Antennas

a monthly feature by
KARL T. THURBER, JR., W8FX

DESIGN, CONSTRUCTION, FACT, AND EVEN SOME FICTION

Antenna Accessories for the Hamshack: Part III

Last month our columnist continued his series on antenna accessories with a discussion of the wattmeter and the s.w.r. bridge. This time, the spotlight is on two other in-line devices: the r.f. transformer and the balun.

To date in this series on r.f. antenna accessories, we have examined a number of useful devices. These have included the dummy load, the r.f. wattmeter, and the s.w.r. bridge—all basic devices for proper transmitter tuneup and antenna adjustment. In this month's column, we will continue this discussion of in-line devices with a look at two other interesting devices: the r.f. transformer and balun. Let's first examine the r.f. transformer.

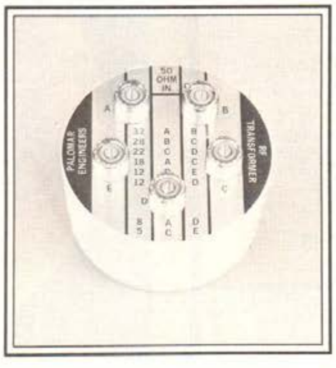
The R.F. Transformer

This versatile device is a relative newcomer to the hamshack. Its popularity has increased considerably since the development of low-loss r.f. ferrite materials and winding techniques which permit efficient and compact designs capable of handling respectable power levels. The set-and-forget device also requires no tuning other than initial impedance-tap selection.

The typical r.f. transformer for h.f. operation matches the nominal 50-ohm transmitter output to a half-dozen or more fixed impedances, usually ranging from about 32 ohms down to about 5 or 10 ohms, over the range 1.8 or 3.5 MHz to 30 MHz, depending upon the particular model. While the r.f. transformer cannot handle a range of complex impedances with anything near the flexibility of the transmatch, the device is excellent where a fixed impedance transformation ratio is required. And, while anything put between the transmitter and antenna will have some power loss, the better units can handle the task with efficiencies well over 90% to provide an s.w.r. of under 1.5:1 while requiring no tuning or adjustment other than initial setup.

One of the big uses for the r.f. transformer is in the matching of vertical antennas to coaxial feedline, important since verticals typically show a very low resistance. This is usually on the order of about 32 ohms for a quarter-wave verti-

*317 Popular Drive, Millbrook, AL 36054



Heavy-duty r.f. transformer shown here is capable of matching a 50 ohm source to 32, 28, 22, 18, 12, 8, or 5 ohms, depending on the specific tap selected. Power-handling capability is 2000 watts (6 kw PEP) over the range 1–30 MHz (1–10 MHz when working below 15 ohms). The unit has an r.f. ferrite core, teflon insulation, and sealed construction. (Photo courtesy Palomar Engineers)

cal with no reactance. To match such an antenna to the transmitter through standard 50 ohm coaxial cable is a fairly simple matter of connecting a suitable r.f. transformer at the base of the antenna and setting the impedance selection switch at 32 ohms, or at the closest available setting; if the antenna is exhibiting the proper characteristics, a near 1:1 match should be the result.

A shorter antenna will have a lower resistance and will exhibit capacitive reactance. For example, a 2/10-wavelength vertical will show a resistance on the order of 18 ohms, and a capacitive reactance that can be tuned out through the use of a loading coil. The short vertical is adjusted by first resonating the antenna with the loading coil installed, which should result in the antenna showing a base impedance of 18 ohms, resistive. The transformer tap or switch is then set at the nearest tap for a low-s.w.r. match to the transmission line to complete the match.

It's possible to make especially good use of the r.f. transformer with solid-state, broadband transmitters and transceivers, since you can generally eliminate the need for an antenna tuner or transmatch to compensate for antenna impedance variations. Thus, the number of antenna matching and loading knobs required to be adjusted when changing frequency is reduced.

Another important use for the r.f. transformer is in h.f. mobile operation, where it's often difficult to get the s.w.r. on the whip down to a tolerable level because of the very low base impedances usually encountered. Specialized, compact r.f. transformers are available that can help solve that problem by matching the low impedance of the loaded whip to the nominal 50 ohms required by most solid-state transceivers.

In mobile operation, the r.f. transformer is usually mounted as close as possible to the base of the whip in the trunk. Tuning is accomplished by first adjusting the loading coil or other resonating device to the desired frequency and observing the s.w.r. obtained on the transmission line. The r.f. transformer is then installed close to the base of the whip, and the transmitter is keyed at a low power level on each of the available tap or switch positions on the r.f. transformer. The setting that results in the lowest s.w.r. should be used; this should be recorded, as the tap setting would be expected to change when changing bands. Note that one should not "hot-switch" from one tap position or setting to the next with the transceiver putting forth r.f.—at the risk of serious damage to both transceiver and matching device.

While the r.f. transformer has been discussed primarily in terms of its use as a *step-down* device, most units may also be used to match a 50 ohm transmitter output to a *higher* antenna impedance by reversing the connections to the r.f. transformer. Used in this manner, the transmitter would be connected to the "antenna" or "output" connector, and the antenna would be connected to the "transmitter" or "input" connector.

For the purpose of illustration, using the tap settings of 50, 38, 28, 19, 12, 7, and 3 ohms available on the Swan/Cubic "MMBX" Matchbox, if the antenna impedance is known, the step-up impedance ratios in the table below may be used to determine the correct switch or tap position. For example, if the antenna impedance is 72 ohms, the ratio of 50:72 is 1:1.44. The available 1:1.3 ratio, which is obtained by placing the switch to the 38 ohm position, will provide the closest approximate impedance match. Of course, if the antenna impedance isn't known, then an s.w.r. meter should be used to determine the position on the r.f. transformer that produces the lowest s.w.r. Here's the table described above:

Step-Up Impedance Ratios

3 ohms	1:16
7 ohms	1:7.1
12 ohms	1:4
19 ohms	1:2.6
28 ohms	1:1.8
38 ohms	1:1.3
50 ohms	1:1

This example has only considered a transmitter output of 50 ohms. Most r.f. transformers can be used with any reasonable transmitter output impedance, since the device is simply a transformer with selectable turn ratios and can be used, as described above, to match antenna impedances that are higher or lower than the transmitter impedance. When used with transmitter outputs *other than* the nominal 50 ohms usually encountered, the ratios in the table below can be used to determine the switch/tap position for matching an antenna of lower impedance than the transmitter, again using Swan/Cubic ratios as examples.

Step-Down Impedance Ratios

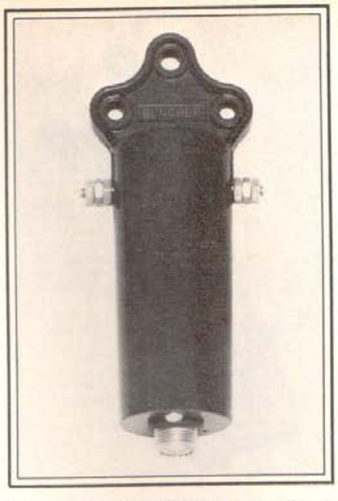
50 ohms	1:1
38 ohms	1.3:1
28 ohms	1.8:1
19 ohms	2.6:1
12 ohms	4:1
7 ohms	7.1:1
3 ohms	16:1

By the same token, an antenna of higher impedance than the transmitter may be matched to a transmitter of other than 50 ohms (such as 72 ohms) using the step-up ratios shown in the first table. For example, using this same unit, given a transmitter output of 72 ohms and an antenna impedance of 300 ohms, the desired step-up ratio is 1:4.16. By consulting the step-up table, we find that the best match is found by setting the tap at the 12 ohm position, since this provides a close enough 1:4 impedance step-up. Simple!

Many other impedance combinations can be obtained, and other uses can be found for these handy r.f. devices. However, they can't necessarily take the place of a good, wide-range transmatch, where flexibility is paramount, and they can't be expected to perform the specialized functions of the balun—which brings us to the next area of discussion.

The Balun

This device is closely related in function to both the transmatch and the r.f. transformer. The balun, derived from "balanced-to-unbalanced," is a special kind of matcher that transforms an unbalanced transmission line condition (one side at ground potential) to a balanced one (neither conductor at ground potential) in order to maintain overall system "balance" and reduce line radiation. Whereas coaxial cable is now the most commonly used transmission line, many amateurs prefer to use openwire or twinlead lines; both of these are considered to be "balanced." Mounted at the transmitter, the balun allows the coaxial output, standard on most transmitters and transceivers, to be adapted to these balanced lines. The balun can also be mounted at the antenna itself to enable coaxial feedline to be effectively coupled to inherently balanced antennas, such as dipoles and most beams.



Bencher balun shown here is "pull tested" at 600 lbs. of antenna load, is rated at 5 kw peak power, and is fabricated of insulated, heavy-gauge, solid copper wire with an interwinding insulation of greater than 6000 volts. A ferrite core is not used in this design, which is said to be free of problems of saturation and loss at higher frequencies. Two models are available: the ZA-1, which is designed for 3.5–30 MHz operation, and the SA-2, which is optimized for 14–30 MHz and which includes stainless steel and aluminum hardware for a 2-inch boom. (Photo courtesy Bencher, Inc.)

The simplest balun is the "1:1" kind—that is, one that has the same impedance at its input side as that at its output side; there is no transformer action (step-up or step-down) involved. On the other hand, the popular "4:1" balun is *also* a transformer: it is used both as a step-down device, as well as a means of converting balance conditions. The former type of balun is usually used to feed simple dipoles and beam antennas with coaxial cable, while the latter is frequently used to feed antennas such as folded dipoles and quads. Several transmatch designs include built-in baluns for direct feeding of openwire or twinlead transmission lines—more on this later.

The term "balun" actually describes a *class* of balancing devices all having the purpose of maintaining symmetry or balance in the antenna and feeder system and detuning or decoupling the line for "antenna" currents in order to reduce or eliminate unwanted feedline radiation. Several forms of linear (transmission-line section) balun using metal sleeves or actual line sections have been developed to prevent unbalanced currents from flowing on the outside of the transmission line when a coaxial feeder is used in connection with an inherently balanced antenna, such as a dipole. One such classic arrangement is the *bazooka*, which makes use of an electrical quarter-wavelength sleeve installed over the coaxial transmission line at the antenna. While decoupling the antenna from the transmission line, this device has no effect on the impedance relationships between the antenna and the coaxial line. Another popular design is the half-wave phasing section, used to couple between an unbalanced and balanced circuit when a 4:1 impedance ratio is required. Other variations are possible.[1]

Linear baluns are cumbersome and are not well-suited to multiband operation. More convenient are **coil and toroidal baluns.** The **coil balun** is, in effect, a variation of the linear balun in which the transmission line is wound into coils. Actually, a definite line length is necessary only for purposes of decoupling (the length of line in each coil should be about equal to a quarter-wavelength at the lowest frequency to be used). As long as there is sufficient decoupling, the system will serve as a 4:1 ratio impedance transformer regardless of line length. With each line wound into a coil, the inductances formed will act as chokes to isolate the "balanced" end from any ground connection that is placed on the "unbalanced" end. This type of balun will operate over a wide range of frequencies, since choke inductances are not critical.

Most air-wound baluns are rather bulky when designed for operation in the popular h.f. ranges of 1.8 to 30 MHz and don't lend themselves well to outdoor use. More compact baluns can be constructed by using **toroidal ferrite core** material as a foundation for bifilar-wound coil balun transformers. It's a fairly simple matter to design the toroidal balun with various impedance-transformation ratios so that the balun can effectively do double-duty as a precision transformer as well as a balance transformation device. Baluns having 1:1 and 4:1 ratios are the most common ones, being used either for adapting 50 or 75 ohm transmission lines to feed dipoles or allowing these lines to feed 300 ohm folded dipoles and similar balanced antennas. Popular commercially available ratios also include 1.5:1, 2:1, 3:1, 5:1, 6:1, 7.5:1, 9:1, 12:1, and

[1] *Various balun construction details are provided in the ARRL* Handbook *on pp. 19-6 through 19-9 in the 1981 edition.*