# No. 48: The Ubiquitous 4:1 Balun

**L. B. Cebik, W4RNL**

In our last episode, we introduced the idea of a balun. We noted that in its most generic use, the term "balun" refers to any device that enables us to make a transition from a balanced circuit to an unbalanced circuit--or vice versa. The most common application of the term occurs in antenna and feedline work.

More specifically, many uses of the term "balun" wish to indicate the use of a transmission-line transformer, a specialized wide-band transformer whose turns have a characteristic impedance, that is, whose turns are formed with transmission line sections. We noted that such impedance transformers come in many forms, ranging from linear air-wound versions to the more common toroidal form using a ferrite core (or cores, for high power transformers.

Balun transformers can have a large range of impedance transformations, running at the low end from 1:1 up to as much as 9:1. Perhaps the individual who has written the most on the basic balun transformer and done the most in developing versions that one can build is Jerry Sevick, W2FMI. He has several books on the subject.

In our last episode, we looked at the all-50-Ohm (or, more generally, the all coax) system. We discovered that the balun transformer is only one of the devices that we can use to effect a transition from a balanced to an unbalanced system. Besides the transmission line transformer, we could use a ferrite bead choke or even a specially would coil of coax to attenuate common-mode currents virtually anywhere along the line, depending on our needs.

In this episode, let's look at the balun transformer itself. Its purpose is to transform impedances over a wide range of frequencies--for example, the entire HF range from 3 to 30 MHz. It just happens also to attenuate common mode currents as well.

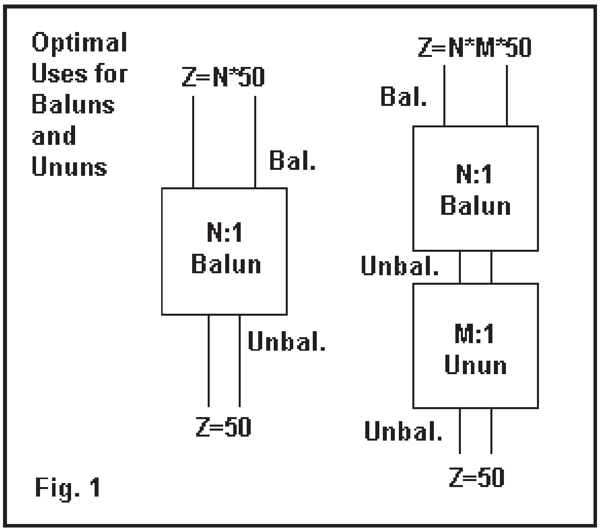


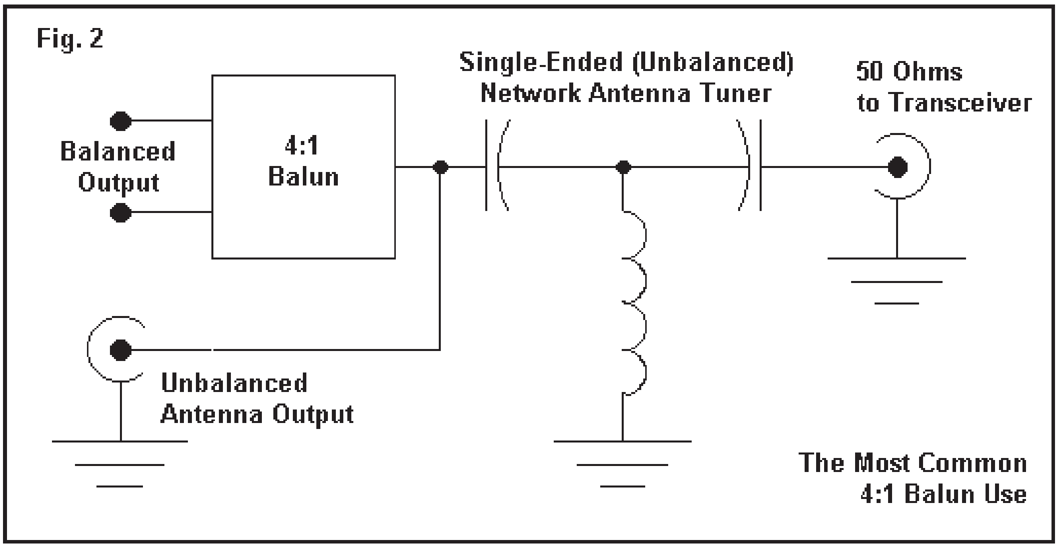
Fig. 1

**Fig. 1** shows the ideal situation for a transmission-line transformer as a balun--on the left. We buy or build a balun transformer with the desired impedance transformation relative to our 50-Ohm main feedline cable. Actually, most baluns are able to handle impedances over a range, so the 50-Ohm side can vary somewhat. If our balanced impedance is 200 Ohms, then a 4:1 balun will change that to 50 Ohms on the unbalanced side. In fact, I know of at least one contest operator who designs his beams to produce a 200-Ohm impedance in a Tee-match and then uses a 4:1 balun at the feedpoint for his 50-Ohm cable.

However, we are not restricted to a 4:1 balun. In fact, the balanced side need not have a higher impedance than the input side. There are 4:1 baluns that will transform a 12.5-Ohm balanced impedance to a 50-Ohm unbalanced impedance. We cannot simply turn the common 4:1 balun around, since it is doing two jobs at once: transforming the impedance and effecting a balanced-to-unbalanced transition.

We noted that the greatest efficiency occurs when the characteristic impedance of the balun winding is the geometric means between the high and low impedances. Sometimes, the transformation that we need is very high, for example, 16:1 in some cases (with terminated folded dipole all-band antennas, for example). In these instances, we may start with a 4:1 balun. Then we can add a 4:1 unun, that is, a transmission-line transformer designed for unbalanced input and output sides. The right side of Fig. 1 shows this option. If we must match 800 Ohms to 50 Ohms and go from a balanced side to an unbalanced side, then the dual transformer option is sometimes best.

When used properly, transmission-line transformer baluns can be over 99% efficient. However, they do have their limits. For one, they tend to become lossy when the impedance on the antenna side has considerable reactance. Sevick recommends that all matching to remove reactance be done on the antenna side of any balun transformer. It is also possible to over-power baluns so that they begin to heat before the cores reach saturation. Whatever signal energy turns into heat is energy no longer available for radiation and communication.




Now let's look at **Fig. 2**, the most common application of the ubiquitous 4:1 transmission-line transformer balun. The sketch shows in simplified form the typical unbalanced (or single-ended) network tuner. The coils and capacitors in a real tuner would be variable or switched, and the unit might even have a built-in SWR meter. However, we can see, just by looking at the ground symbols, that the main purpose of the tuner is to match unbalanced antenna impedances as they occur at the output coax connector to 50 Ohms at the other coax connector.

However, the chief use for most antenna tuners is to handle multi-band wire antennas using parallel feedlines for low losses in the presence of a very wide range of antenna-terminal impedance values. Most multi-band antennas will not only show both high and low impedances, but as well, the impedances will have both resistive and reactive components, both of which may be high. The impedance at the balanced terminals of our tuner will be a function of 3 variables: the antenna terminal impedance, the characteristic impedance of our feedline, and the length of the line itself. When the antenna impedance is not an exact match for the feedline impedance, the value of impedance will undergo continuous transformation along the line every half-wavelength at the operating frequency.

To handle these impedances, tuner makers install a 4:1 balun. Depending on the tuner maker, these units may range from poor to excellent in quality. But they are still 4:1 baluns. Even at their highest efficiency, they transform the impedance at the terminals down to a value that is 25% of the tuner terminal value.

However, because the impedance undergoes continuous transformation along the way, it may already have a low impedance at the tuner terminals. If it is already 20 Ohms (a value that has occurred in many instances), then a completely efficient 4:1 balun will transform it to 5 Ohms. Most tuners will be able to transform the 5 Ohms up to 50 Ohms, but they will not do so efficiently. Considerable power will be lost, not in the balun, but in the tuner. Since the tuner components are large, you may not be able to detect the heat, but the losses will be there.

So far, we have assumed that the balun is completely efficient. However, as we have noted, the impedance at the tuner terminals may consist of both resistance and reactance. Many balun designs become lossy in the presence of high values of reactance.

The end result is a system that is lossy by design. The 4:1 balun has been added to the single-ended tuner as an afterthought, a convenient way of claiming that the tuner will handle both balanced and unbalanced antenna side loads. However, we must always ask how well it will handle such loads, and the answer is not always pleasing.

If you do use a multi-band antenna with parallel feedlines for operation on the "other" HF bands, there are better ways to handle the matching requirements. There are still a few link-coupled antenna tuners left over from ancient times, such as the Johnson Matchboxes produced from the 50s through the early 70s. European operators can still find a few good Annecke link-coupled tuners.

More recently, several makers have introduced balanced network tuners. These tuners, shown in outline form in the last episode, do their matching work while still in the balanced configuration. At the transceiver side of the unit, where the impedance is now 50 Ohms or very close to it, some builders install a 1:1 current balun to transition from the balanced impedance to an unbalanced line, namely, the coax from your tuner to the rig. (I have recently seen a low cost balanced tuner circuit that does not indicate the presence of a balun. In this case, you will have to add one.)

Balanced network tuners are not without limits. They have their widest matching range--that is, their ability to handle high impedances with relatively high reactive components) at the lowest frequencies. The matching range tends to narrow as the frequency goes up. At the high end of the spectrum, the required values of inductance and capacitance for high impedances tend to be below the minimum values that the components can achieve.

Now let's suppose that you already have a single-ended network tuner. Let's also suppose that you want to spend your money on other things than a new balanced network tuner. Is there a way to press the unbalanced tuner into service and to get reasonably good (even if not perfect) performance from it? The answer is affirmative, and **Fig. 3** shows how.

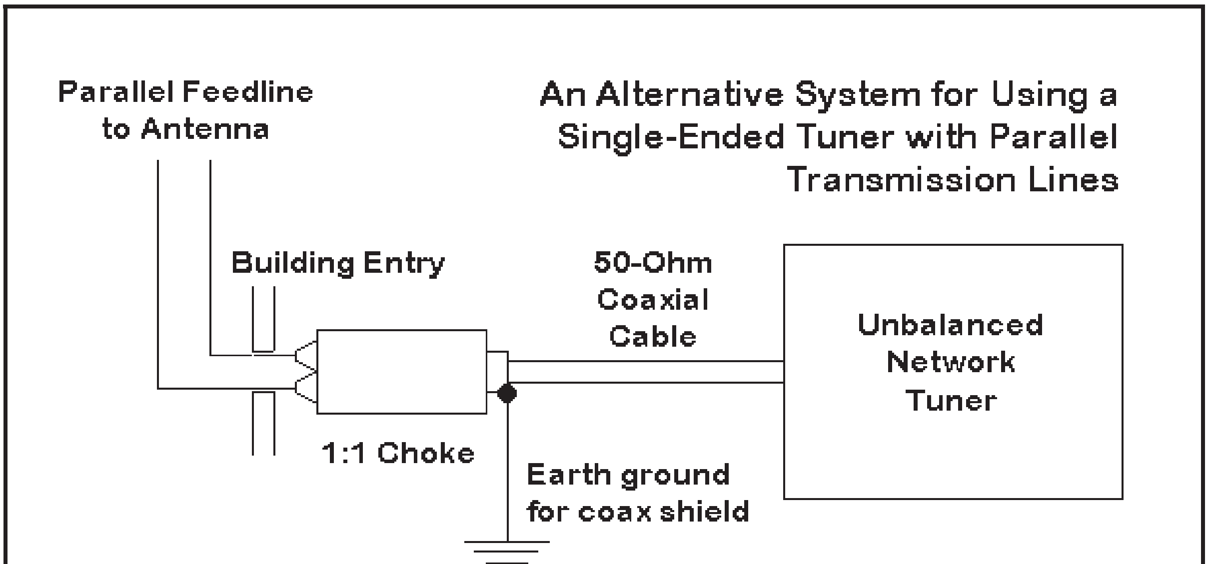


Fig. 3

First, we shall forget about the 4:1 balun inside the tuner and use the unbalanced coax connector antenna-side output. We shall obtain a short length of coax, just enough to reach from the tuner to the entry point for the feedline to our multi-band antenna. If we obtain the very lowest loss coax we lay our hands on, so much the better, and if we can keep the coax run as far under 20' as possible, so much the better to keep losses minimized. At the entry point, either indoors or outdoors, we shall install a 1:1 choke. For this application, I tend to prefer ferrite bead type chokes, since the antenna side terminals may have considerable reactance. Note that on the coax side of the choke, we run a s hort lead to a ground rod from the coax braid. The lead should be as short as feasible and the rod as long as possible. Finally, we connect our parallel feedline to the antenna side of our 1:1 choke.

In this configuration, we use our single-end tuner in the mode for which the design is most apt. We do not transform any low impedances down any further. The system will have losses. The high SWR on the coax run becomes lossier the higher we go in frequency and the longer we make the run. Hence, keeping the run very short and using very low loss coax are essential. The choke will also suffer some losses, depending on the SWR value we see there. However, the system has proven more effective in many instances than using the 4:1 balun inside the tuner. As well, because the parallel line is wholly outdoors, the system has freed many ham shacks of troublesome RF indoors. The system is not perfect, but is has proven over the last 20 years to be reasonably effective.