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OPTIMAL VERTICAL ANTENNA LOADING TECHNIQUES

The author discusses the various techniques used to load vertical antennas. From the viewpoint of reasonable performance, ease of construction and bandswitching, a combination of top and base loading is favored. The construction of a pratical antenna is illustrated.

Many amateurs are faced with antenna placement situations which do not allow the erection of full-sized antennas. A loaded type of vertical antenna is often the only antenna possibility. Often, even a trap-type vertical cannot be used on the lower frequency bands because of the size of such an antenna and its support requirements. The only choice then is to use as long a vertical antenna as possible with as much loading inductance as necessary to resonate the antenna on a desired band. The physical length of such an antenna may be 1/6 or less of the electrical length it represents through inductive loading.

The subject of how to produce efficient, extremely short-loaded antennas has been the subject of numerous studies by commercial and military organizations. The purpose of this discussion is not to delve into the more advanced techniques which have been developed since such techniques often require special construction and special equipment for a relatively small gain in antenna efficiency. This approach may be necessary in some situations where the capacity of the power supply for a portable transmitter is limited and the only possibility to improve the radiated signal is through increased antenna efficiency. In the amateur case, and particularly for the newcomer who starts with a low-power transmitter, it is often easier and more economical to first try increasing the transmitter output level (via an inexpensive linear amplifier, for instance) rather than getting involved with complicated antenna construction projects. Therefore we will discuss only the simple forms of antenna loading which have been well proved and which are easy to build. The material is particularly oriented toward the newcomer who would like to construct a simple loaded type of vertical antenna that will give reasonable results on one or more high-frequency bands.

Loading Variations

A full-length quarter-wave antenna will have the current distribution shown in Fig. 1A. If the physical length of the antenna is made shorter than the required electrical length, a loading inductor can be used to establish the correct electrical length. When this is done, the current distribution may appear different than in Fig. 1A, depending upon where the loading inductor is placed. If the loading inductor could be distributed over the entire length available for the antenna (helical loading) the current distribution would look the same (Fig. 1B). Placing the loading inductor either at the extreme top or bottom of the antenna will

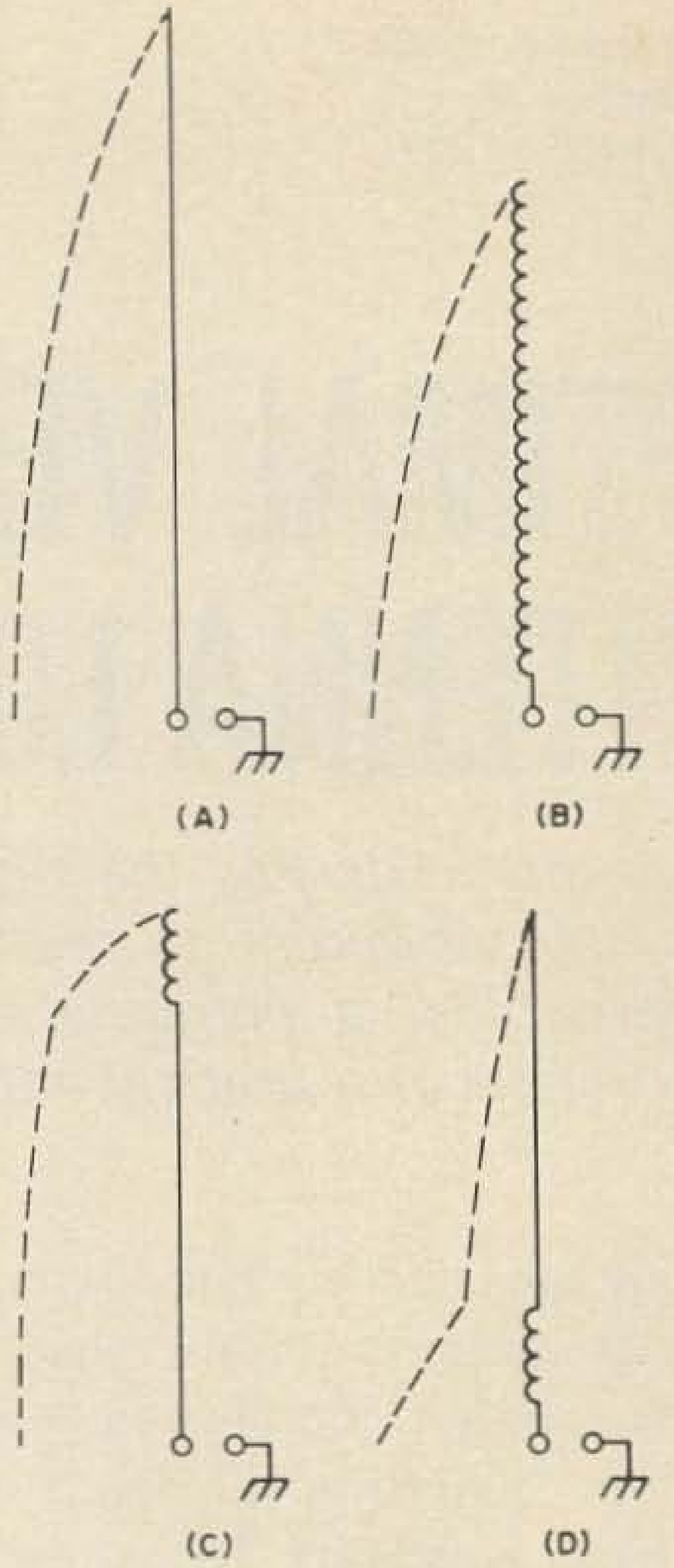

Fig. 1. The dotted lines show the current distribution on a full length ¼λ vertical antenna (A) and various forms of physically shorter, inductively loaded antennas.

produce the current distributions shown in Figs. 1C and 1D. Various points can be advanced for either top or bottom loading. Top loading has the advantage that the greatest current flow will take place in the metal rod section of the antenna and, therefore, less I^2R losses will take place in the loading inductor on top. Bottom loading has the advantage that the loading inductor can easily be bandswitched. Also, if the loading inductor is constructed of heavy enough wire, the losses can be held to a tolerable level.

Aside from placing the loading inductance either at the extreme top or bottom of the antenna, one could also place the loading inductance at the center of the antenna or place a portion of the inductance at the top and a portion at the bottom of the antenna. The current generation of mobile antennas generally uses center loading because of a

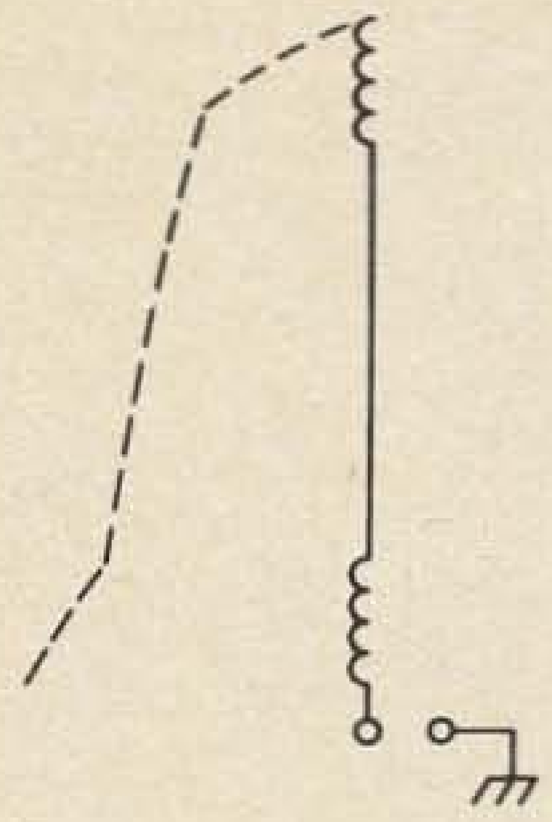

Fig. 2. Splitting the inductive loading to both ends of the antenna produces the current distribution shown.

combination of electrical and mechanical factors. The loading inductor need not be as heavy as a base-loading inductor to keep losses to a reasonable level, and the physical placement of the inductor allows a flexible upper section for the antenna, as well as access to the inductor for bandswitching by changing inductors. However, for home-station usage, the proper placement of part of the loading inductance at the top and bottom of the antenna, as shown in Fig. 2, has a better combination of electrical and mechanical advantages. The placement of part of the loading inductance at the base does not optimize the situation where the highest current flow is through the metal rod of the antenna, but it is also true in a practical situation that the most severe ground losses would still take place at the base of the antenna. So the actual increased loss that results as compared to solely top loading the antenna is a small price to pay for the convenience factors involved in bandswitching and impedance matching the antenna to a transmission line. The top loading that is used insures that a good portion of the highest current flow will take place in the metal rod.

Finally, the splitting of the loading inductance between the base and the top of the antenna greatly simplifies construction of the antenna for home station usage where a single long aluminum or steel piece of tubing is used as the main element of the antenna.

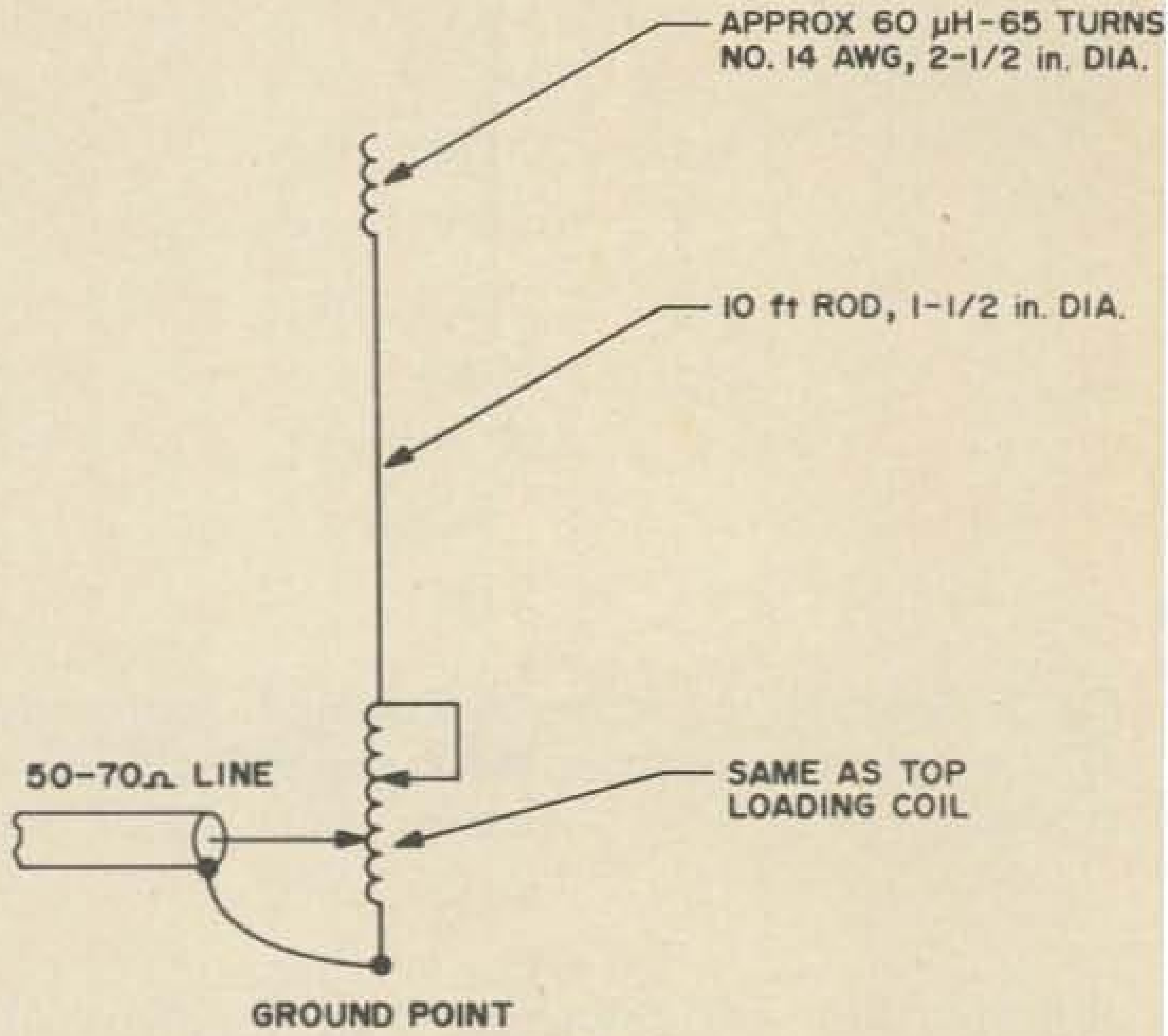

Fig. 3. Dimensions and coil sizes for 80/40m antenna.

Practical Example

Figure 3 shows a simple antenna using a 10 ft aluminum rod and top and base loading which I constructed for use on 80 and 40m. The maximum amount of top loading was utilized that would still permit enough base loading to be present on 40m so a coaxial transmission line could be tapped on the base-loading inductance for a proper impedance match. For the 10 ft rod, this meant a maximum top-loading inductance of about 60 μH. Since the top loading is fixed, this meant that the base-loading inductance has to be increased as necessary on 80m to resonate the antenna. Again, about 60 μH is necessary. The coil dimensions shown in Fig. 2 are those for which B&W or Air Dux coil stock is available. If possible, it would be desirable to increase the diameter-to-length ratio of one or both coils (maintaining the same inductance) so that the diameter is about half the coil length. This would raise the Q and improve the overall antenna efficiency. Such construction would make it more difficult to tap the transmission line on the base-loading coil but it should be easy to implement for the top-loading coil. The top-loading coil used is a salvaged coil from a commercial trap-type vertical antenna. The necessary loading inductances for other bands or with other lengths of tubing can either be calculated from handbook data or it can be easily experimentally determined. In the latter case, the maximum amount of top-loading inductance is used on the highest frequency band that still allows a sufficient amount of base-loading to permit matching the transmission line. The base loading is then increased as necessary to resonate the antenna on the lower frequency band.

An swr meter is the only instrument necessary to adjust the antenna. Starting on the highest frequency band, the minimum amount of inductance is used in the base coil that permits the transmission line to be tapped on with a 1:1 swr. On the lower frequency band, the base coil tap is first changed to bring the swr down and then the transmission line tap readjusted to finally lower the swr. It may be possible to find a compromise tap point for the transmission so its position does not have to be changed when changing bands. The actual changing of the coil or transmission line taps can be done with relays or manually with clips, as desired.

Summary

No simple, short-loaded antenna will be extremely efficient on the lower frequency bands. However, the antenna described will work reasonably well for its size and it is a practical solution for a simple to construct and inexpensive antenna where space is limited. One point that should be carefully observed in installing the antenna is to provide a good ground connection either in the form of radials or connection to some large metal structure. If no ground connection possibility exists where it is desired to install the antenna and no room exists for radials, two antennas with similar loading coil arrangements can be combined to form a vertical dipole, or they can even be mounted at right angles to each other in the form of an L.

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