Lightweight Trap Antennas — Some Thoughts

Portable multiband antennas need not be heavy and bulky. Small traps and light-gauge wire can provide a trap dipole that fits in a lunch bag. Try these practical guidelines for your next small antenna.

By Doug DeMaw,* W1FB

Vacationers, campers, sales people and QRPers take note! You need not carry a large multiband trap dipole afield if your transmitter is in the 150-W-output class, or lower. You can construct your own traps inexpensively with ordinary materials, and they can be made quite small without becoming poor performers. This article describes some easy techniques for fabricating homemade antenna traps. Additional hints are offered for keeping the bulk and weight of portable antennas within reason.

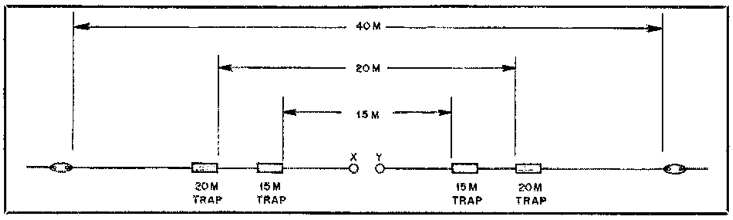

Fig. 1 — Representation of a three-band trap dipole antenna.

A Review of the Trap Concept

A "trap" is exactly what the term implies. It traps an rf signal to prevent it from passing beyond a specific point along an electrical conductor. At some other frequency, however, it no longer acts as a trap, and permits the passage of rf energy.

An antenna trap is designed for a particular operating frequency, and there may be several traps in the overall system — each designed for a specific frequency. Therefore, a 40- through 10-meter trap dipole might contain traps for 10, 15, 20 and 30 meters. On 40 meters, all of the traps are "absorbed" into the system to become part of the overall 40-meter dipole. Owing to the loading effect of the traps, the 40-meter portion of the antenna will be somewhat shorter than a full-size 40-meter dipole with no traps. The antenna bandwidth will be narrower when traps are used. Fig. 1 illustrates the general format for a multiband dipole.

A trap style of antenna is not as efficient as a full-size dipole. This is because there will always be some losses in the traps. But the losses in a well-designed system are usually so low that they are hard to measure by simple means. The losses represent a small tradeoff for the convenience of being able to accommodate many ham bands with one radiator and a single feed line. Yagi antennas contain traps in the parasitic elements (directors and reflectors) as well as in the driven element. Therefore, a multielement antenna of that type may have as many as 12 traps.

Electrical Characteristics

An antenna trap is a parallel-resonant L-C circuit. Therefore, it is similar to the tuned circuit in a transmitter or receiver. A resonator of this kind, if designed correctly, has a moderate Q and a fairly narrow bandwidth. This means that the trap capacitor should have a high Q and the trap coil should contain wire that is reasonably large in cross section. These traits will help to reduce losses.

Fig. 2 shows the equivalent circuit for an antenna trap. Once this network is adjusted to resonance in the desired part of an amateur band, it will not be affected significantly by the attachment of the wires that comprise the antenna. A well-designed and -constructed trap should not change frequency by any great amount when the temperature or humidity around it varies. Therefore, it is important to use a stable capacitor, a rigid coil and some type of sealant.

Mini Trap Using a Toroid Core

In an effort to scale down the size of my antenna traps during a design exercise for a portable antenna, I decided to investigate the worth of small toroid cores upon which to wind the coils. Ferrite cores were ruled out because they aren't as stable as powdered-iron ones. Furthermore, the powdered-iron material has a much greater flux density than an equivalent-size ferrite core, which means that the core will not saturate as easily at moderate rf power levels.

Development work started with Micrometals Corporation T50-6 toroids, which are sold by Amidon Associates, Palomar Engineers and RadioKit (see *QST* advertisements). My first effort resulted in a pair of very small 20-meter traps. A silver-mica capacitor was chosen for the parallel-tuned circuit. Ceramic capacitors were not used because of previous experiences I had with changes in value under temperature extremes; I had better results with dipped silver-mica units.

My rule of thumb for choosing the coil and capacitor values for traps is based on a reactance of approximately 200 ohms, although values up to 300 have also

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yielded good results. Using 200 ohms as the basis for the design, I calculated the capacitor to be a value that was very close to a standard one — 56 pF for trap resonance at 14.100 MHz. This was obtained from

$$C(\mu F) = \frac{1}{2\pi\, f(MHz)\, X_c} \qquad \text{(Eq. 1)}$$

Hence

$$C = \frac{1}{6.28 \times 14.1 \times 200}$$

$$= 0.0000564\ \mu F\ (56\ pF)$$

Since X_c and X_L are equal at resonance, the coil was calculated by means of Eq. 2:

$$L(\mu H) = \frac{X_L}{2\pi f(MHz)} \qquad \text{(Eq. 2)}$$

Hence

$$L = \frac{200}{6.28 \times 14.1} = 2.25\ \mu H$$

(approximate)

The value of the coil will have to be adjusted slightly after the trap is assembled to allow for capacitor tolerance and stray capacitance, which accounts for the term "approximate" in Eq. 2.

The Amidon toroid tables were consulted to learn the A_L factor of a T50-6 core (1/2-inch-diameter toroid). The value is 40. From this I calculated the number of turns from

$$\text{Turns} = 100\sqrt{L_{\mu H}/A_L} \qquad \text{(Eq. 3)}$$

Hence

$$\text{Turns} = 100\sqrt{2.25/40} = 23.7$$

For practical reasons a 24-turn winding was used: A partial turn is not convenient on a toroid form.

The same procedure was used for the remaining traps in my antenna. This article is not a course in basic math, but the equations can be useful to those who have not previously designed resonant circuits or used toroidal cores.

Toroidal-Trap Adjustment

It's best to use the largest size wire that will fit easily on the toroid core. The stiffness of the heavier magnet wire will help to keep the coil turns in place, thereby minimizing detuning. I used no. 24 enameled wire.

The capacitor leads and coil "pigtails" should be kept as short as possible. Fig. 3 illustrates the layout I used. The leads at each end of the mica capacitor are soldered to the related coil leads before final adjustment is made.

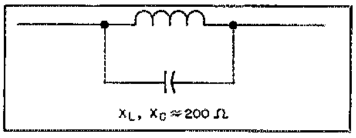

Fig. 2 — Electrical equivalent of an antenna trap. The ac resistance is not shown. A suitable reactance value for the coil and capacitor is 200 ohms.

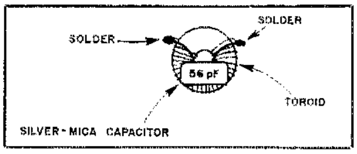

Fig. 3 — Physical arrangement for one of the toroidal L-C traps. Put spaghetti tubing over the capacitor leads to prevent them from shorting to the turns on the toroid.

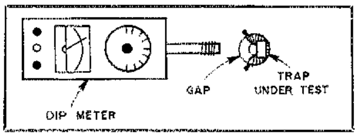

Fig. 4 — Test method for finding the resonant frequency of a trap. Different points around the toroid will yield better dip indications. Experiment with the position of the dipper coil.

A dip meter can be used to determine the resonant frequency of the trap, as shown in Fig. 4. Although a prominent feature of a toroidal coil is the self-shielding characteristic, which makes it difficult for us to get ample coupling with a dip meter, it is possible to read a dip. I have found that by inserting the dip-meter coil into the area of the winding gap on the tuned circuit (Fig. 4) a dip can be obtained. By approaching the trap from different angles, it should be easy to find a spot where a dip can be read on the meter. Once the dip is found, back off the instrument until the dip is barely discernible (the minimum coupling point). Monitor the dip-meter signal on a calibrated receiver to learn the resonant frequency of the trap.

Select a part of the related amateur band for trap resonance. I adjust my traps for the center of the frequency spread I am most interested in. For example, I set my 20-meter traps for resonance at 14.025 MHz because I work only cw from 14.000 to 14.050 MHz. For phone-band coverage, I'd pick 14.275 MHz as the trap frequency. A compromise frequency for phone and cw operation would be 14.100 MHz. Owing to the trap Q, coverage of an entire band is not possible without having an SWR of 2:1 or greater at the band-edge extremes. The absolute bandwidth will depend on the trap Q and the Q of the antenna itself.

If the trap is not on the desired frequency, move the turns of the toroid coil farther apart to raise the frequency. Push them closer together to lower the frequency. An alternative method for finding the trap resonance is shown in Fig. 5. The trap being tested is connected to terminals x and y. The coupling is very light in order to prevent the test-circuit capacitance from appearing in parallel with the trap. For this reason the coupling capacitors are only 2 pF. The station transmitter is adjusted for the lowest power output that will provide a reading on M1. The VFO is then swept manually across the band. When the resonant frequency of the trap is located, the meter (M1) will deflect upward sharply, indicating resonance. Adjust the trap for a frequency that is approximately 5% lower than the desired one. This will compensate for the shunt capacitance presented by the 2-pF coupling capacitors.

When the coil turns are set in the correct manner, spread a bead of fast-drying epoxy cement across the turns on the two flat sides of the toroid. This will prevent unwanted position changes that could cause a shift in resonance later on from handling.

Housing the Mini Trap

I learned that a 7/8-inch-OD PVC plumbing coupling, 1-1/4 inches long, would serve nicely as a housing for the toroidal traps.[1] A ridge inside the couplings at the center can be filed out easily to provide clearance for the trap. A rat-tail file does the job quickly. Fig. 6 shows a breakaway view of how the trap is assembled. Slices of dowel rod are used for end plugs. A knot is tied in the antenna wire that enters the trap housing; this prevents strain on the trap coil.

After the antenna wire has been soldered to the trap at each end, add a layer of epoxy glue to the outer perimeter of one of the dowel plugs, then insert it into the PVC coupling until it is flush. Fill the coupling with noncorrosive sealant; I used aquarium cement. Finally, place epoxy glue on the remaining end plug and insert it in the PVC coupling. Allow the trap to set for 48 hours, until the sealant has hardened. Fig. 7 is a photograph of a mini trap, along with a dipole center insulator made from a PVC T-coupling. The coupling is filled with sealant after the wires are soldered to the coaxial feed line. Long plugs are used to close the three open ends of the T connector. A closed nylon loop, made from strong spaghetti tubing, was fed through two small holes at the top of the T-coupling to permit erecting the dipole as an inverted V. A small eye bolt and nut could have been used instead.

There was a minor downward shift in trap resonance after the sealant hardened. Both 20-meter traps shifted roughly 30 kHz lower. No doubt this was caused by increased distributed capacitance across the coil turns with the sealant in place.

[1] Notes appear on page 18.

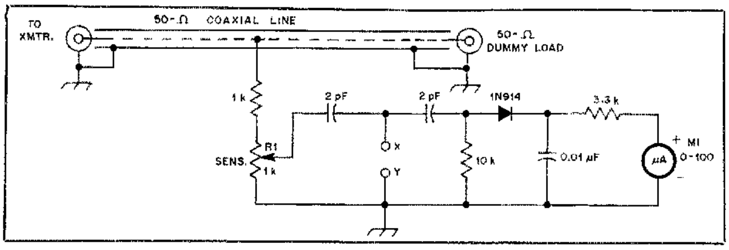

Fig. 5 — Test fixture suitable for checking trap resonance with the station transmitter. Use the least amount of power necessary for meter deflection.

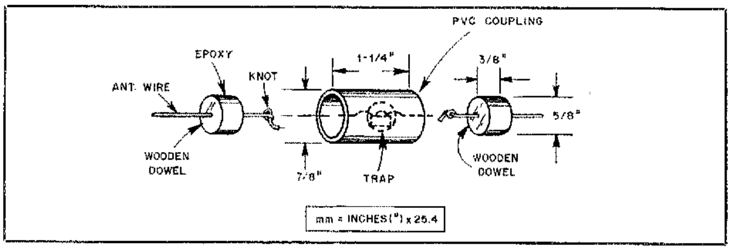

Fig. 6 — Breakaway view of a toroidal mini trap. The knots in the wire prevent stress on the tuned circuit.

This seemed to have no effect on the trap quality; it had a measured parallel resistance of 25 kΩ before and after encapsulation (using the laboratory RX meter for tests). Generally, anything greater than 10 kΩ is suitable for an antenna trap.

Mini Coaxial-Cable Traps

Two very interesting articles concerning antenna traps appeared in the amateur literature during 1981.[2,3] After reading them a second time, I decided to attempt building some traps along the lines discussed in those articles. Some advantages over the usual coil/capacitor style of trap were described by the authors: (1) The traps were not especially frequency sensitive to changes in temperature and climate; (2) the coaxial trap offers greater effective bandwidth; and (3) parallel resistance is quite high — on the order of 50 kΩ.

The articles under discussion contained practical information about the use of RG-58/U and RG-8/U cable for the trap coils. I wanted a small, lightweight trap, so elected to see what could be done with miniature cable — RG-174/U. A completed mini coaxial trap for 20 meters is shown in Fig. 8.

The principle of operation is covered well by O'Neil (note 2). Since this article deals with the practical aspects of traps, we won't delve into the electrical characteristics of the coaxial trap too deeply. However, a diagram showing how it is hooked up is offered in Fig. 9B. A length of coaxial line is wound on a coil form, and the inner conductor at one end is attached to the outer conductor at the opposite end. The distributed capacitance of the two conductors and the inductance of the coil combine to provide a resonant circuit. An acceptable Q results, and the trap can accommodate considerable rf voltage and current without being damaged. A parallel resistance of 50 kΩ was measured for the 20-meter trap of Fig. 8. The bandwidth at the 10 kΩ points was somewhat greater than with the toroidal trap.

Coaxial-Trap Assembly

I found 5/8-inch-OD PVC plumbing pipe to be an acceptable and low-cost material for the coaxial traps. End plugs made from 1/2-inch wooden dowel fit snugly inside the PVC pipe. The completed trap contains a length of bus wire inside it for connecting the braid and center conductor of the cable together, as discussed earlier. The ends of the bus wire and the related cable ends are routed outside the PVC tubing through small holes, then soldered. Aquarium cement was again used, this time to seal the six small holes drilled in the tubing. Epoxy cement was applied to the sides of the wooden plugs before inserting them into the tubing. A layer of vinyl electrical tape can be wound over the coaxial coil if desired, although this should not be necessary. If weather protection is desired, a coating of exterior polyurethane varnish can be applied to the completed close-wound coil. This will keep the turns affixed in the desired position after final adjustment. Tune-up is carried out in the same manner as prescribed for the toroidal traps, using a dip meter or the test fixture described in Fig. 5.

The length of the coaxial cable used will have to be determined experimentally. My 20-meter coaxial trap contains 15 close-wound turns of RG-174 cable (36 inches, 89 pF) to provide resonance at 14.100 MHz. Final adjustment was done by moving the three outer turns at one end until the desired frequency was noted. The coil form for the 20-meter trap is 2-1/2 inches long. The wooden end plugs are 3/8 inch thick. The inside of this trap is not filled with sealant, but it could be if desired. Avoiding the use of filler will make the traps lighter in weight, thereby permitting the use of lighter-gauge wire for the antenna sections.

Trap Performance

Both styles of trap were subjected to rf power tests to determine whether they could handle the output of a typical 150-W class transceiver. A Bird wattmeter was connected between the trap and the transmitter. A 50-ohm dummy load was attached to the opposite end of the trap. Next, 40- and 80-meter rf energy was applied (in separate tests) gradually while observing the reflected power, which of course was not conducive to providing an SWR of 1:1 with the trap in the line. Neither trap showed signs of heating or breakdown at power levels up to 150 W. A key-down period of five minutes was tried during the tests, using a linear amplifier adjusted for 150-W output. Still no sign of power limitation. The SWR did not change under these conditions. I did not advance the power beyond 150 W, but it's safe to conclude that the coaxial-cable trap could sustain substantially more power without damage. This may not be true of the toroidal trap. I lacked the courage to find out!

Toward a Lightweight Dipole

Having solved the problem of lightweight, small traps I set about the task of reducing the bulk of the remainder of my multiband dipole. I am a dedicated miser, so the cost of materials was an important factor in the selection of wire and end insulators. I recalled a type of wire I had used on a number of DXpeditions: It was strong and light in weight, and the price was right! This wire is available from Radio Shack and similar outlets for use as speaker cable. It has a clear plastic outer covering, contains a no. 22 conductor (two each) and costs less than $5 per 100 feet. Hence, for this price we end up with 200 feet of wire (less than 2.5 cents per foot); the parallel conductors can be pulled apart easily without harming the outer insulation. In addition to the insulation aiding the strength of the wire portions of the antenna, it protects the copper

Fig. 7 — View of a toroidal mini trap, an encapsulated toroid and a PVC T-coupling for use as a center insulator. RG-58/U cable is shown in this example (see text).

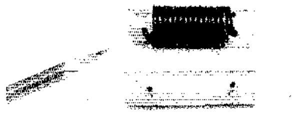

Fig. 8 — A completed 20-meter coaxial trap with miniature RG-174/U coaxial cable.

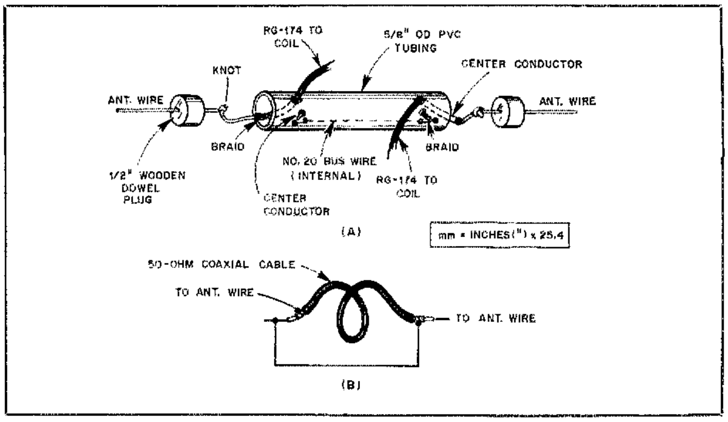

Fig. 9 — At A is a breakaway view of a coaxial trap. The illustration at B shows the electrical connections for a coaxial trap.

wire from corrosion. This can be especially beneficial in areas where salt water and industrial pollutants affect the atmosphere. The Radio Shack number for this wire is 278-1385. I have observed no apparent deterioration of this type of conductor, even though some of my antennas have been aloft for three years.

Although RG-58/U coaxial cable is less offensive in terms of loss per 100 feet than is true of RG-174/U, we may want to trade losses for portability by using '174. Normally, a 50-foot length of feeder cable is adequate for portable work. In an effort to determine exactly what the hf-band losses per 50 feet might be, I tested this cable from 3.5 through 29 MHz. A Bird wattmeter was connected to each end of the 50-foot test cable. One wattmeter was terminated with a 50-ohm dummy load, and the other wattmeter was connected to a transmitter. The loss in decibels was as follows: 3.5 MHz — 1.19; 7.0 MHz — 1.42; 14.0 MHz — 1.67; 21 MHz — 1.93; 29 MHz — 2.0. Therefore, in a worst-case situation (10 meters), a 100-W power input to the cable would result in an antenna feed-point power of 63 W. RG-58/U, on the other hand, would have a 1-dB loss at 29 MHz, which would mean an antenna feed-point power of 79.4 W. This is not too significant when operating in the 50-150 W range, but it can be important when using a QRP rig with only a few watts or milliwatts of output power. I must say in defense of RG-174/U cable that I operated 20-meter cw with 2 W of output power from 8P6EU while using a dipole with 50 feet of RG-174/U feed line, and I worked the world without difficulty. I received many RST 599 signal reports. The tiny feeder cable and the hookup-wire dipole could be rolled up and stuffed in my hip pocket! The end and center insulators for that antenna were also lightweight. I made them from scraps of pc board from which the copper had been removed. The end insulators for the trap dipole discussed in this article were fashioned from inch-long pieces of 5/8-inch-diameter PVC tubing through which holes were drilled to accommodate the dipole wires and nylon guy lines.

Summary Comments

The overall length of any dipole section in a trap type of antenna will be less than if the dipole were cut for a single band without traps. The exception is the first dipole section after the feed point (out to the first set of traps). The following percentages (approximate) were typical in a coaxial-trap dipole I built for use from 40 through 10 meters, compared to the length of a full dipole (100%) for each band: 10 meters — 100%; 15 meters — 92.4%; 20 meters — 88.8%; 40 meters — 83.6%. The shortening becomes more pronounced as the frequency is lowered, owing to the cumulative loading effects of the traps.

These percentages can be applied during initial structuring of the antenna. Starting with the highest band, the dipole sections for each frequency of interest are trimmed or lengthened for the lowest attainable SWR. After the exact dimensions are known, continuous lengths of wire can be used between the traps. This will add strength to the antenna by avoiding breaks in the speaker-wire insulation, if that type of conductor is used. The percentage reductions listed above are not necessarily applicable to antennas that use toroidal or other coil/capacitor traps. The wire diameter and insulation may also affect the final dimensions of the dipole.

For long-term installations, I would suggest the use of some type of sealer (spar varnish or polyurethane) over the wooden end plugs of the traps. All trap holes need to be sealed securely to prevent moisture from building up inside them.

Miniature antenna traps and lightweight trap dipole antennas are practical and inexpensive to build. Try one during your next vacation or business trip.

Notes

[1] mm = in. × 25.4; m = ft × 0.3048.

[2] G. O'Neil, "Trapping the Mysteries of Trapped Antennas," *Ham Radio*, Oct. 1981, p. 10.

[3] R. Johns, "Coaxial Cable Antenna Traps," *QST*, May 1981, p. 15.

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