.25 in. Diameter Coax	
Band (meters)	Freq. (MHz)	Coil Diameter(s)		Coil Diameter(s)	
		18 in.	11.25 in.*	9.5 in.*	5 in.
		# turns	# turns	# turns	# turns
160	1.8	9	13	14	38
80–75	3.5	6	9	9	21
40	7	4	6	6	13
30	10	4	5	5	9
20	14	3	4	4	7
17	18	3	3	4	6
15	21	3	3	3	5
12	24	2	3	3	5
10	28	2	3	3	4
6	50	2	2	2	3
		75-ohm Coax			
		0.5 in. Diameter Coax		**0.25 in. Diameter Coax**	
Band (meters)	**Freq. (MHz)**	**Coil Diameter(s)**		**Coil Diameter(s)**	
		18 in.	11.25 in.*	9.5 in.*	5 in.
		# turns	**# turns**	**# turns**	**# turns**
160	1.8	11	17	19	56
80–75	3.5	8	11	12	30
40	7	5	7	7	16
30	10	4	6	6	12
20	14	4	5	5	9
17	18	3	4	4	8
15	21	3	4	4	7
12	24	3	4	4	6
10	28	3	3	3	5
6	50	2	3	3	4

**Two "'standard size" plastic pails available in paint, hardware, and home-maintenance stores to use as winding forms. Dimensions given are average. The 11.25-inch unit is 12 inches at the top opening. The 9.5-inch unit is 10 inches at the top opening.*

Table I– Coax RF choke parameters.

turns is unknown. One solution to this dilemma is to input a large dimension and repeatedly perform the calculation, narrowing down the answers until a logical value is achieved. The author has written a computer program that does this labor. It calculates required number of turns and adds any needed length to fill a partial winding. This also fulfills the requirement to have a minimum of ten times the impedance of the coax in use.

Fig. 3 is a simple sketch showing the addition of a coax RF choke to be a 1:1 balun. Notice that the choke is located at the antenna feedpoint. The choke is drawn considerably oversize and the number of turns shown is simply for example.

When winding coax, there are some potential problems that may result and they need to be considered. One is how to wind and give some permanence to the coil. Forms may be helpful during winding. These might include buckets or pipes, but no metallic conductor device should be included in the permanent structure. Once the coil is wound, strips of heavily varnished wood or electric-fence fiberglass rods can be attached using strong weatherproof glue. For small coils a simple reinforcement made of nylon cord at the feed/start area will be sufficient. When cured, the coil can be slid off the form.

The second and probably most important thing to consider is the coax itself. Various types of coax react differently to bending or winding. For each type there is a limit to how sharp the bend can be. Foam types have larger diameter limits than solid types. The problem is that the coax may flatten, or even worse, the inner conductor can migrate through the foam, permanently damaging the coax. In these cases the coax impedance is changed. It is best to err toward winding larger coil diameters than smaller ones. Be aware, understand, and control these parameters. They are easily accommodated.

In the application where a single feedline is used to feed two or more antennas in parallel, the RF choke should be designed for the lowest frequency-band antenna. An example of this application is one where multiple-band center-fed dipoles are fed by one coax feedline. A trap multi-band antenna, either vertical or horizontal, would be another. A choke designed for low frequencies becomes an even higher reactance device at higher frequencies.

As noted previously, designing a coax RF choke, especially calculating the number of turns of the coax feedline required, is a bit difficult and time consuming. A collection of calculated coax RF choke lengths is outlined in Table I. In this table are listed the two most common outer coax diameter types and the two most common coax characteristic impedance types. Notice that the design frequencies used were chosen from the lowest end of each band. The diameters of coax shields are somewhat smaller than the overall outer diameter. The overall diameter is the measurement that determines coil length. This is only for information, as actual variation is not too critical. It was accommodated in the noted computation program.

The coil diameters, 11.25 inches and 9.5 inches, were selected based on using common plastic buckets as forms on which to wind coils. Holes were drilled on the bucket sides to allow passage of tie-wraps for holding the start and finish turns to allow finishing of the coil. Photos A and B show the winding of a coil using the "bucket form" approach.

Start winding with the antenna feed end. Secure this end to the hole nearest the bottom of the bucket. Wind the required number of turns and then tightly secure the coil end. Apply cement to the coil and allow drying time. Cements used for boats and plumbing are a good choice. Do not allow the cement to flow onto the bucket. When dry, slide the coil from the form and apply cement to the inside of coil. When this is dry, tie a few turns of heavy nylon cord to the coil at the start and end areas. Apply cement to the cord and let all dry.

Protect the coax feed physically by adding a strain relief so that strain is not placed on the feed connection. A good installation might include the choke tied to the support beam or post. Weatherproof all open coax and connections if the choke is to be left outside.

A Step Beyond...

The previous discussion centered on a 1:1 balun. Certain "Q" (quarter-wave) sections of coax of different characteristic impedance can act as RF transformers.[6] For example, a quarter-wave section of 75-ohm coax added at the end of the 50-ohm feedline could produce a match between the 50-ohm feedline and an 80- to 160-ohm antenna. This would include certain quads. Another similar RF transformer can be made of two quarter-wave sections of 50-ohm coax that are connected in parallel. This produces a quarter-wave section of feedline having impedance of 25 ohms. This Q section will effect a good match to an antenna having 9 to 17 ohms input. This would include some Yagis and shortened antennas such as halos. These Q sections can be wound into the RF choke, producing a matching current balun. ■

References

1. *The ARRL Handbook for Radio Amateurs,* 2005 edition, chapters 21 & 22,"Balun," published by The American Radio Relay League, Newington, CT 06111.

2. See ref. 1.

3. See ref. 1.

4. *The ARRL Handbook for Radio Amateurs,* 2005 edition, chapter 4, "Inductance and Reactance."

5. See ref. 4.

6. *Radio Handbook,* by William I. Orr (W6SAI), "The Q-Section," Howard Sams, Indianapolis.