random-length antenna couplers

Solutions to the antenna-matching problem using proven switching circuits

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With a few basic components you can build an antenna coupler that will couple a transmitter to almost any antenna length on any band. The key to this coupler is to use all the possible interconnections between the coupler components.

When using a random-length wire for an antenna, either in a portable or fixed station, the usual procedure is to build a pi-network coupler to match the antenna to a transmission line or transmitter designed to work into a fixed antenna impedance (usually 50-70 ohms).

The pi-network is capable of matching a wide range of impedances, including some reactive antenna loads, to a fixed-impedance transmission line or transmitter—once the proper component values for the network are determined. However, it's not always the most economical or efficient circuit, especially if a random length of wire is used on several amateur bands. Also, if the antenna wire length changes drastically, as in portable operation with unpredictable geographical restraints, the fixed pi-network can require considerable readjustment before proper antenna tuning results.

The problem is that one often tries to put too much flexibility into a circuit using components of a fixed (finite) value. Changing component values beyond their normal variable range is impractical. Therefore, the only other solution is to alter the circuit for greater matching flexibility.

This article explores the range of coupling circuits using up to three components (two capacitors and one coil or two coils and one capacitor). The variety of possible circuits will surprise those used to the familiar pi-network as being the only useful three-component matching network.

These circuits are presented as impedance-matching devices only. They vary greatly in their ability to attenuate harmonics (the pi-network ranks high in this category). However, assuming you have a reasonably harmonic-clean transmitter and are concerned only with coupling for maximum power transfer to a random-length antenna, many of the circuits should be very useful.

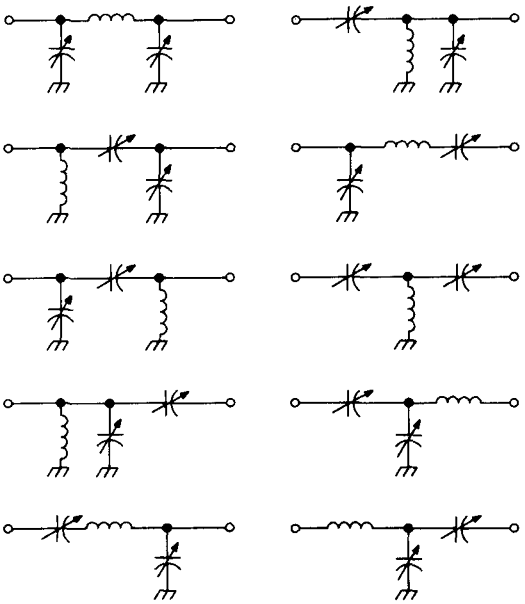

fig. 1. Matching networks that use one inductor and two capacitors.

circuits containing a single inductor

Fig. 1 shows circuits using a single inductor and two capacitors. Notice that some are simply others "turned around." They should not be disregarded, however, because either an impedance step-up or step-down between antenna and transmitter or vice-versa may be necessary. Each circuit represents a specific matching network possibility.

The range of reactive impedances a circuit can match depends on frequency and the range of the variable components. Often it will be found that more than one circuit will easily match the same antenna load to a transmitter. Deciding on the best circuit is covered later.

multicircuit switching

An antenna coupler can be built with sufficient switching capabilities to use all ten of the possible combinations shown in **fig. 1.** All circuits except one can be constructed with one side of one of the variable capacitors connected to ground. This greatly simplifies construction since only one "floating" variable capacitor is required.

Fig. 2 shows a circuit that allows switching for 9 of the 10 circuits shown in **fig. 2.** Practical component values for a typical 80-10 meter coupler are also noted on the diagram. The switch has only 5 positions; the other coupler circuits are formed by reversing the coupler connections. Thus, for each switch position, the coupler has to be tried both forward and reversed. An internal reversing switch would probably be worthwhile for portable use where the antenna length or band is frequently changed.

component ratings

The voltage rating of the capacitors, switch insulation, and coil depend a great deal on the use to which the coupler will be put. Transmitter power level and the range of antenna reactances are significant. The components in **fig. 2** should work well with a 100-150 watt transmitter with almost any antenna length. For higher power, capacitors with larger spacing and a heavy coil will be necessary if very short antennas are to be matched without arcing. The cost of such a coupler, unless surplus components are used, can be very high for transmitters having more than a few hundred watts output. It might be better in this case to use a loaded antenna.

construction

The construction of the coupler entails no particular precautions. Since harmonic attenuation is not a consideration, the coupler can be installed in a plastic container. This immediately solves the problem of ground-floating variable capacitors. The switch should be wired with the same size wire as the coil. Leads on the switch sections should be as short as possible. The wiring should present no problem if the scheme shown in **fig. 2** is followed.

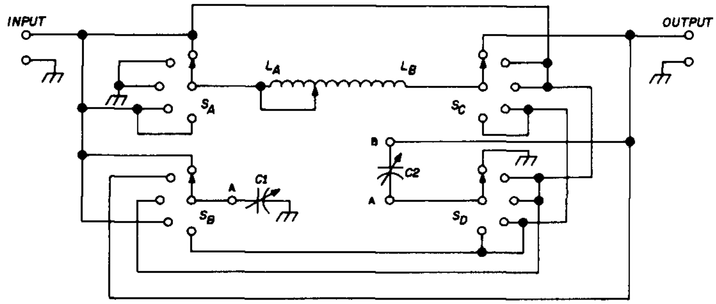

fig. 2. Nine of the ten circuits shown in fig. 1 can be formed with this circuit (the tee network with the two floating capacitors is the exception). Capacitors C1 and C2 are 250-pF air variables (Hammarlund MC-250-M); the inductor is a B&W 3900, 5 to 6 inches long, tapped with a spring clip.

dual-inductor circuits

Matching circuits using two inductors and one variable or fixed capacitor are shown in **fig. 3.** These are the equivalent of the single-inductor, two-capacitor circuits of **fig. 1,** but they do have some different features.

With extremely short antennas (one-eighth wavelength or less), some of the **fig. 3** circuits will give superior coupling efficiency—provided the inductors have low ohmic losses. This is very important, as discussed below.

The high circulating currents in a network matching an extremely short antenna could be 20-50 amperes. This would produce serious I^2R losses. With a fixed antenna length, the only way to reduce these losses is to construct the coupler with components having the lowest possible losses for the frequencies involved.

Antenna couplers having an extremely wide range of impedance-matching capabilities can be made using the circuits of **fig. 3** if each inductor has a maximum value of 10-20 μH and the variable capacitor has a range of 350 pF or more. This should permit matching a 16- to 20-foot or rod wire on 80 meters without difficulty. The cost of such a coupler can be fairly high if new commercial components are used. If you use surplus components, such as the capacitors and roller inductors in BC-191 and BC-375 units, very good couplers can be constructed at moderate cost. Alternatively, the inductors can be made from 1/8- or 1/4-inch copper rod or tubing to provide a 10-20 μH inductance.

In any case, when dealing with extremely short antennas, I'd suggest a hard-wired interconnection of the coupler components rather than a switching arrangement. It's difficult, but all-important, to remember that with such an antenna you're dealing with very high currents with even a medium-power transmitter. With circulating currents of 40 amperes, for instance, it takes only **0.1 ohm** in the inductors or connections to the matching network to throw away 160 watts of power in heat loss.

The contact resistance of many simple switches exceeds this 0.1-ohm value, and this fact alone explains why many well-constructed couplers seem ineffective when used with extremely short antennas. (Mobile enthusiasts take note.) The advantage of low ohmic resistance components in a coupler for extremely short antennas cannot be overemphasized. That's why military couplers use oversized components for moderate power levels.

tuning and adjustment

If you have only a pi-network available as an antenna coupler, the usual procedure would be to adjust it for minimum standing-wave ratio (swr). Indeed, this would be the

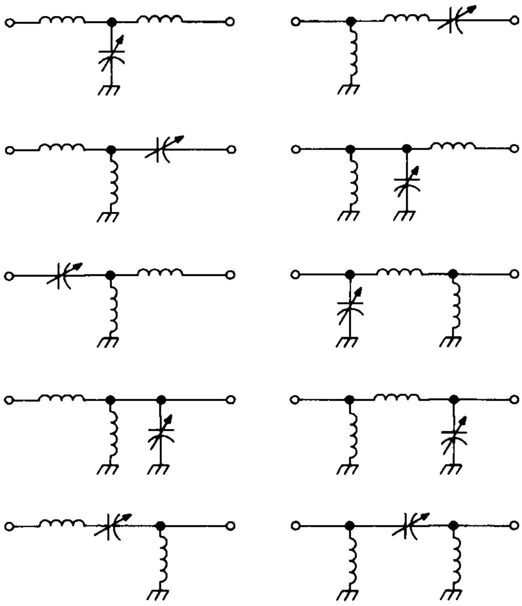

fig. 3. Matching networks that use one capacitor and two inductors.

only possible matching adjustment when tuning up a transmitter with a pi-network antenna coupler.

When using a coupler of the type in **fig. 2** with random-length antenna wires (30 feet or more), note that several coupler forms on the same band might produce a minimum swr. In each case all coupler component values should be adjusted to achieve a minimum swr when the coupler is set for a specific circuit form. The same situation will often occur when using the coupler forms shown in **fig. 3.**

swr and field strength

Minimum swr doesn't necessarily mean maximum radiated power. Minimum swr can result from transmitter power completely transferred to the antenna, completely absorbed in the coupler network, or any condition in between. The only way to determine what is taking place is with a field-strength meter.

The field-strength meter should be placed away from the coupler's immediate field. It doesn't matter which coupler circuit is tried first, as long as the sensitivity control on the field-strength meter isn't touched once a reading has been established for a particular coupler circuit. Other coupler circuits should be compared against the first, which is established as a reference, until one is found that produces the greatest field intensity.

After you determine which coupler circuit produces the lowest swr with greatest field strength on a given band, you can log the coupler settings for changing bands quickly. The time spent in initial setup to determine the optimum coupler circuit with each different antenna or ground connection will be worthwhile.

The matching networks shown can be used on any band, but the unconventional types will find their greatest application on the high-frequency bands when used with odd-length antennas. For simple situations where an impedance match is desired and no reactive components are involved, a simple L or pi-network generally suffices. The latter circuit also has some harmonic suppression as well.

grounds

A good ground connection is always desirable when using a random-length antenna, particularly if the antenna is less than a quarter wavelength long. In portable work, care should be taken to check the radiated field strength both with and without the ground connection. It's possible to have a ground connection that will actually reduce the radiated signal. You could lay a wire along the ground as a substitute for a radial system. In any event, the installation should be checked with a field-strength meter, as described above.

ham radio