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A 6-FOOT-HIGH 7-MHZ VERTICAL ANTENNA

The following material was extracted from earlier editions. Figure and Equation sequence references are those from the 21st edition of *The ARRL Antenna Book*

Figs 64 through 67 give details for building short, effective vertical quarter-wavelength radiators. This information was originally presented by Jerry Sevick, W2FMI.

A short vertical antenna, properly designed and installed, approaches the efficiency of a full-size resonant quarter-wave antenna. Even a 6-foot vertical on 7 MHz can ommended for best results, although the builder may elect to reduce the number at the expense of some performance. The radials can be tensioned and pinned at the far ends to permit on-the-ground installation, which will enable the amateur to mow the lawn without the wires becoming entangled in the mower blades. Alternatively, the wires can be buried in the ground, where they will not be visible. There is nothing critical about the wire size for the radials. Radials made of 28, 22, or even 16-gauge wire, will provide the same results. The radials should be at least 0.2 λ long (27 feet or greater on 7 MHz).

A top hat is formed as illustrated in **Fig 65**. The diameter is 7 feet, and a continuous length of wire is connected to the spokes around the outer circumference of the wheel. A loading coil consisting of 14 turns of B&W 3029 Miniductor stock (2½-inch dia, 6 TPI, #12 wire) is installed 6 inches below the top hat (see Fig 65). This antenna exhibits a feed-point impedance of 3.5 Ω at 7.21 MHz. For operation above or below this frequency, the number of coil turns must be decreased or increased, respectively. Matching is accomplished by increasing the feed-point impedance to 14 Ω through addition of a 4:1-transformer, then matching 14 Ω to 50 Ω (feeder impedance) by means of a pi network. The 2:1 SWR bandwidth for this antenna is approximately 100 kHz.

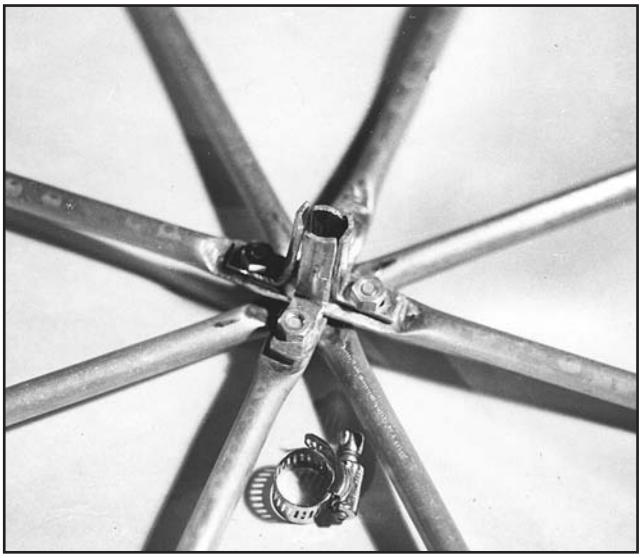

Fig 65—Construction details for the top hat. For a diameter of 7 feet, ½-in. aluminum tubing is used. The hose clamp is made of stainless steel and is available at Sears. The rest of the hardware is aluminum.

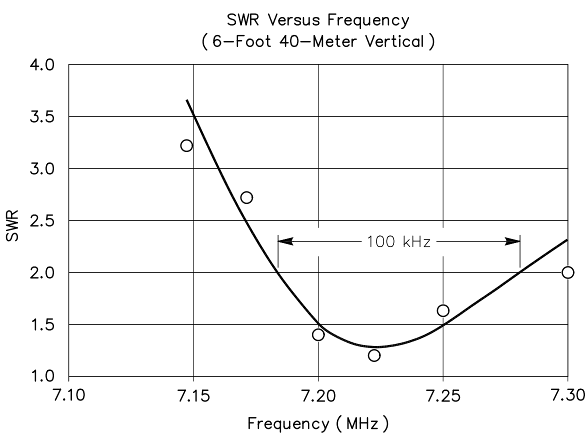

Fig 66—Standing-wave ratio of the 6-foot vertical using a 7-foot top hat and 14 turns of loading 6 inches below the top hat.

More than 200 contacts with the 6-foot antenna have indicated the efficiency and capability of a short vertical. Invariably at distances greater than 500 or 600 miles, the short vertical yields excellent signals. Similar antennas can be scaled and constructed for bands other than 7 MHz. The 7-foot-diameter-top hat was tried on a 3.5-MHz vertical, with an antenna height of 22 feet. The loading coil had 24 turns and was placed 2 feet below the top hat. On-the-air results duplicated those on 40-meters. The bandwidth was 65 kHz.

Short verticals such as these have the ability to radiate and receive almost as well as a full-size quarter-wave. Trade-offs are in lowered input impedances and bandwidths. However, with a good radial system and a proper design, these trade-offs can be made entirely acceptable.

Short Continuously Loaded Verticals

While there is the option of using lumped inductance to achieve resonance in a short antenna, the antenna can also be helically wound to provide the required inductance. This is shown in **Fig 68**. Shortened quarter-wavelength vertical antennas can be made by forming a helix on a long cylindrical insulator. The diameter of the helix must be small in terms of λ to prevent the antenna from radiating in the axial mode.

Acceptable form diameters for HF-band operation are from 1 inch to 10 inches when the practical aspects of antenna construction are considered. Insulating poles of fiberglass, PVC tubing, treated bamboo or wood, or phenolic are suitable for use in building helically wound radiators. If wood or bamboo is used the builder should treat the material with at least two coats of exterior spar varnish prior to winding the antenna element. The completed structure should be given two more coats of varnish, regardless of the material used for the coil form. Application of the varnish will help weatherproof the antenna and prevent the coil turns from changing position.

No strict rule has been established concerning how short a helically wound vertical can be before a significant drop in performance is experienced. Generally, one should use the greatest amount of length consistent with available space. A guideline might be to maintain an element length of 0.05 wavelength or more for antennas which are electrically a quarter wavelength long. Thus, use 13 feet or more of stock for an 80-meter antenna, 7 feet for 40 meters, and so on.

A quarter-wavelength helically wound vertical can be used in the same manner as a full-size vertical. That is, it can be worked against an above-ground wire radial system (four or more radials), or it can be ground-mounted with

Fig 67—Base of the vertical antenna showing the 60 radial wires. The aluminum disc is 15 inches in diameter and ¼ inches thick. Sixty tapped holes for ¼-20 aluminum hex-head bolts form the outer ring and 20 form the inner ring. The inner bolts were used for performance comparisons with more than 60 radials. The insulator is polystyrene material (phenolic or Plexiglas suitable) with a 1-inch diameter. Also shown is the impedance bridge used for measuring input resistance.

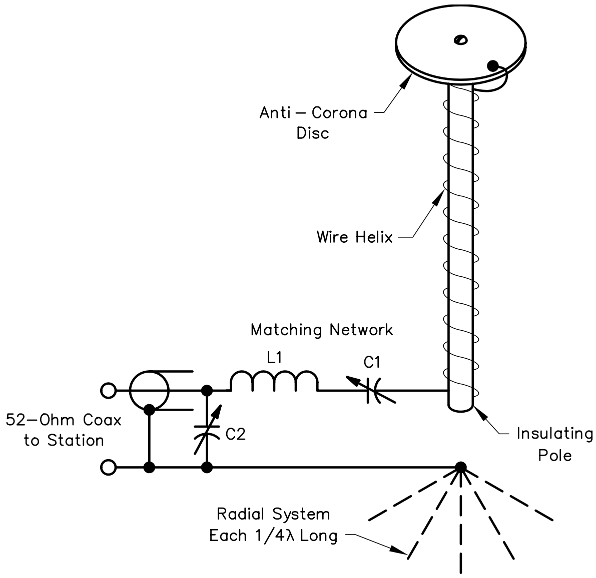

Fig 68—Helically wound ground-plane vertical. Performance from this type of antenna is comparable to that of many full-size λ/4 vertical antennas. The major design trade-off is usable bandwidth. All shortened antennas of this variety are narrow-band devices. At 7 MHz, in the example illustrated here, the bandwidth between the 2:1 SWR points will be on the order of 50 kHz, half that amount on 80 meters, and twice that amount on 20 meters. Therefore, the antenna should be adjusted for operation in the center of the frequency band of interest.

radials buried or lying on the ground. Some operators have reported good results when using antennas of this kind with four helically wound radials cut for resonance at the operating frequency. The latter technique should capture the attention of those persons who must use indoor antennas.

Winding Information

There is no hard-and-fast formula for determining the amount of wire needed to establish resonance in a helical antenna. The relationship between the length of wire needed for resonance and a full quarter wave at the desired frequency depends on several factors. Some of these are wire size, diameter of the turns, and the dielectric properties of the form material, to name a few. Experience has indicated that a section of wire approximately one half wavelength long, wound on an insulating form with a linear pitch (equal spacing between turns) will come close to yielding a resonant quarter wavelength. Therefore, an antenna for use on 160 meters would require approximately 260 feet of wire, spirally wound on the support.

No specific rule exists concerning the size or type of wire one should use in making a helix. Larger wire sizes are, of course, preferable in the interest of minimizing I^2R losses in the system. For power levels up to 1000 W it is wise to use a wire size of #16 or larger. Aluminum clothesline wire is suitable for use in systems where the spacing between turns is greater than the wire diameter. Antennas requiring close-spaced turns can be made from enameled magnet wire or #14 vinyl jacketed, single-conductor house wiring stock. Every effort should be made to keep the turn spacing as large as is practical to maximize efficiency.

A short rod or metal disc should be made for the top or high-impedance end of the vertical. This is a necessary part of the installation to assure reduction in antenna Q. This broadens the bandwidth of the system and helps prevent extremely high amounts of RF voltage from being developed at the top of the radiator. (Some helical antennas act like Tesla coils when used with high-power transmitters, and can actually catch fire at the high-impedance end when a stub or disc is not used.) Since the Q-lowering device exhibits some additional capacitance in the system, it must be in place before the antenna is tuned.

Tuning and Matching

Once the element is wound it should be mounted where it will be used, with the ground system installed. The feed end of the radiator can be connected temporarily to the ground system. Use a dip meter to check the antenna for resonance by coupling the dipper to the last few turns near the ground end of the radiator. Add or remove turns until the vertical is resonant at the desired operating frequency.

It is impossible to predict the absolute value of feed impedance for a helically wound vertical. The value will depend upon the length and diameter of the element, the ground system used with the antenna, and the size of the disc or stub atop the radiator. Generally speaking, the radiation resistance will be very low—approximately 3 to 10 Ω. An L network of the kind shown in Fig 68 can be used to increase the impedance to 50 Ω. The Q_L (loaded Q) of the network inductors is low to provide reasonable bandwidth, consistent with the bandwidth of the antenna. Network values for other operating bands and frequencies can be determined by using the reactance values listed below. The design center for the network is based on a radiation resistance of 5 Ω. If the exact feed impedance is known, the following equations can be used to determine precise component values for the matching network. (See Chapter 25, Coupling the Transmitter to the Line, for additional information on L-network matching.)

XA QRL (Eq 7)

$$X_{C2} = 50\sqrt{\frac{R_L}{50 - R_L}} \quad \text{(Eq 8)}$$

$$X_{L1} = X_{C1} + \frac{R_L 50}{X_{C2}} \quad \text{(Eq 9)}$$

where

X_{C1} = capacitive reactance of C1
X_{C2} = capacitive reactance of C2
X_{L1} = inductive reactance of L1
Q = loaded Q of network
R_L = radiation resistance of antenna

Example: Find the network constants for a helical antenna with a feed impedance of 5 Ω at 7 MHz, Q = 3:

$$X_{C1} = 3 \times 5 = 15$$

$$X_{C2} = \sqrt{\frac{5}{50 - 5}} = 16.666$$

$$X_{L1} = 15 + \frac{250}{16.666} = 30$$

Therefore, C1 = 1500 pF, C2 = 1350 pF, and L1 = 0.7 µH. The capacitors can be made from parallel or series combinations of transmitting micas. L_1 can be a few turns of large Miniductor stock. At RF power levels of 100 W or less, large compression trimmers can be used at C1 and C2 because the maximum RMS voltage at 100 W (across 50 Ω) will be 50 V. At, say, 800 W there will be approximately 220 V RMS developed across 50 Ω. This suggests the use of small transmitting variables at C1 and C2, possibly connected in parallel with fixed values of capacitance to constitute the required amount of capacitance for the network.

By making some part of the network variable, it will be possible to adjust the circuit for an SWR of 1:1 without knowing precisely what the antenna feed impedance is. Actually, C1 is not required as part of the matching network. It is included here to bring the necessary value for L1 into a practical range.

Fig 68 illustrates the practical form a typical helically wound ground-plane vertical might take. Performance from this type antenna is comparable to that of many full-size quarter-wavelength vertical antennas. The major design trade-off is in usable bandwidth. All shortened antennas of this variety are narrow-band devices. At 7 MHz, in the example illustrated here, the bandwidth between the 2:1 SWR points will be on the order of 50 kHz, half that amount on 80 meters, and twice that amount on 20 meters. Therefore, the antenna should be adjusted for operation in the center of the frequency spread of interest.