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Short Antennas for the Lower Frequencies

In Two Parts

Part II — Trap Construction and Adjustment; Some Applications

BY YARDLEY BEERS, PH.D,* WØJF

THE WRITER has used a wide assortment of components for traps. However, experience has been limited to powers of 150 watts and less, and certainly many of his components would have been unsatisfactory if the legal limit of power had been used. As inductors, coils from war-surplus tuning units, plate tank coils from dismantled homemade transmitters, and Miniductors have been used. More recently some coils wound with plastic-covered bell or hookup wire on plastic pill bottles have been adequate under conditions where large currents are not expected – that is, for monoband loads or traps with low *L/C* ratios.

Ideally, the capacitor should be the air- or vacuum-dielectric type. However, such capacitors are expensive and are too bulky to be used except with base loading. For the most part, the writer has used prewar mica capacitors with 1000- or 2000-volt ratings and having screw terminals or thick lug terminals. These have worked better than reasonably could have been expected. A modern ceramic capacitor with a 20,000-volt rating and screw terminals has been most satisfactory. However, ceramic capacitors with pigtail leads, even those with a 6000-volt rating, have been unsatisfactory in that as the transmitter key is held down, the resonant frequency of the trap drifts out of tune as the capacitor heats up. The reader should be reminded that in this application the voltage rating is of little direct interest. The important properties are dielectric losses and lead losses when high currents flow. In some cases it may be desirable to use a number of capacitors in series or parallel in order to improve the power-dissipating capability.

Design and Experimental Checking Procedure

As a starting point, it is convenient to employ a rough rule of thumb that the portion of the antenna between the load and the end (H_1 in Fig. 1, Part I) can be expected to have a capacitance of about 2 pF per foot – perhaps 1.9 for wire and about 2.4 for one-inch tubing. For conventional inductive loading of a short monoband antenna, choose a coil having an inductance which will resonate the capacitance of this portion of the antenna at the desired operating frequency.

For the first try in designing a trap, select a capacitor having five to ten times the capacitance of H_1 and choose an inductor which resonates with the total capacitance (capacitor plus H_1). Fortunately, inductances determined this way are likely to be a little too large because additional inductance is contributed by the lower portion, H_2. You are then ready to start trimming.

In the case of a trap which is not mechanically an integral part of the antenna, the resonant frequency should be checked in the shack with a grid-dip meter, with an allowance for the capacitance of H_1. Otherwise, it is necessary to work with the complete antenna. Several procedures and different instruments may be used to arrive at the desired results. However, the writer finds that results are obtained most rapidly by first locating the center of the resonance, which is mainly controlled by the trap, and for this operation a grid-dip meter can be used as a signal generator to drive a Wheatstone-bridge type standing-wave detector.[9] (Standing-wave detectors of this type usually require lower input power than reflectometer types.) Coupling is achieved by wrapping two turns of insulated wire around the middle of the grid-dip meter coil and connecting the ends to the input of the bridge.

It is not necessary to obtain a large deflection on the bridge meter; one or two divisions are adequate. Set the bridge to indicate reflected power and rotate the GDO dial until a sharp dip is observed, indicating approximately the center of the resonance. If the frequency is far from that desired, preliminary adjustments to bring the resonance near to the desired frequency can be

9 A bridge of this type is described in the *A.R.R.L. Antenna Book*, Chapter 3, page 128 in the Eleventh Edition.

> *The term "trap," by long-established usage, means a circuit whose function is to act as an absorber or decoupling device for an unwanted frequency, and has been used in this sense in connection with multiband antennas operating on the principle described in the* A.R.R.L. Antenna Book. *As used in this article the word has a much broader meaning — a parallel* LC *circuit tuned so as to provide a specific needed value of reactance for loading an inherently nonresonant antenna.*

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TABLE I

LOADING NETWORKS FOR 40-FOOT BASE-LOADED VERTICAL ANTENNA

Band (MHz)	*Fig. No.*	*Capacitance (pF)*	*Inductor*					*Notes*
			L *in* μH	*No. of Turns*	*Diameter Inches*	*Length Inches*	*Wire Size*	
			SINGLE-BAND OPERATION					
2.0	3A	0	70	26	3 1/2	1 3/4	16 (dcc)	Close-wound.
3.5	3A	0	17	22	1 3/8	1 1/2	18	War-surplus tuning coil.
7.0	3B	--	0	Short Circuit				
14	3E	0	1.4	11	2 5/8	2 3/8	12	Coax tap 3 turns from ground end.
21	3D	35 (APC Type)	1.4	8	1 1/4	7/8	16	Miniductor, coax tap 2 turns from ground end.
28	3B	--	0	Short Circuit				SWR rather high. Fig. 3D or Fig. 3E should be used if lower SWR is desired.
			TWO-BAND OPERATION (LOW-FREQUENCY TRAPS)					
2-7	1 $H_2=0$	1000	4	9	2 1/2	1	16	Miniductor, not fully evaluated. Other *L/C* ratios have not been tried.
3.5-7	1 $H_2=0$	500	2.5	11	1 3/8	1 1/8	18	War-surplus coil.
3.5-7	1 $H_2=0$	1000	0.7	6	5/8	1 1/2	16	Miniductor. Location of leads very critical.

Note: Inductance values of coils determined from dimensions by use of ARRL lightning Calculator.
Coils are space-wound except for 2-MHz coil, as noted.

carried out with no other kind of measurement. However, when resonance approaches the desired frequency it is necessary to be more careful: Use a frequency source of higher stability, observe both forward and reflected power, and calculate the SWR first just at one frequency at the nearest band edge and then, finally, at various frequencies throughout the band. For this purpose the writer uses a transmitter and, often, a reflectometer-type detector instead of the bridge type.

Unexpected spurious resonances, in addition to the expected one, sometimes are observed. These usually occur at low frequencies, at which line losses are rather low even with impedance mismatches, and at which the length of the transmission line is close to 1/4 or 3/4 wavelength. They result from having the transmission line act as a tuned feeder, and may be distinguished by connecting in an extra length (20 feet or more) of line; if the dip in reflected power then occurs at a significantly different frequency the resonance is a spurious one.

The resonant frequency which has just been discussed is the one which is more critically dependent upon trap adjustment (f_1 for a low-frequency trap or f_2 for a high-frequency trap). The SWR at the other frequency (f_2 for a low-frequency trap or f_1 for a high-frequency trap) next should be checked. In most cases it is likely to be acceptable if the original antenna length is close to the self-resonant length. If it is not acceptable, it is necessary to (1) readjust the length of one or both sections, or (2) use a trap with a different capacitance and therefore a different *L/C* ratio. The writer has only changed the *L/C* ratio, in his own experience, but the earlier remarks should be helpful in providing guidance as to whether the second capacitance should be larger or smaller than the previous one. Ultimately, by a succession of readjustments the performance of the antenna can be optimized at both frequencies. If the antenna is close to self-resonance at one of the frequencies, usually a second *L/C* ratio need not be tried, but if the antenna is somewhat shorter and auxiliary loading must be employed the adjustments are very critical, and the process can become very tedious.

In principle, the whole adjustment procedure can be accomplished with a transmitter having a built-in reflectometer-type standing-wave detector, and in practice this may be done if the antenna is initially resonant close to the desired frequencies. However, in other cases such a procedure may be undesirable. If the bandwidth of the antenna is narrow and if the initial resonant frequency is far from any which may be reached with the transmitter, the SWR is very high and it is difficult to tell whether any readjustment is causing an improvement or not. And one cannot tell how many MHz frequency shift is produced per turn removed from a coil, and the trimming operation may become unnecessarily tedious. Also, it may be difficult to recognize spurious resonances. If a constant frequency is used the SWR should remain constant (with lossless transmission lines) when extra line is added if the resonance is a desired one, but should change if the resonance is spurious. However, losses in the line may cause such a procedure to be undefinitive.[10]

The preceding discussion has been concerned only with reactance adjustments and has ignored resistance, although the change of *L/C* ratio undoubtedly affects the resistance match. In cases where circuits like Figs. 3D and 3E (see Part I) – or other schemes like gamma matches which

[10] The apparent SWR also can change with line length if there is rf current on the outside of the coax line.

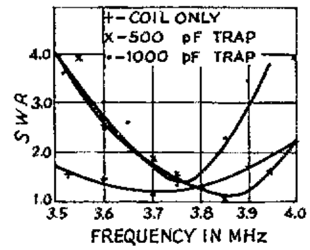


Fig. 6 — Standing-wave ratio of 40-foot vertical antenna as a function of the 4-MHz band frequency with various types of loading. In this graph and in Figs. 7 and 8, no correction has been made for losses in the line, about 50 feet of RG-58/U.

provide for a transformation of resistance – are used it is desirable still to find the resonant frequency and adjust it to be the desired one as described previously. Then proceed to adjust the resistance transformation to obtain an SWR close to 1 to 1. In Figs. 3D and 3E this is mainly determined by the position of the tap to which the line is connected. It is likely, of course, that there will be a small interaction with the resonant frequency, and it may be necessary to make a minor change in the position of the other tap.

Some Practical Applications

Most of the theoretical ideas which have been described have been applied to a versatile vertical antenna which, for the last seven years, has been used with lengths varying between 15 and 40 feet and with both base and body loading. However, in recent years operation has settled upon the use of 40 feet with base loading during the winter, and upon 25 feet during the summer with a high-frequency trap 10 feet above the ground for 7 and 14 MHz, plus auxiliary base loading for 4 MHz.

In the summer, the guys that are required for the 40-foot antenna get in the way of gardening activities, and at that time the lower frequencies are used only for local contacts; also, the 25-foot antenna does not need guying, thus this shorter length seems to be a better overall compromise.

The "Winter" 40-Foot Vertical Antenna

The top 16 feet of the "winter" antenna is a war-surplus tank whip antenna, which probably could be replaced by an 8-foot mobile whip joined to a section of aluminum electrical conduit. The remainder of the antenna is composed of 1 1/4-inch diameter television mast sections. To prevent intermittent contacts when the wind blows, it is necessary to put electrical jumpers, consisting of strips of aluminum, held with hose clamps, at the junctions of the mast sections.

The junction between the whip and the top section of the mast is made as follows: Four longitudinal cuts 8 inches long are made with a hacksaw in the end of the mast, dividing it into eight strips. Four alternate ones are removed. Two concentric pieces of plastic garden hose, about 1 foot long, are slipped over the end of the whip, and a small clamp is fastened to the whip just where it

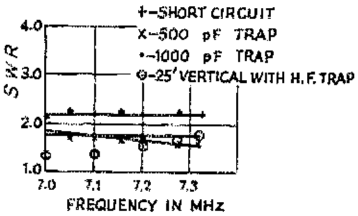


Fig. 7 — Standing-wave ratios of a 40-foot vertical antenna with various types of loading, and of a 25-foot vertical antenna as a function of frequency in the 7-MHz band.

emerges from the plastic tubing to restrain it from sliding in any further. The end of the whip is about 1 inch inside the tubing. The outside diameter of the plastic tubing is slightly smaller than the inside diameter of the TV mast. A hole is drilled an inch or two below the ends of the strips and a machine screw is put through this hole to keep the tubing from sliding farther into the mast. When the upper assembly is slid into the mast as far as it will go, the dimensions are such that the tubing extends an inch or two above the ends of the strips. Then two hose clamps are used to squeeze the ends of the strips down tightly on the tubing. The total capacitance – capacitor and whip – is about 85 pF, and this assembly can act as the capacitor of a high-frequency trap, for use in the "summer" antenna. With the "winter" antenna the capacitor is shorted out by a thin strip of aluminum, which is held under the various clamps already present.

The antenna is supported by a wood 2-by-4 which has been buried in the ground about 4 feet. The antenna is held on the wood by U bolts. No insulation other than the wood is provided for the mounting. Also mounted on the wood are some insulated banana jacks in which base-loading networks and a ground terminal may be plugged.

Before the wood was buried, a piece of metal foil was tacked to the bottom, and a lead to it forms part of the grounding system. In addition there are two 66-foot and four 33-foot radials buried in the ground. The coax lead is also buried, and might be considered as an additional radial. These wires make irregular angles because of numerous obstructions – large rocks, flower beds, and a neighbor's fence.

To learn something about the effect of radials, the writer carried out an experiment with two 33-foot pieces of wire. At both 3.5 and 7 MHz a very small but definite change in SWR was observed when one piece of wire was laid out and connected as a radial in addition to the mast ground and coax already in place. A second approximately-equal change in the SWR was observed when the second piece of wire was connected as an additional radial. However, when the two wires were connected in series to form a single 66-foot radial, there was no change over that caused by a single 33-foot piece. At 3.5 MHz this last observation was rather surprising, since 66 feet at this frequency is a quarter wavelength, and with a voltage antinode at the free end a voltage node should be expected at the point of connection; this node could be expected to make a significant improvement in the effective ground. Instead, the experiment seemed to strongly suggest that it is more important to have a large number of short nonresonant radials than a smaller number of resonant ones.[11]

A larger number of loading arrangements have been tried with this antenna, and nearly all were successful. The principal ones used now are shown in Table I.

SWR curves for various kinds of loading are shown in Fig. 6 for the 3.5-MHz band; in Fig. 7 for 7 MHz. Fig. 8 shows 14-MHz SWR curves for the 40-foot vertical antenna with base loading, the 25-foot vertical antenna with a high-frequency trap, and the commercial three-element triband beam used by the writer. It is to be noted that the behavior at 3.5 MHz is in accordance with the earlier discussion: The bandwidth with single-band loading is much broader, and the bandwidth decreases with increasing trap capacitance. With the 40-foot antenna at 7 MHz, the SWR is lower with either trap present than with a short circuit. This result is to be expected, as 40 feet is longer than a quarter wavelength, and a small amount of capacitive reactance, as supplied by a suitable trap, is required to bring it to resonance. Probably an intermediate value of capacitance, about 750 pF, would have given a still lower ratio. An experimental trap using 200 pF gave a very poor SWR at 7 MHz. At 14 MHz it is to be observed that the beam has a much narrower bandwidth than either vertical, undoubtedly due to the reaction of the parasitic elements.

On the air, this antenna has been used to make numerous East Coast contacts on 1.8-MHz cw. On 3.5 MHz, numerous Japanese, Hawaiian, and West Indian contacts have been made, and on 7 MHz, numerous DX contacts have been made all over the world. On 14 MHz, the antenna has sometimes rivaled the 3-element beam. Indeed, at times there is a diversity effect where for a short time one is better, and then a few minutes later the other is better. However, in the long run the beam seems to be the better of the two. This antenna has not been very well evaluated on 21 and 28 MHz, as only a few contacts have been made.

The 25-Foot "Summer" Vertical

In summer, the overall length is reduced to 25 feet by removing some of the TV mast sections, leaving a height of 10 feet to the point where the

[11] This is consistent with the findings of Brown, Lewis and Epstein in a classic paper, "Ground Systems as a Factor in Antenna Efficiency," *Proc. IRE*, June 1937, the conclusions of which are summarized briefly in *The A.R.R.L. Antenna Book*, Chapter 2 (page 61 in the Eleventh Edition).

It is to be remembered that a 33-foot piece of wire is approximately one-quarter wavelength at 7 MHz only when the wire is in free space. When the wire is on the surface of the ground or buried in it the wavelength is greatly fore-shortened, and 33 feet may correspond to a much larger number of wavelengths.

When the length of the antenna H becomes comparable to a half wavelength the effect of the grounding system is likely to become very unimportant, and the system may even be omitted with little deterioration of performance.

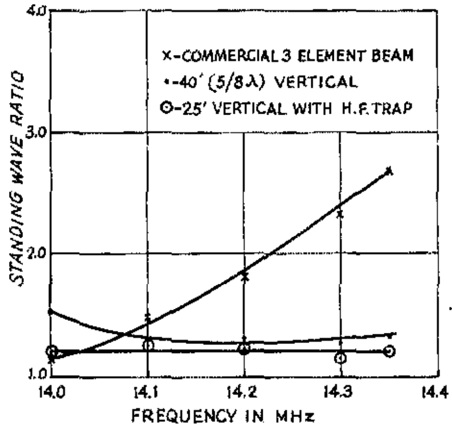


Fig. 8 — Standing-wave ratios of 40-foot vertical, 25-foot vertical, and commercial three-element triband beam as functions of frequency in the 14-MHz band.

whip is mounted. An inductor is connected in parallel with the capacitor incorporated between the two sections of the antenna. Originally this was a Miniductor, 1 1/4 inches in diameter with 16 turns per inch, and was intended to provide monoband body loading. Ten turns were used for 7 MHz, 28 turns for 4-MHz phone, and 35 for 3.5-MHz cw.

However, it was a nuisance to take the antenna down to change the loading, and it became the established practice to leave the tap set for 7 MHz and achieve 3.5-MHz operation by using an auxiliary loading coil at the base. For this purpose a war-surplus coil having 26 turns of No. 18 spaced to a length 1 3/8 inch on a 1 1/4-inch diameter form (about 14 μH) is used. Furthermore, it was discovered that by pure accident the 10-turn tap also gave an SWR minimum at 14 MHz. In other words, with this coil a two-band high-frequency trap was obtained. More recently, since it has been decided to obtain 3.5-MHz operation by use of auxiliary loading, the Miniductor has been replaced by a coil of 12 turns of No. 18 plastic-covered bell wire close-wound on a 1 1/8-inch diameter pill bottle. This is equivalent to the 10-turn tap, and mechanically it is more rugged.

Operation on 28 and 21 MHz may be achieved by using the networks shown in Table I, but with minor readjustment in some cases. Also, the traps shown in Table I may be used, making the antenna a three-band affair. At 28 MHz, a capacitance of 65 pF (Fig. 3C) should be used.

On 3.5 MHz this antenna has been used only for local contacts. On 7 MHz a number of Japanese and Australian stations have been worked, and on 14 MHz a number of DX contacts all over the world have been made. Evaluation on 21 and 28 MHz is very scant, but on 21 MHz a number of East Coast USA contacts have been made without much trouble.

Any comparison between the 40- and 25-foot antennas must be subjective, and it is the author's opinion that while the 25-foot one is adequate as a standby and for making local contacts, on DX it is noticeably inferior.

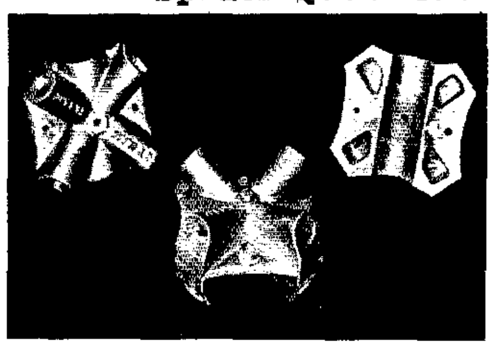
This 25-foot antenna demonstrates the use of a high-frequency trap as a device to produce a capacitive reactance just compensating for the upper 15 feet of the antenna. The whole 25 feet are participating in producing the radiation.

Conclusion

The antennas which have been described have not been completely evaluated on all bands, and the effects of moving the location of a trap have not been investigated. Although not discussed above, experiments with a 40-foot horizontal dipole using a low-frequency trap pair, for two-band operation on 3.5 and 7 MHz, demonstrated again the theory which has been outlined. However, in spite of such omissions the author believes that sufficient information has been given for the reader to understand how trap loading works, and to design and adjust antennas to suit his own needs. QST

• New Apparatus

The VK3ASC Spider-Quad Hub



THERE ISN'T much argument that a triband quad antenna with optimum — spaced elements is the best way to go when building a cubical quad. However, the clinker in such a design is how to do the job, and do it simply. It appears that VK3ASC has come up with one answer to the problem — a well-designed hub for mounting the spiders so that the quad elements can be proportionally spaced.

The unit shown is made from heavy cast aluminum and can be mounted on a mast whose diameter can be large as 1 3/4 inches. The take-off angle for the spreaders is approximately 22 degrees, referenced against the plane of the mast. This works out to a spacing of 10 feet, 6 inches on 20 meters, 7 feet on 15 meters, and 5 feet, 4 inches on 10 meters. The spreader support holes are 1-inch in diameter, so any bamboo or fiber glass poles with that butt dimension can be used. Net weight of the hub assembly is 4 pounds, 6 ounces, and it measures 6 x 6 x 5 inches. Cost of the complete unit is $16.00 (Australian funds), postpaid, to any point in the world. The hubs can be ordered directly from Syd Clark, VK3ASC, 26 Bellevue Ave., Victoria, 3084, Australia. — *W1ICP*