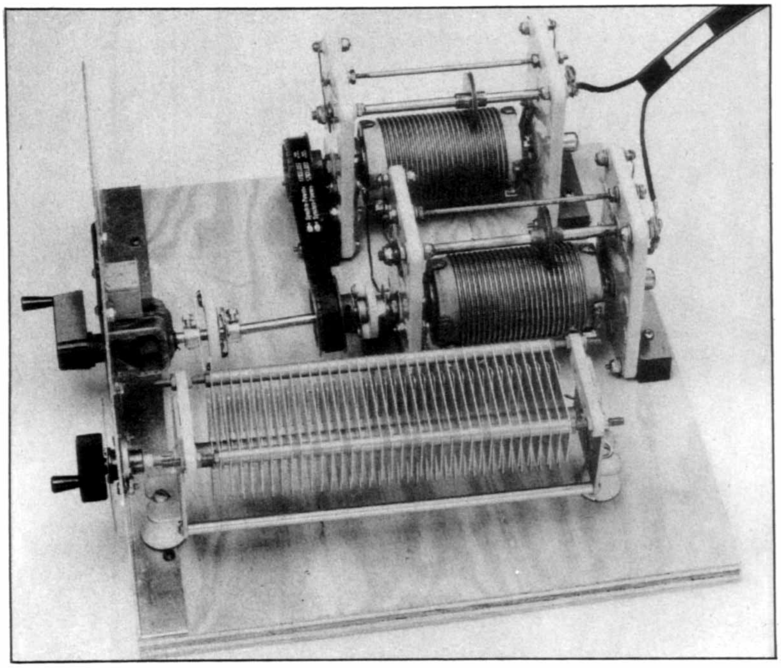
A *Balanced* Balanced Antenna Tuner



Are you using the right antenna tuner for the job? If you use a balanced, open-wire-fed antenna, the versatile balanced **L** network is *the* circuit for you!

By Richard L. Measures, AG6K
6455 La Cumbre Rd
Somis, CA 93066

Antenna tuners are like shovels. It takes more than one kind of shovel to perform a variety of jobs efficiently. For example, a snow shovel isn't suitable for digging holes in hard ground. A tiling spade could be used to shovel snow, but it wouldn't be very efficient. Similarly, no single antenna tuner circuit can do every antenna-matching job extremely well.

A balanced-load tuner should be designed—from the ground up—for the job that it is intended to perform. This article describes a circuit that does a superb job of feeding an open-wire transmission line (ladder line). It cannot be used for unbalanced loads such as a coaxial transmission line or for end-fed Marconi or Hertz antennas.

Now that we have nine Amateur Radio bands below 30 MHz, an open-wire line, center-fed-wire antenna system looks even more attractive than it did when such antennas first came into popular use in the 1930s. (In those days, we had only five bands below 30 MHz.) Taking advantage of this versatile antenna system requires a box that will interface the 50-Ω unbalanced output of today's transceivers to the highly variable impedance (Z) of the balanced feed points of multiband antennas.

Many makers of antenna tuners claim that their circuits can operate into an unbalanced load, or a balanced load, such as ladder line. Actually, most of the contemporary "matches everything, balanced or unbalanced" antenna-tuner circuits produce a semi-balanced output when used with a balanced load. Although the antenna will radiate in this situation, a semi-balanced output is like having a semi-balanced checking account: It is less than wonderful.

A look at the schematics for the contemporary "matches-everything" antenna-tuner circuits reveals that they are usually unbalanced, high-pass-filter-characteristic, **T** networks with balancing devices hooked to their unbalanced outputs. This is a compromise design which, not surprisingly, has compromise performance when used with a balanced load.

The imbalance in these "balanced" tuners can be easily confirmed with an RF voltmeter or RF ammeter(s). The actual current or voltage at each output terminal is progressively more imbalanced above about 7 MHz. At 28 MHz, it is not uncommon to have 50% more current or voltage in one of the legs than in the other leg.

Some may ask, "Why not use the same balanced tuner design that was in vogue in the 1930s?" As many old-timers know, the 1930s-era balanced tuner consisted of a resonant (or near-resonant), center-link-coupled tank circuit with movable taps on the secondary. For each band change, the taps had to be moved and reoptimized, the total inductance changed and the tuning capacitor retuned. Changing bands was labor-intensive! These tuners were seldom built in enclosures, because near-constant access to the taps and the inductor(s) was a necessity for changing frequency. It was a common practice to build these tuners on a breadboard for maximum accessibility.

In the 1950s, the E. F. Johnson Company marketed its Matchbox® series of balanced antenna tuners. These tuners used the same center-link-coupling arrangement as the earlier tuners, but they eliminated the movable-tap arrangement by using a double-differential capacitive voltage divider across the tank inductor. (A differential capacitor is the RF equivalent of a potentiometer dc-voltage divider.) This allowed the operator to increase and decrease the voltage fed to the antenna electrically, without changing taps. The Johnson circuit worked, but the Z-matching range was severely limited. Frequently, the SWR could not be reduced to a satisfactorily low level.

The balanced tuner described in this article has two front-panel adjustments, an optional high-Z/low-Z switch, and no adjustable taps. It uses the rarely seen, balanced version of the familiar, unbalanced **L** network. Changing bands is a piece of cake with this tuner, and the matching range can be made very wide by using enough L and C to handle the job.

The Trouble with Baluns

On paper, an unbalanced tuner, feeding a balun, connected to a ladder-line-fed antenna should work well. In practice, it does not work well. The reason for this lies in the balun.

As a rule of thumb, a balun should have about four times as many reactive ohms as there are resistive ohms in the load. This means that, for use with a 600-Ω balanced load, the balun should have a secondary-winding reactance of about 2.4 kΩ. For 80-meter operation, this works out to be more than 100 μH of balun inductance! To create this much inductance on an appropriate MF/HF-rated (μ = 40) ferrite core, an impractically large number of turns of wire would be required.

The use of a balun in high-impedance (particularly highly reactive) circuits inevitably creates two very sticky problems:

More turns mean more ampere-turns of magnetic flux in the balun's core, and high magnetic flux densities can cause ferrite cores to saturate. This distorts the RF waveform and creates harmonics that extend well into the UHF range. The remaining problem with using many turns of wire is that doing so increases the winding capacitance of the balun. The high capacitance of the winding creates unwanted reactance and/or balun imbalance. This is especially true with the commonly used 4:1 bifilar-wound balun, which does not have an evenly distributed winding capacitance like the trifilar-wound balun. When enough turns are placed on the 4:1 bifilar balun for satisfactory 80-meter operation, the inherent capacitive imbalance in the balun causes a progressively greater imbalance in the balun's output voltage as the operating frequency increases. This imbalance causes a differential RF current to flow through the ground wire on the tuner. The term *4:1 balun,* as it is applied to most commercial products, is a misnomer. These devices are much better suited for broadband, unbalanced-to-unbalanced 4:1 transformer service, such as that needed in the input circuit for a grid-driven, class-AB_1 amplifier with a grid-terminating resistance of 200 Ω.

There is a problem with a substantial current flowing in the ground wire on any tuner: Since *all* conductors, no matter how wide, have inductive reactance, the RF current that flows through the ground wire or strap can develop a large RF voltage on the tuner end of the ground wire.[1] With 1 kW on 21, 24 or 28 MHz, the RF voltage on the "matches-everything" tuner chassis can brilliantly light a neon lamp, make sparks with a graphite pencil and burn fingers!

The 1:1 trifilar-wound balun solves the capacitive-imbalance problem of the 4:1 balun. Unfortunately, it does *not* solve the problem of high capacitance in the windings themselves. And, more importantly, it does not solve the problem of core saturation resulting from the high magnetic-flux density created by the large number of turns required for any high-impedance balun.

The bottom line: High-impedance baluns are a very likely source of *grief*, no matter how carefully they are engineered and constructed.

All of these problems are easily avoided. The solution is simple: Don't put the balun in the highest-impedance part of the circuit. Instead, put the balun in the lowest-impedance part of the circuit (in most cases, the lowest-impedance part of the circuit is the 50-Ω coax input to the antenna tuner), and build a balanced **L**-network tuner for the balanced output of the low-impedance balun.

So, why have we been putting the balun in the wrong part of the circuit for all these years? Good question!

An Inexpensive, High-Performance, Ugly, 50-Ω Balun

Building a no-grief 1.8- to 30-MHz 50-Ω balun is easy. No costly ferrite cores are needed, just a short length of 3- to 5-inch plastic pipe, about 30 feet of 50-Ω coax, and some nylon cable ties. Solid-dielectric coax is best for this application, because the center conductor of foam-dielectric coax has a tendency to migrate through the dielectric over a period of time if such cable is bent too sharply. This can result in dielectric breakdown.

The required length of the plastic pipe depends on the diameter and length of the coax used and the diameter of the pipe. For RG-213 coax, about one foot of 5-inch pipe is needed for a 1.8- to 30-MHz balun.[2,3] For 3.5- to 30-MHz coverage, about 18 to 20 feet of coax is needed. The number of turns is not critical, because the inductance depends more on the length of the coax than on the number of turns, which varies with the pipe diameter.

The coax is close-wound in a single layer

Calculating the Series and Shunt Reactances

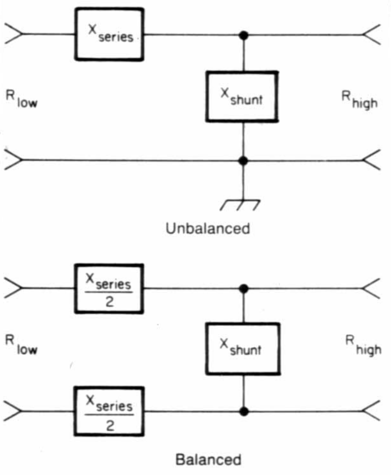
The equations for calculating the total series reactance (X_{series}—in $\pm j$ Ω) and the shunt reactance (X_{shunt}—in $\pm j$ Ω) in a balanced **L** network are shown in Fig A. These ohmic values can be converted into values of capacitance and inductance for a specific frequency by using the two equations at the bottom of Fig A. Note that, for a balanced **L** network, the series reactance must be divided into two equal parts, and the shunt reactance must be completely isolated from ground.

The reactance equations give exact values only for nonreactive (purely resistive) loads. If the reactances of the **L** network are adjustable, a wide range of load reactances can be canceled by adjusting the **L** network to create an equal and opposite reactance. This is accomplished by applying a small amount of RF to the tuner and adjusting the **L** network for zero reflected power.

The shunt and series reactances that are found with the equations can be either inductive or capacitive, but they must always be opposites for resistive loads. If a high-pass-filter characteristic is desired, as is frequently the case on 160 meters (where strong local broadcast stations would otherwise cause receiver overload), the series reactance is capacitive and the shunt reactance is inductive.

If an **L** network is to be used on just one band, only one of the two reactances usually needs to be variable in order to obtain a low SWR over the entire band. A good use for this technique is with a half-wave antenna for the 160- or 80-meter bands. This antenna would otherwise have a low SWR at the middle of the band and a high SWR at the band edges (assuming that the antenna is tuned to resonate at midband). With a single-variable-component, **L**-network tuner, the SWR can be reduced to less than 1.1:1 at the band edges. (Of course, if both components are variable, the SWR need not exceed 1:1.)

If a band-pass filter characteristic is needed for a specific single-band operation, a high-pass **L** network can be coupled to a low-pass **L** network, and each network should be designed to contribute about half of the total resistance transformation. This way, only one of the two-stage **L** network's four reactances usually needs to be variable to allow coverage of the entire band with a low SWR. I use this circuit in a 160-meter tuner. It keeps the local broadcast stations from overloading my receiver, and it attenuates the second harmonic of my 160-meter signal to −63 dBc.



$$X_{series} = \pm j \sqrt{([R_{low}\,R_{high}] - R_{low}^2)}$$

$$X_{shunt} = \pm j \frac{R_{low}\,R_{high}}{X_{series}}$$

$$L = X_L \div 2\pi f \qquad C = 1 \div (X_C 2\pi f)$$

Fig A—Unbalanced and balanced L-network configurations, and equations for matching resistive loads using L networks.

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[1] Notes appear on p 32.

on the plastic pipe. The first and last turns of the coax are secured to the plastic pipe with nylon cable ties passed through small holes drilled in the plastic pipe. The coil winding must not be placed against a conductor. This simple-but-effective device is called a *choke balun.*[4]

Some people build choke baluns, without a plastic coil form, by scramble-winding the coax into a coil and taping it together. The problem with scramble winding is that the first and last turns of the coax may touch each other, which creates two complications: The distributed capacitance of the balun is increased, and the RF-lossy vinyl jacket of the coax is subjected to a high RF voltage. The single-layer-winding-on-a-plastic-coil-form construction method solves these problems by dividing the RF voltage and capacitance evenly across each turn of the balun.

A more compact, less ugly, 1:1, 50-Ω, trifilar-wound (with wire) ferrite-core balun could also be used, but there are some trade-offs. Ferrite cores are not as cheap as plastic pipe. Also, the air core of the coax balun can't saturate like the ferrite core and, unlike ferrite-core wire-wound baluns, single-layer coax baluns almost never have insulation-breakdown problems. Also, trifilar-wound baluns do not like to work into anything but perfectly balanced loads. With an unbalanced load, the coax balun—unlike the trifilar balun—does not generate a differential RF current on the outside of the coax that brings the RF to the input of the tuner. The choke balun is not fussy; it works as well into a less-than-perfectly balanced load as it does into a perfectly balanced load, and does so without the possibility of creating a differential RF current on the station ground that can fricassee the operator's fingers!

The Versatile L Network

The L network is *the* basic RF-impedance-transformation tool. It is also used to build high-pass, low-pass and band-pass filters. The unbalanced L network forms the basis for all of the antenna tuners that are currently being sold. All contemporary high-power MF/HF tube amplifiers use two or more L networks in series to match the high anode (plate) impedance of the amplifier tube to the low resistance of the coaxial output. Most amplifiers use two L networks in series, which is more commonly known as a pi (π) network. A few amplifiers use three L networks in series, which is called a π-L network. So-called no-tune/broadband amplifiers may use five or more fixed L networks in series for each band-switch position. More L networks means more harmonic suppression in the amplifier output. The complex-appearing Butterworth and Chebyshev filters are nothing more than a series of basic L networks.

When used for matching resistive loads, an L network consists of one capacitor and one inductor. When the L network is used for matching loads that contain both resistance and reactance ($R \pm jX = Z$), the reactance of the load may partially—or sometimes completely—replace one of the reactances in the L network. Thus, in rare cases, it is possible to build an L network with only one component, but only for a specific frequency and load impedance. In some situations, canceling the load reactance requires the use of a larger reactive component in the L network. In more extreme situations, the load may be so reactive that the L network must be made from two capacitors or two inductors!

There are four ways to connect the capacitor and the inductor in an L network. See Fig 1A. When inductance is used for the series reactance and capacitance is used for the shunt reactance, the L network acts as a low-pass filter as well as an impedance-matching device. When capacitance is used for the series reactance and inductance is used for the shunt reactance, the L network acts as a high-pass filter and an impedance-transformation device.

The resistance-matching range of the L network is remarkably wide. It can match 50 Ω to a 1-Ω or a 10-kΩ load with ease and good efficiency, provided that a reasonably high-Q inductor is used.

When the L network is used for stepping up the input impedance, the shunt reactance is placed across the load. For stepping down the input impedance, the shunt reactance is placed across the source (the input of the L network). Put another way, the shunt reactance is always connected across the highest-impedance side of the L network. This means that, for a 50-Ω input, wide-range tuner that will match loads of more than 50 Ω and less than 50 Ω, a step-up/step-down impedance switch must be provided so that the shunt reactance can be switched between the input and output sides of the tuner. The same result could be accomplished by reversing the input and output connections; the switch saves time.

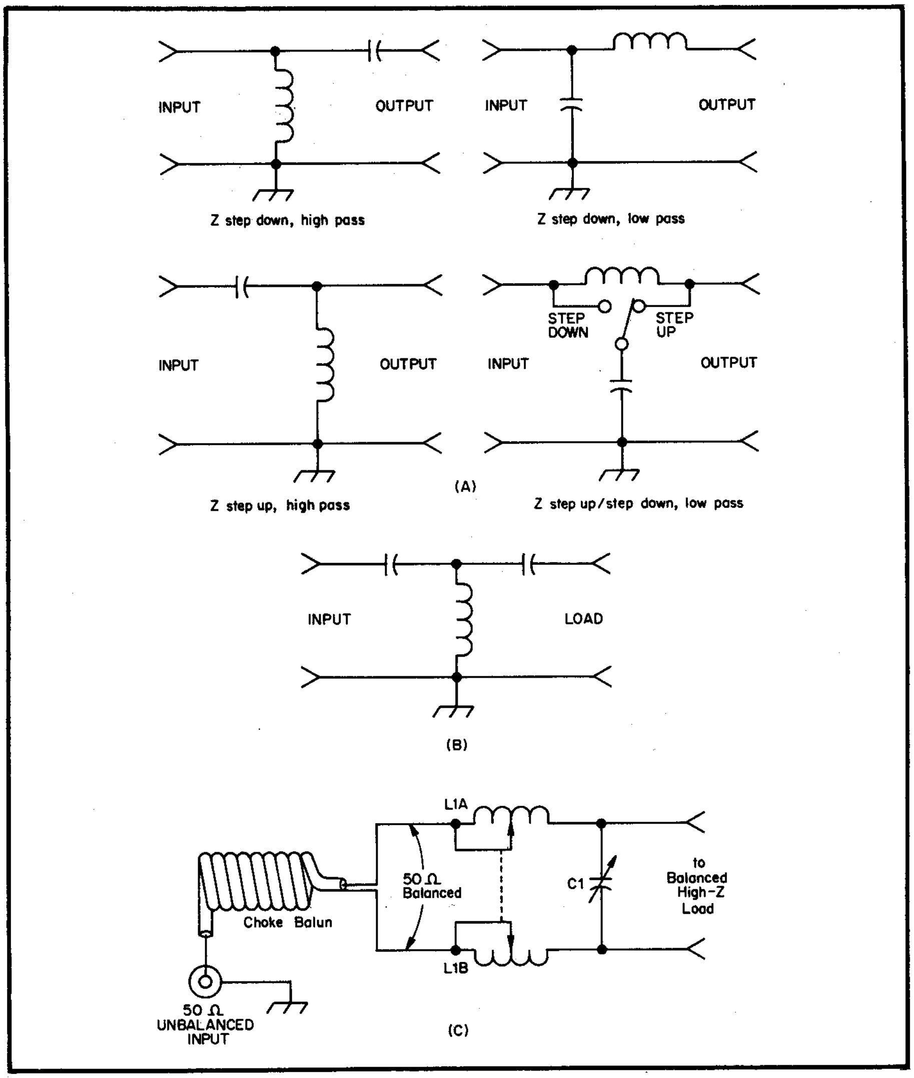

Fig 1—At A, the four basic L-network configurations. At B, the unbalanced-T network. At C, the balanced L network, fed by a choke balun made of coaxial cable wound on a plastic-pipe form.

The **T** network eliminates the need for the step-up/step-down switch. Ac circuit analysis shows that, for every R-X series circuit, there is an equivalent R-X parallel circuit. (Of course, this also works in reverse.)

See Fig 1B. An additional capacitor is placed in series with the load of a resistance-step-up **L** network that will not normally match a load resistance lower than the input resistance (usually 50 Ω). If the added series capacitor or inductor is adjusted so that it has a sufficiently high reactance, the resistive component of the series load's parallel-equivalent circuit will be above 50 Ω, and the step-up **L** network will be able to match the load.

For example, given: An impedance-step-up, series-L/shunt-C (low-pass-filter characteristic) **L** network that will only match load resistances that are greater than 50 Ω is connected to a 1-Ω load. Problem: Obtain a Z match.

One solution is to add a $+j10$-Ω (inductive) reactance in series with the 1-Ω load ($Z = 1 + j10$ Ω) This series R-X circuit is electrically equivalent to a circuit consisting of a 101-Ω resistor in parallel with an inductor whose reactance is $+j10.1$ Ω. Because a load resistance of 101 Ω is above 50 Ω, a match could be achieved if $-j10.1$ Ω is added to the L-network's shunt capacitor in order to cancel the parallel-equivalent circuit's $+j10.1$ Ω reactance. (Adding more capacitive reactance with a variable capacitor is easy: Simply adjust the capacitance to a lower value.)

The Balanced L Network

The **L** networks shown in Fig 1A and 1B will only work with an unbalanced input and an unbalanced load. A balanced **L** network must be used for a balanced load. The balanced **L** network is similar to an unbalanced **L** network; the difference is that the balanced **L** network's series reactance is divided into two equal parts, and both ends of the shunt reactance must be above ground. See Fig 1C. The balanced **L** network must be fed from a balanced source (such as the output of a choke balun, fed by an unbalanced transmitter).

Mechanical Considerations for Balanced L Networks

The tuning shafts of the variable inductors and the variable capacitor are hot with RF, and must be insulated from each other and from the outside world. Also, the insulated frame of the variable capacitor should be kept well away from any grounded surface. This requirement is much easier to meet if the balanced tuner is built in a wooden box, instead of in a metal box. The (RF-hot) frame of a single section variable capacitor should be elevated on standoff insulators. This helps to keep the circuit capacitively balanced.

If a split-stator variable capacitor is used, it won't be necessary to insulate its tuning shaft for high-voltage RF, or to keep the capacitor well away from ground. Use an insulated tuning knob with a well-recessed setscrew (instead of an all-metal tuning knob). This should keep you from being bitten by RF if the split-stator capacitor proves to be less-than-perfectly balanced.

The variable inductors must have equal inductances and be driven in synchronization by one tuning shaft. It is possible to end-couple the two variable inductors with an insulated coupling that can handle minor axial shaft misalignment, but this does not result in good electrical symmetry or optimum inductive decoupling between the two variable inductors unless a shaft extension is used. Good symmetry is probably a moot point for 80-meter operation, but it is a consideration on the higher-frequency bands. If you decide to use end-to-end coupling, use 1/4-inch polyethylene tubing for the coupler. It is a very tight fit over 1/4-inch shafts, and it can be held in place with 5/16-inch flat spring clamps. This tubing is available in stores that carry drip-irrigation materials, and is ideal for end-coupling RF components.

Another method of coupling the variable inductors is to use a 3/8-inch plastic timing belt and two plastic pulleys (like those used in xerographic copiers). This allows the variable inductors to be placed side by side, spaced at least two coil diameters apart (to avoid mutual coupling), resulting in better layout symmetry. A pulley-and-belt system can be used to drive the inductors. Pulleys (available with matching belts from Small Parts—see the section called "Parts"), come in two varieties: single flange and dual flange. Using these pulleys, the pulley/belt system operates like those used in many overhead-cam automobile engines: The belts have protruding rectangular blocks, positioned perpendicular to the belt axis, that are spaced to match corresponding notches on the pulleys. One single-flange and one dual-flange pulley should be used so that the belt cannot slip off, and so that the belt can be changed and adjusted without requiring dismounting of either one of the pulleys or one of the variable inductors from the chassis. Small flats can be ground into the variable inductor's tuning shafts so that the pulley's setscrews will stay put.

The ends of variable inductors that have a coil-end contact that is electrically connected to their tuning shafts should be connected to the lower-voltage (input) side of the balanced tuner. This minimizes the RF-voltage stress on the insulated parts that synchronize and drive the variable inductors. The roller contact must be shorted across the unused turns of the inductor to the low-voltage end of the variable inductor. This stops the Tesla-coil-transformer effect, which can cause spectacular RF arcing at some inductor settings. The wider-pitch ends of variable-pitch, variable inductors is placed at the higher-voltage (output) side of the tuner.

Sometimes it is more convenient to put a balanced **L**-network tuner in a remote location so that the ladder line does not need to be brought through the wall of the house. A simplified diagram of a remote-controlled, permanent-magnet reversible dc-motor-driven tuner is shown in Fig 2. This simplified diagram does not show the detailed wiring of the control cable and the remote indicator/control box/power supply.

Limitations

The balanced **L** network, as illustrated, is designed to work with balanced (or nearly balanced) loads that have a resistance greater than 50 Ω. The vast majority of open-wire-line-fed antennas fit into this category. Rarely, open-wire-fed antennas have resistances of less than 50 Ω. (This is the case with a half-wavelength dipole, less than ¼ λ above ground, fed with a transmission line that contains an even number of quarter wavelengths.) If a load resistance of less than 50 Ω is to be successfully matched, the variable capacitor must be switched to the input side of the variable inductors, or, as in a **T** network, a matched pair of appropriate reactances can be inserted in series with the load to obtain a match.

Because the impedance at the bottom of a ladder-line-fed multiband antenna can be almost anything imaginable, it is prudent to include a DPDT step-up/step-down impedance switch in the design of a balanced **L**-network antenna tuner, as mentioned earlier.

Selecting a Suitable Peak-Voltage Rating for the Capacitor

The peak RF voltage that appears across the capacitor varies widely depending on the feed-line impedance and the power level used. The voltage can be calculated if the impedance and power at the feed point are known. The formula for calculating this is $E = \sqrt{(P \times Z)}$. Because P is measured in RMS watts, the ac voltage (E) is in RMS volts, which can be converted to peak volts (e) by multiplying the result by $\sqrt{2}$. For example, if $Z = 600\ \Omega$ and $P = 1500$ W, $e = \sqrt{(1500\text{ W} \times 600\ \Omega)} \times \sqrt{2} = 1341$ V peak.[5] Capacitors rated at least 1.5 kV should handle just about all matching requirements in this circuit.

When using a vacuum-variable capacitor, it is important to realize that the maximum-RF-voltage rating at 30 MHz is usually 60% of the rated dc/60-Hz peak-voltage rating. Thus, a 5-kV-dc/60-Hz rating is equivalent to a 3-kV-peak *RF* rating.[6] Used or new-surplus vacuum-variable capacitors should be tested before use, because they may have developed air leaks that render them useless.

Parts

In this circuit, as in any other antenna tuner, component-value selection is depen-

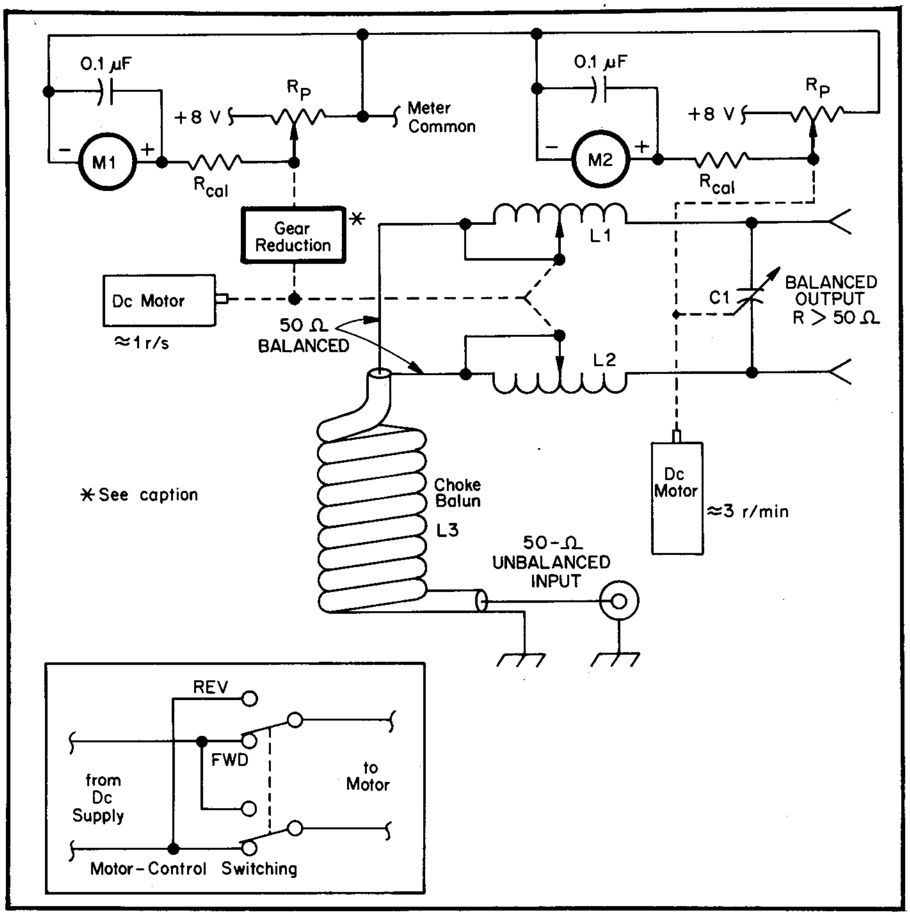

Fig 2—Schematic of a basic remote-control scheme for the balanced antenna tuner. A control cable with at least seven conductors is required for this arrangement; the meter-common and motor-common leads *must not* be connected together. Conductors are needed for: (1) approximately +8 V, regulated; (2) meter common; (3) motor common; (4) capacitor-drive motor; (5) inductor-drive motor; (6) capacitor-position-indicator meter; (7) inductor-position-indicator meter. Each motor is controlled by a DPDT momentary-contact toggle switch (see inset). If the tuner is to be used for loads of less than 50 Ω, a relay and additional control lines must be added to the circuit to switch the variable capacitor from the output to the input side of the L network.

Parts List

M1, M2—Position-indicator meters. 100 µA to 100 mA full scale, placed at operating position and fed through control cable to tuner.

R_p—Resolving potentiometer. 1- to 10-kΩ, single-turn linear-taper type. Some ordinary, 270° potentiometers work for this application if the internal stops are removed. A multiturn potentiometer can be used for the inductor-position-resolving potentiometer, eliminating the need for the gear-reduction scheme required to drive a single-turn resolving potentiometer from the variable-inductor drive motor.

R_{cal}—5- to 75-kΩ, ¼-W potentiometer. Adjust these for full-scale readings on M1 and M2 when the inductors and capacitor are set for maximum inductance and capacitance, respectively.

Motors—Permanent-magnet dc gear motors, one 3 r/min (for driving the capacitor), one 1 r/s (for driving the inductors).

dent on the load-impedance range over which the circuit is expected to provide a transformation from a 50-Ω unbalanced input. For matching a 600-Ω nonreactive load at 1.8 MHz in this circuit, the variable capacitor should be at least 488 pF. In general, the capacitor should have a peak rating of at least 1.5 kV, and the variable inductors should be wound with wire no smaller than no. 12 AWG for good efficiency.[7]

Maintenance note: Variable-inductor roller bars and other sliding-RF-contact surfaces should be routinely wiped clean with a lint-free cloth and then lubricated, about once a year. A suitable lubricant is GC Electronics Tunerlub, catalog no. 26-01. This material must be applied *thinly* (more is *not* better) with a lint-free cloth.

Miniature timing belts and pulleys are available from Small Parts, Inc, 6901 NE Third Ave, PO Box 381736, Miami, FL 33238-1736. To obtain a catalog, call 305-751-0856.

Acknowledgment

Kudos to Charlie Michaels, W7XC, who provided valuable input during the editing of this article. If you would like to discuss this or any of my articles with me, call me at 805-482-3034.

Notes

[1] For example, a 1-foot-wide × ≈7-foot-long silver strap connected to a 10-acre, salt-marsh ground looks like a ≈¼-λ *RF choke* at 28 MHz!

[2] Although PVC pipe works in this relatively low-voltage application, ABS pipe is better suited to this purpose, because ABS has much less RF loss than PVC.

[3] The specified size of plastic pipe is an approximate inside-diameter (ID) measurement. For example, schedule-80 pipe has an outer diameter (OD) about ½ inch larger than the specified pipe size.

[4] If the choke balun will be exposed to ultraviolet light, it is important to use black cable ties. Natural nylon (translucent) cable ties deteriorate quickly when exposed to sunlight.

[5] The PEP power measurement is an instantaneous, RMS measurement—not a peak-power measurement. The peak power of a sinusoidal wave is *twice* its RMS power. True peak-power measurements are seldom used in the Amateur Radio world, even though such measurements are necessary for calculating the peak-voltage ratings of components, such as the L network's capacitor.

[6] See R. Measures, "High-Voltage Breakdown Tester," *QEX*, Aug 1988, p 5, for a vacuum-variable-capacitor testing procedure.

[7] A source of variable capacitors and inductors is Cardwell Condenser Corp (Johnson Capacitor Division [capacitors], Multronics Division [inductors]), 80 E. Montauk Hwy, Lindenhurst, NY 11757, tel 516-957-7200. Call for a catalog. Cardwell manufactures the former E. F. Johnson line of 5-A (229 series) and 10-A (226 series) variable inductors. Their part number for an 18-µH, 5-A variable inductor is 229-202-1 @ $56.95 each. These inductors are suitable for matching nonreactive loads of up to 3 kΩ at 1.8 MHz, 6 kΩ at 3.5 MHz, and so on. The 28-µH version is part no. 229-203-1 @ $62.21 each. These inductors can be used to match nonreactive loads of up to 6 kΩ at 1.8 MHz, 12 kΩ at 3.5 MHz, etc. (Cardwell-Multronics part numbers for these inductors are the same as E. F. Johnson's). Cardwell takes Visa® and MasterCard® telephone orders. Cardwell's capacitor line includes 1.5-kV (type L) variables, such as their part no. 167-3-1, a 5.2- to 75-pF unit. Another source for variable inductors is Fair Radio Sales, Box 1105, Lima, OH 45802, tel 419-223-2196. They have carried used-surplus, 5-A, 14.35-µH units for $24, part no. 339/L44-MED. Fair Radio also carries variable capacitors and a ceramic HV RF switch that is capable of switching the variable capacitor on the balanced L network between the load side of the circuit and the input side of the circuit. The part number of this switch is 3Z9626, and the current price is $2.50.

Strays

I would like to get in touch with...

☐ any hams who are DJs, commercial broadcasters, or other professional on-the-air personalities. Bruce Brady, KA9SOX, 311 SW Maynard Rd, Cary, NC 27511.

☐ anyone with information on an external, home-brew SSB filter for a Yaesu 747. Andy Birkhead, KB9CAT, 6681 Eagle Potine Dr South 2B, Indianapolis, IN 46254.

☐ anyone who has information about modifying a Motorola model MT-800 handheld transceiver to operate on any ham bands. Dave Mann, VP2EHF, The Valley, Anguilla Island, British West Indies.