Once you have something explained, it's no longer a mystery. KG5B takes the time to explain just what it is that a lot of us use.

Exploring The Vagaries Of Traps

BY CORNELIO NOUEL*, KG5B

At one time or another most of us have used traps in our antenna systems. A trap is simply a resonant circuit consisting of a capacitor in parallel with an inductor. Series resonant traps are sometimes used to reduce or eliminate undesired responses from oscillators or amplifiers. This article, however, will deal only with parallel resonant circuits as they are used in multiband antennas. In the old days parallel tuned traps, or "wave traps" as they were then called, were used in series with the receiver antenna lead-in to reduce blocking from strong nearby stations or perhaps to decrease the strength of second or third harmonic emissions from the transmitter (fig. 1). More recently, however, traps have become quite popular in the design of multiband antennas, since they provide economical and automatic band-selection capability (fig. 2).

The idea of multiband antennas using traps is based on the principle that parallel resonant circuits offer a very high impedance path at their resonant frequency, thus acting as isolators. As the frequency is lowered, they essentially become inductive, acting as loading coils for the next lower bands.

The simplest trap is a single-layer close-wound coil or solenoid that by virtue of its inherent distributed capacitance is self-resonant to a desired frequency. This type of trap will show various series and parallel resonances through a great range of frequencies, so its behavior may be hard to predict. It has been used in at least one known design (fig. 3). Unfortunately, because of its very high L/C ratio it tends to develop very

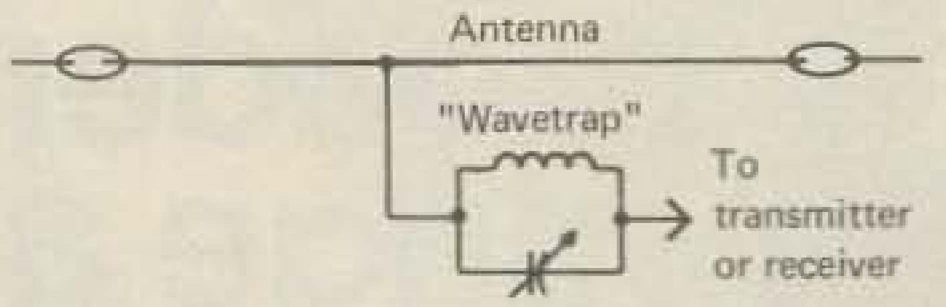

Fig. 1– An old-time "wave-trap."

high voltages, causing corona-discharge problems in high-power applications. It also tends to be "lossy" because of the large amount of r.f. resistance inherent in large inductors, and it is very susceptible to detuning from nearby conducting objects.

Large-value components, whether they are inductors or capacitors, are bulky and heavy, and their relative electrical values affect the efficiency of tuned circuits in different ways. When the L/C ratio is high, the "Q" of the circuit tends to be low, because most of the losses are due to the resistance in the coil. This, however, provides a greater bandwidth. On the other hand, if the L/C ratio is low, the "Q" factor or efficiency of the circuit is high, and then its bandwidth is less. Therefore, a compromise has to be found which will give the most desirable characteristics both mechanically and electrically. The most popular inductors used with traps in multiband wire antennas are the air-core space-wound coils with a relatively large diameter. Their inductance should be such that they resonate at the desired frequency with about 1 to 2.5 pF per meter of wavelength. Beam antennas and verticals use shielded, grooved coil forms which are difficult to make and rather expensive. They work on the same

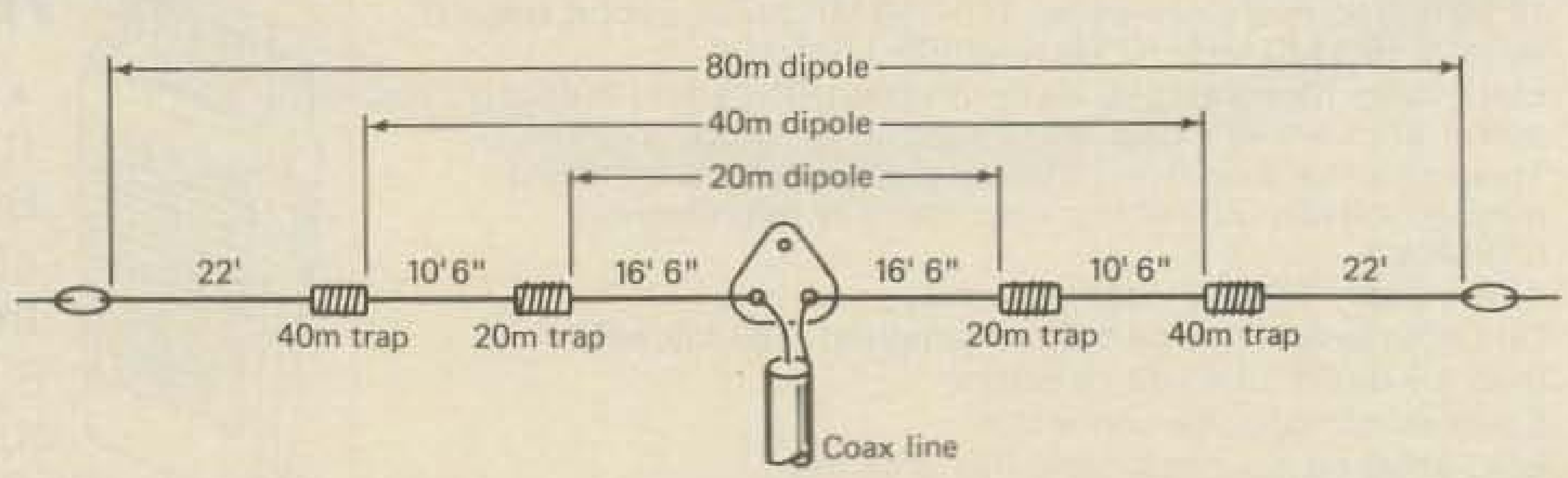

Fig. 2– A typical multiband trap antenna.

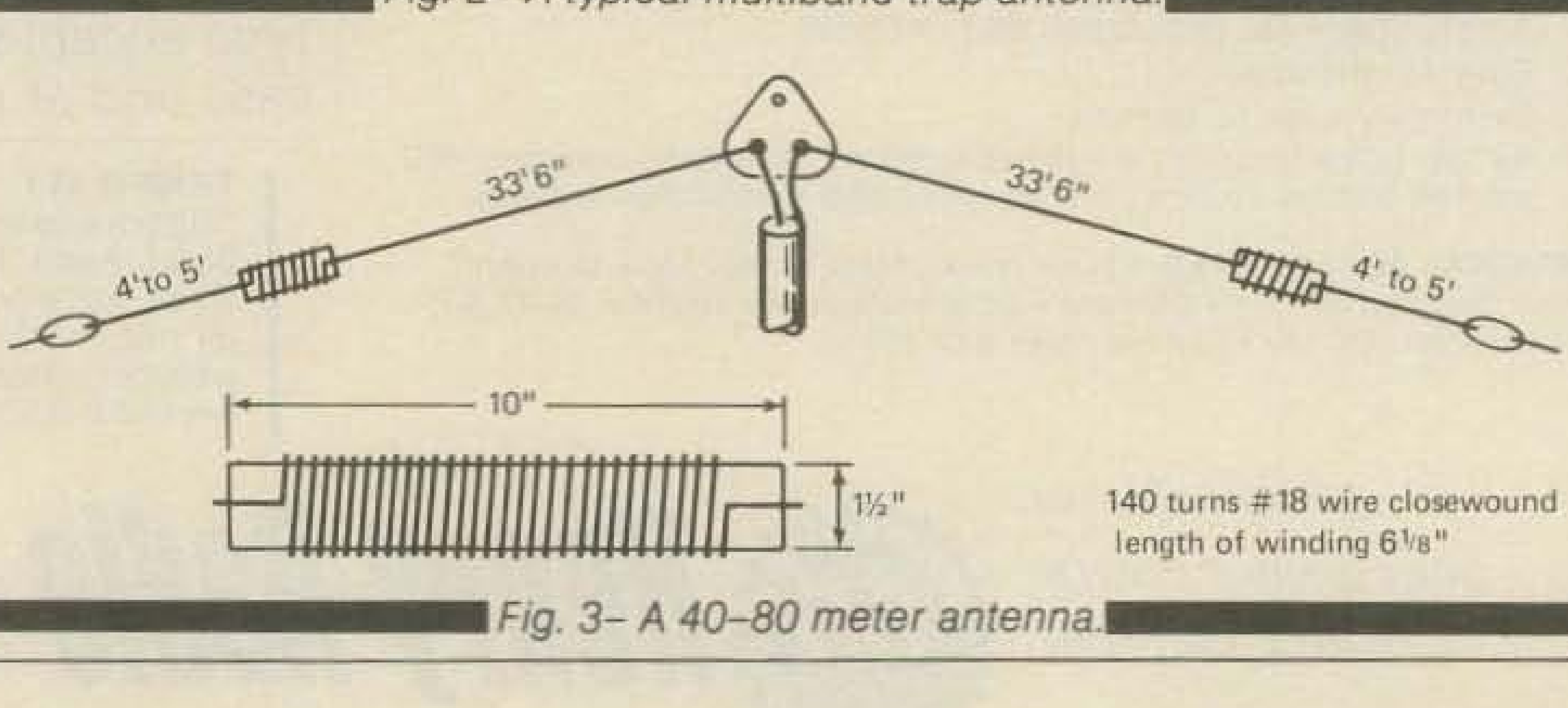

Fig. 3– A 40–80 meter antenna.

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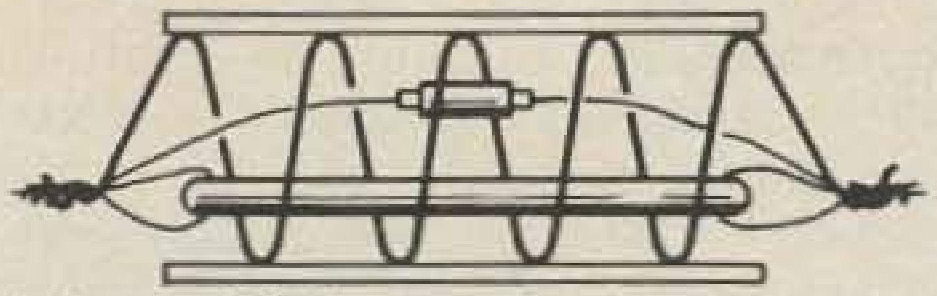

Inductance 8.2μH
Capacitance 60pF (5Kv or more)
Resonance frequency approximately 7.15MHz
For 20m use half of the values given for C and L

Fig. 4– A "classic" trap using a transmitting ceramic capacitor and machine-wound commercial inductors. Egg-type insulators are not recommended; use long insulators for this purpose.

principle as other traps and are very sturdy and mechanically stable, but their construction is beyond the scope of this article. Some of the radio handbooks, however, describe the construction of similar traps which can be used in those applications.

Perhaps the easiest way to design a trap is to start with the capacitor, since this can be purchased or made to the exact value desired. The best capacitor seems to be the ceramic NPO transmitting type, sometimes called the "doorknob" type because of its shape. For up to 1 kw the voltage rating should be no less than 5 kv. For 200 watts or less a rating of 2.5 kv is suitable. These ratings will provide at least a 100 percent safety factor. Receiving-type capacitors should not be used even if their voltage rating is appropriate, because they do not have a good current-handling capability and they may not stand up in use, except perhaps with very low power. Transmitting mica capacitors are also suitable, but they are usually heavier and more vulnerable to the environment.

Fig. 4 shows a classic trap using a ceramic capacitor and an air-core inductor. The values given are for the 40 meter band. The next best choice is the coaxial cable capacitor. This is not only cheaper than most transmitting-type capacitors, but it has the advantage that it can be trimmed to an exact value. However, after the trap is built, the ends should be sealed to avoid changes due to humidity. The size can be calculated by the formula given in the appendix. It is always wise to start with a piece a little longer than necessary and then trim a quarter of an inch at a time until resonance is achieved at mid-band. Fig. 5 shows the recommended way to build a trap using a coaxial cable capacitor. RG58-type cable can be used for powers up to 200 watts or so; for higher powers RG8 should be used. As shown in fig. 5, the cable should be clamped or strapped to the antenna wire. Part of it, however, can be slipped inside the coil form. It is not a good idea to let the coax hang from the coil, since the wind will make it sway, and eventually it will break away.

Another way of building a suitable capacitor is by using a double-sided, copper-clad, fiberglass printed circuit board. A sample (preferably a square or rectangle) of known area should be measured with an accurate capacitance meter, and the capacitance per square inch should be determined. The required area in inches can then be obtained easily by dividing the required capacitance by the pF per inch, which was previously determined. Of course, the shape of the capacitor is unimportant as long as the area (and the capacitance) are correct. Measurements on a 3/64 inch (1 mm) thick pc board have been determined to have about 20 pF per square inch.

No voltage rating is available, but a set of traps using this construction has been used with 100 watts without any problems. It may be a good idea to bevel the board at least on one side to avoid corona discharge. Capacitors made this way are very lightweight and can easily be installed inside the coil form. They should be sprayed with a suitable plastic coating to help preserve them (see fig. 6).

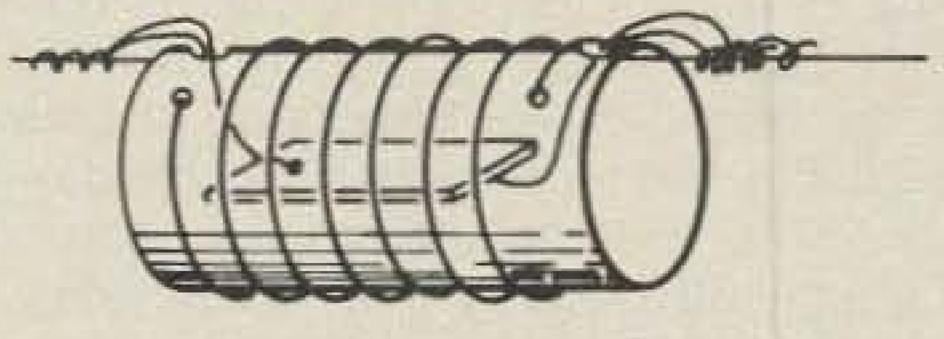

Fig. 6– A trap using a double-sided pc board capacitor.

Commercial "machine-wound" inductors can be used to build traps. They are made by several manufacturers and are not expensive. A coil diameter of at least 1½ inch should be used to keep losses down. The current amateur radio handbooks have extensive data on these inductors. Choose a stock that uses a No. 12 or 14 wire for best results. Cut it to the required length or slightly longer using the data in the handbook or the manufacturer's specifications. If the data is not available, the inductance can be calcu-

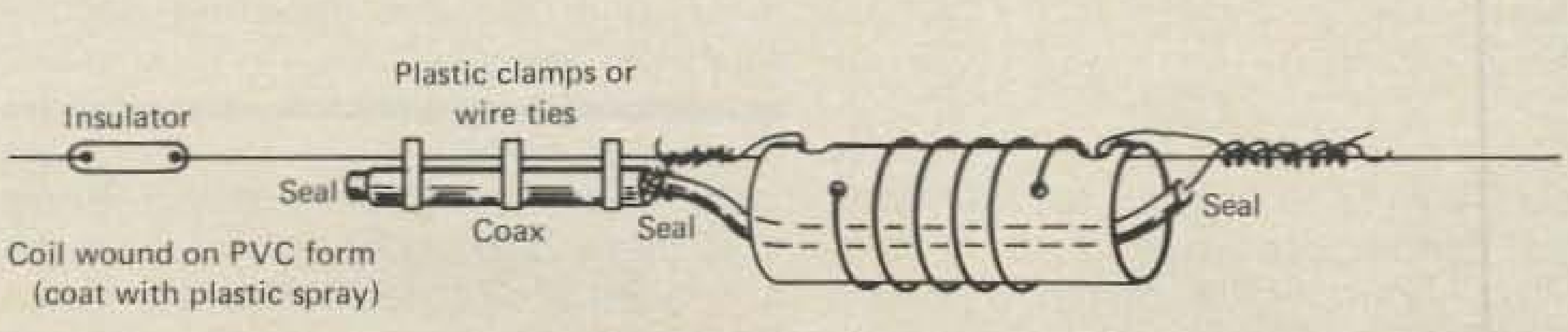

Fig. 5– A trap tuned with a coaxial cable capacitor.

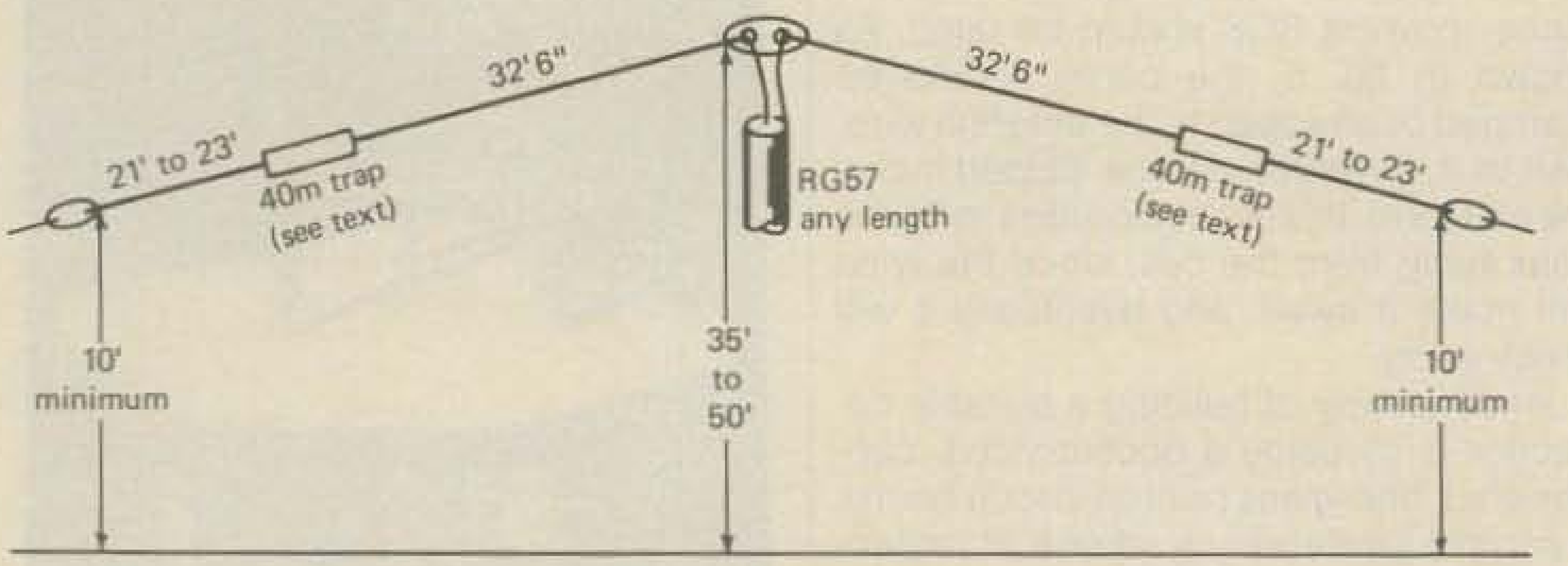

Fig. 7– An "all band" (10–80) trap antenna.

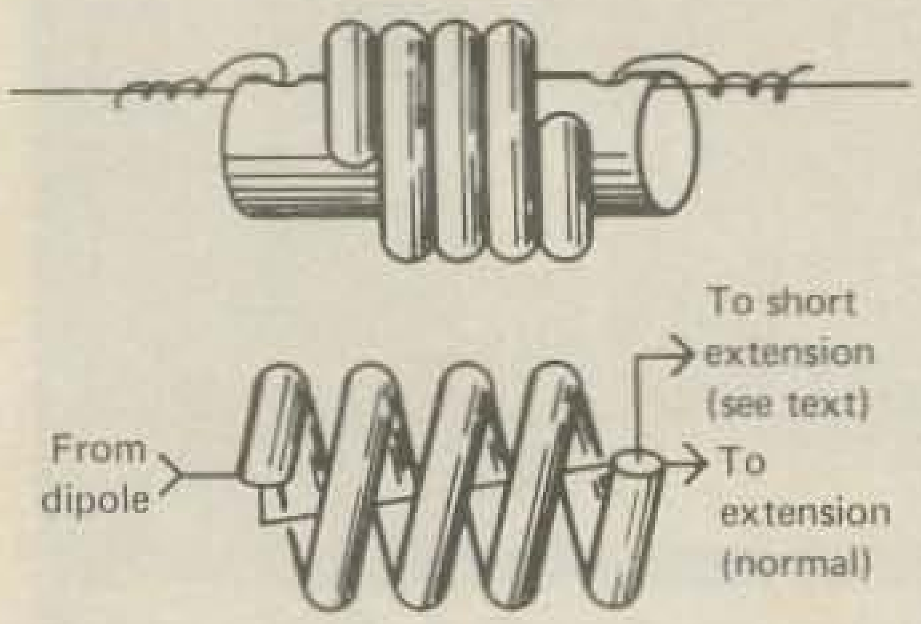

Fig. 8– A coaxial-cable trap.

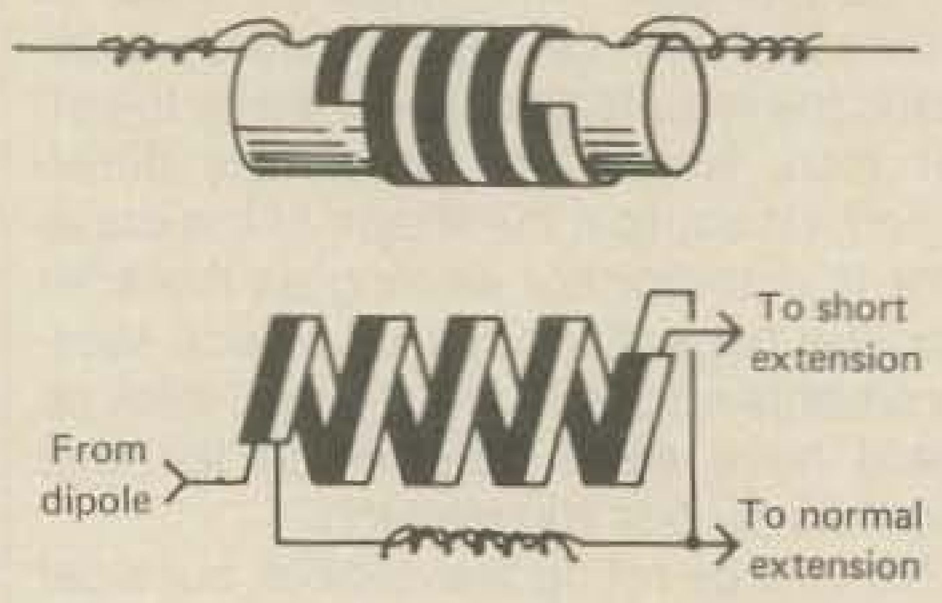

Fig. 9– A speaker-wire trap.

lated by means of the standard solenoid formula shown in the appendix. With this value and the capacitor value the theoretical resonance can easily be estimated. It should fall in about the middle of the desired band. However, when the trap is assembled, it can be checked with a grid-dip meter while disconnected from the antenna. Any adjustments then can be made to the inductor if ceramic capacitors are used, or to the capacitor if coaxial-cable or pc-board types are used.

Inductors can be homemade with relative ease. One of the simplest ways is to use a length of plastic tubing (water-pipe PVC will do a fairly good job). Cut the form 2 or 3 inches longer than required for the winding. A winding length of about 2½ inches should be about right for a 40 meter band trap. Using a 1½ inch diameter form and 21½ turns of No. 14 wire spaced about one wire diameter will create an inductance of about 8.2 microHenry. This coil used in conjunction with a 60 pF capacitor will resonate in the middle of the 40 meter band. Fig. 7 shows an antenna using two of these traps. The antenna is usable on all bands from 80 to 10 meters (except the WARC bands) because of the inherent harmonic relationships.

Band (meters)	Turns	Coax length (inches)	Winding Length (inches)
15	4¾	22.5	1
20	6½	30.5	1¼
30	8¾	41.2	1¾
40	12	56.5	2½

Table I– The winding data for coaxial traps. Tightly close-wound on a 1½ inch form RG58U solid dielectric, 28.5 pF/foot. Allow about 3 inches of extra coax for connection.

A new development that shows some merit is using coaxial cable simultaneously as inductor and capacitor.[1] This is accomplished by winding the coaxial cable on a suitable form and then connecting the inner conductor to the outer conductor at the opposite end of the coil. The outer conductor or shield can now be used as a trap and loading coil as with other types. These traps are easy to make when using small-size cables (RG58/59), but require considerable dexterity with the larger cables, which also produce rather bulky and heavy units. The L/C ratio of these coaxial traps is very small, so they tend to have a rather high "Q," causing the antenna to have a narrow bandwidth. Table I shows some representative values that can be used as guides in their construction. Fig. 8 shows how they are connected. Connecting the extension arm to the unused end of the inner conductor will cause a considerable reduction in the extension length (approximately equal to the length of the cable) with some loss of efficiency. A low-priced substitute, using the same principle, that can be used with powers of 100 watts or so is the bi-filar, clear-plastic "speaker wire."[2] It is very lightweight and flexible,

Band (meters)	Turns	Wire length (inches)	Winding Length (inches)
10	4¾	22.5	⅞
15	5¾	27.2	1⅛
20	8	38.0	1½
30	11	52.0	2⅛
40	14½	68.5	2⅜

Table II– Winding data for speaker wire traps. Tightly close-wound on a 1½ inch diameter form. Radio Shack wire No. 278-1602 or equivalent, 13.5 pF/foot. Allow about 3 inches extra for connection.

so making traps with it results in a very simple operation. This wire has about one half the capacitance of RG58. Therefore, the L/C ratio is higher, showing better bandwidth, although presumably with higher losses—a normal trade-off in any case. Traps made with this material seem to stand up quite well outdoors. Winding data is shown in Table II and fig. 9.

Perhaps it is fair to say that any type of trap or loading coil will consume some power, reducing the overall efficiency. However, the reduction, whatever it may be, is certainly justified by the flexibility and convenience provided by these devices, allowing most of us to operate on the various available bands without having to own an antenna farm. CQ

Appendix

The approximate inductance of a single-layer air-core coil can be found by the following formula:

$$L \text{ (in microHenries)} = \frac{R^2N^2}{9R + 10S}$$

where R is the radius of the coil in inches, N is the number of turns, and S is the length of the winding in inches.

By transposing the terms, the required number of turns can be determined by this formula:

$$N = \frac{\sqrt{L(9R + 10S)}}{R}$$

Required capacitance for a given inductance and frequency can be found by

$$C = \frac{25330}{f^2L}$$

where C is in picoFarads, f is in MHz, and L is in microHenries.

If C is known and L is required, then

$$L = \frac{25330}{f^2C}$$

The length of a coaxial capacitor can be found by

$$l \text{ (in inches)} = \frac{C_{reg}12}{C_{coax}}$$

where l is the length of the coax in inches, C_{coax} is the capacitance of the coax in pF/foot shown in the coax specs, and C_{reg} is the capacitance required to resonate the inductor at the desired frequency.

The area of the double-sided board can be found by

$$A \text{ (in sq. inches)} = \frac{C_{reg}}{C_b}$$

where C_{reg} is the required capacitance in pF, and C_b is the measured capacitance per square inch.

[1] Johns, "Coaxial Cable Antenna Traps, QST, May 1981. O'Neil, "Trapping the Mysteries of Trapped Antennas," Ham Radio, Oct. 1981.
[2] Radio Shack No. 278-1602.