Two Small Helical Antennas for 2 Meters

With performance close to that of full sized antennas, these small helical antennas are low in profile but high in efficiency.

John E. Portune, W6NBC

Figure 1 — The two turn 2 meter base-station λ/2 helix. Height is 6 inches, diameter is 6 inches. Note the coax balun made from several turns of RG-58 coax. The mast is ½ inch PVC pipe.

Helical antennas have long been known for their excellent properties. They have not found much favor in the ham community, however, perhaps because they are more difficult to build than straight dipoles, whips or Yagis. Fortunately a less well-known, but equally high performance version of the helical antenna, the normal mode helix, is quite practical for ham construction. Best of all, it is impressively small in size and low in profile. Figure 1 shows a 2 meter base station λ/2 normal mode helix, only 6 inches high. In Figure 2, we show a λ/4 mobile helix, only 3 inches high — both made from common hardware store materials. It is also quite feasible to apply these principles to small helical antennas for HF.

There is not just one kind of helical antenna. Helices exhibit several modes. The two most common are *normal* and *axial* mode. Many hams are familiar with axial mode helical antennas. These are big corkscrew shaped direction beams, often on long booms. They use large circumference turns, wide turn spacing and a large ground plane at the feed end. Gain is axial along the boom, as the mode's name implies.

The helical antennas shown here operate in the normal or dipole mode. Circumference and turn spacing for VHF are measured in inches instead of feet. I use one of the mobiles on the roof of my recreational vehicle. It is mounted under a *radome* made from a plastic food container (see Figure 3). Before installing it, I kept knocking full sized 2 meter antennas off of the top of my vehicle.

A Classical Ham Experiment

These antennas are the result of a series of ham level cut-and-prune experiments that began one day when I simply wondered what would happen if I were to wind a full sized 2 meter λ/2 dipole (38 inches long) into a small helix. And what about doing the same with a λ/4, 19 inch spike? I knew that they would be smaller, but would they work almost as well as

their full sized straight cousins?

To find out, I made five helices (1 to 5 turns), each from roughly 38 inches, of ¼ inch aluminum tubing — a full λ/2. These helices were all self resonant. The mobile version is half of this, λ/4 of tubing. I matched all to a 1:1 SWR with small inductive loops as shown.

According to John Kraus, W8JK (SK), normal mode helices (much less than λ/2 in circumference and turn spacing) have gain perpendicular to the helix.[1] In other words, they behave like dipoles. You can visualize the pattern by imagining a full sized straight dipole lying along the center axis of the helix.

To begin investigating their performance as replacements for full sized dipoles and monopoles, I used *EZNEC* to model the radiation patterns.[2] I was amazed how little difference there was. All five had much the same gain and radiation pattern. Figure 4 shows the elevation patterns for the total field of the 2 meter, two turn λ/2 helix compared to a full sized linear dipole. Figure 5 shows a similar comparison of the λ/4 version.

So to answer my first question, a small λ/2 helix has only minimally less gain (about 0.4 dB less) and slightly shallower nulls than a full sized dipole. The same is true for a λ/4 mobile monopole. Yet they have much the same radiation pattern. Azimuth patterns are not shown since they are essentially omnidirectional for the vertical orientation.

There is one major difference, however — polarization. The electric (E) and magnetic (H) fields in a small helix trade places compared to a dipole. The same is also true for a single turn compact transmitting loop. Polarization is
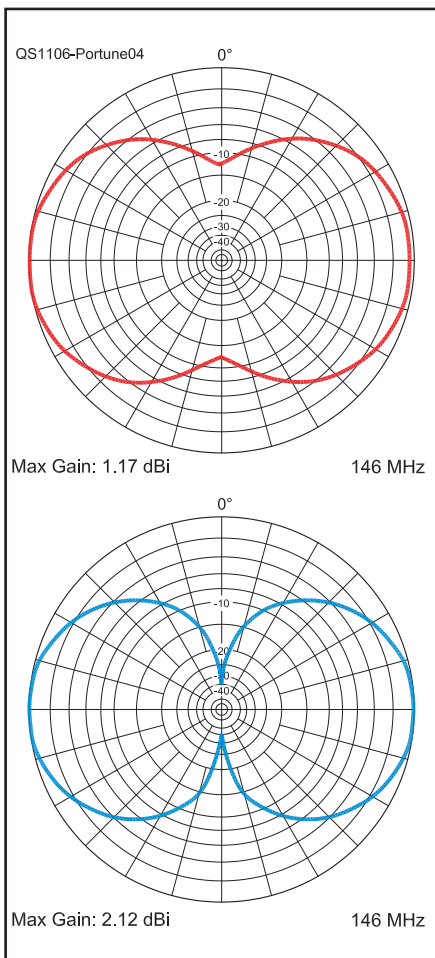
[1]Notes appear on page 00.
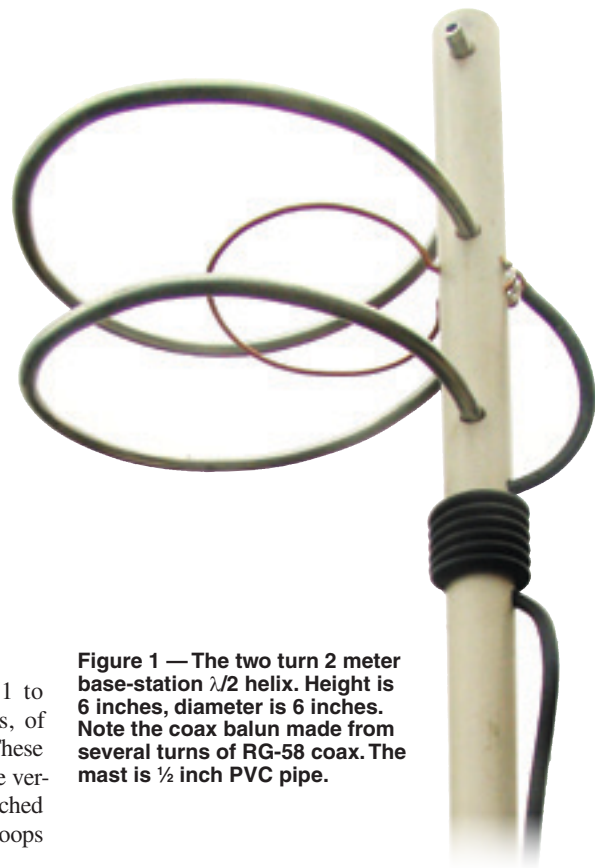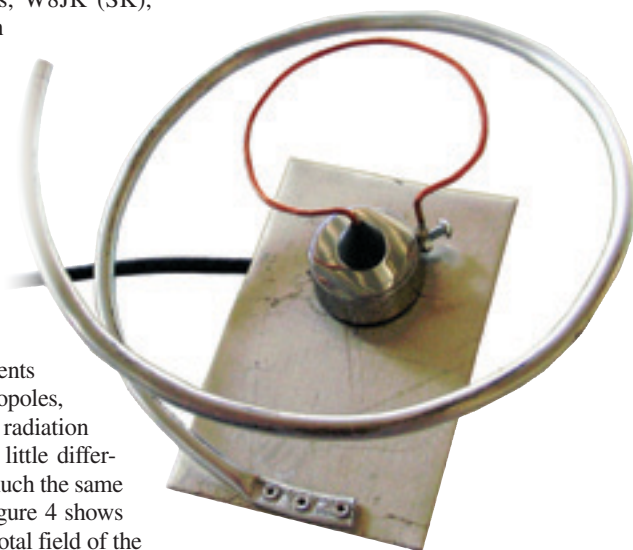
Figure 2 — The 1¼ turn low profile 2 meter grounded λ/4 mobile helix on a modified NMO mount. Height is 3 inches, diameter 6 inches.

rotated 90°. A helix, though, has an advantage here. It is also somewhat circularly polarized. The degree depends on the height to diameter ratio. Hence how one mounts a helix is not as critical as for a linearly polarized antenna. This is useful on bands such as our VHF, UHF and 10 meter bands, in which both horizontal polarization (for SSB) and vertical polarization (for FM) are in use.

This is a two edged sword. The good news is that it provides the flexibility to work stations using either vertically polarized (FM)
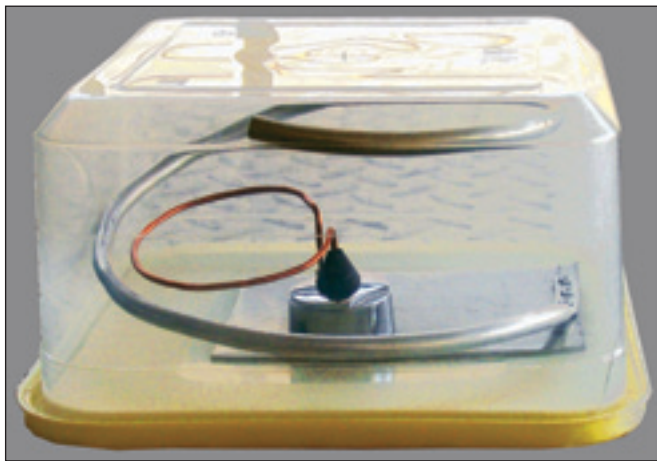
Figure 3 — Grounded mobile λ/4 helix on top of my RV, mounted under a plastic food container radome.

Max Gain: 5.55 dBi   146 MHz

Max Gain: 4.373 dBi   146 MHz

Figure 5 — Elevation patterns of a λ/4 vertical whip (blue) and the total field of the 2 meter λ/4 mobile helix above perfect ground (red) — typical of the body of a vehicle.

Max Gain: 1.17 dBi   146 MHz

Max Gain: 2.12 dBi   146 MHz

Figure 4 — Free space *EZNEC* elevation radiation patterns of a 2 meter λ/2 vertical dipole (blue) and the total field (red) of two turn λ/2 helix. Note how similar they are. The nulls are slightly shallower for the helix. Gains are normalized, but only differ by less than 0.5 dB.

being almost entirely circular — split evenly between right and left hand circular.

Losses

My second question was efficiency. Will one experience high loss with a small helix? As many hams know, small antennas often exhibit considerable lack of efficiency. This is due to low radiation resistance. For example, this shortcoming is common for HF mobile whips and shortened HF beams, in which radiation resistance may be only a fraction of an ohm. In a full sized antenna, however, where radiation resistance is closer to 50 Ω, efficiency is much higher.
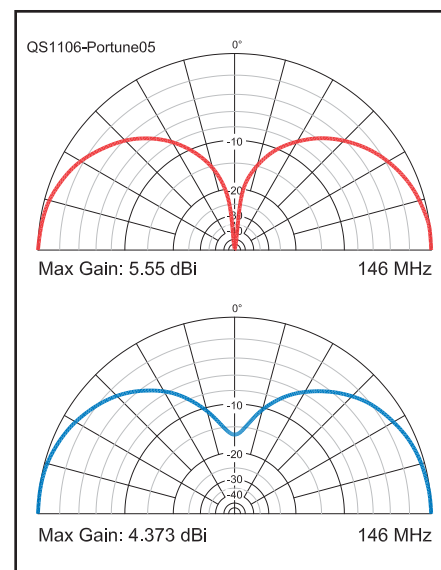
Low efficiency is caused by the fact that an antenna's radiation resistance is in series with its conductor and loss resistance. The portion that goes to radiation resistance creates the radio wave. That which goes to conductor resistance is wasted as heat. There is no exception. To give some numbers, if the radiation resistance of an antenna is exactly equal to its conductor resistance, the overall efficiency is only 50%. Half of the power is wasted. In the real world of small antennas, even greater loss is very often the case. For example, a typical coil loaded 40 meter mobile whip antenna is seldom more than 5% efficient.

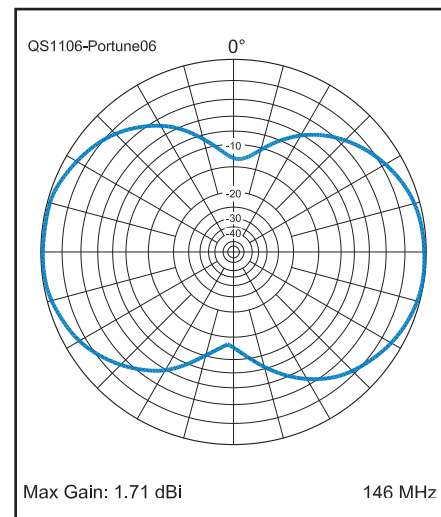Fortunately, loss in small helices can be minimized by observing two precautions:

■ Use large diameter conductors of low resistance metals — copper or aluminum, not steel, brass or stainless steel. These metals have too much resistance.

■ Keep the turns of a helix widely spaced compared to its conductor diameter.

Kraus suggests a turn spacing of at least four times conductor diameter. Closer spacing

Max Gain: 1.71 dBi   146 MHz

Figure 6 — Free space *EZNEC* azimuth pattern of a 2 meter, two turn λ/2 helix at the horizon. The total field is in blue, vertical component in red, horizontal green. The field of the λ/4 version is almost entirely vertical — good for mobile work.

or horizontally polarized (SSB, CW and AM) antennas equally well. The bad news is that each is down about 3 dB compared to a linearly polarized antenna of a single sense. The circularly polarized component is also suitable for the reception of satellite signals. Figure 6 shows the free space azimuth patterns of the λ/2 helix at the horizon including horizontal and vertical components as well as the total field. Interestingly, the dimensions of the mobile λ/2 version result in the field

increases skin effect loss. RF can't flow on the sides of conductors facing closely spaced adjacent turns. This makes the conductors seem smaller and more resistive. Hence, both antennas here have wide turn spacing, 12 times the conductor diameter. In contrast, notice my five turn test helix shown in Figure 7. It has minimum turn spacing.

So the answer to my second question is that small normal mode helices can compare favorably to full sized λ/2 dipoles and λ/4 mobile whips in efficiency.

Figure 7 — My five turn 2 meter test helix, illustrating minimum turn spacing. Note also the ferrite balun.

Bandwidth

My third concern was bandwidth. My five turn helix, for example, was more efficient but was also had a narrower bandwidth than those with fewer turns. A full sized linear dipole or monopole has a greater bandwidth.

Putting all of this together — efficiency, bandwidth, number of turns and physical size — I concluded that a two turn helix is the best choice for the base station helical antenna, and one turn for the mobile. Due to the reflection of its single turn in its ground plane, the mobile acts as if it also has two turns. These helicals are much smaller than their linear counterparts, but still exhibit acceptable SWR across the band, as shown in Figure 8.

Building the Antennas

If these helices are made from common soft aluminum or copper tubing they are almost self supporting. A single length of PVC pipe is sufficient for mounting. For the 2 meter helix I used ½ inch tubing. For 6 meters use ½ inch tubing. These tubing diameters give acceptable efficiency.

No Hard Dimensions

Unlike full sized linear antennas, which can be successfully built from cookbook plans, there are too many variables in a small helix to allow the same approach. Hence, the dimensions of Figures 9 and 10 are only guidelines. One always arrives at final dimensions during tuneup and with the antenna mounted in its final operating location.

The only fixed starting point is 40 inches of

2M 2 Turn Helix

QS1106-Portune08

Figure 8 — SWR curve of the two turn base station helix.

tubing for the base station helix and half that for the mobile. This is close to the free space λ/2 length of a linear dipole. The final total length of my helices ended up close to this. For the mobile version, add an extra inch (21 inches total) to allow for the blind rivet attachment to the aluminum plate — it acts like part of the plate — not part of the antenna.

Constructing the λ/2 Base Station Antenna

Begin by drilling an opposing set of hole pairs, 3 inches apart down the ½ inch PVC mast. See Figures 1 and 9. These maintain the turn spacing. Make them a little larger than ¼ inch to facilitate helix insertion. Also drill the holes on one side slightly lower than on the

Figure 9 — Construction details and starting dimensions for the base station helix.

Labels in figure: 6 inch, 3 inch, #12 AWG Bare Solid Copper Wire, NMO MOUNT 3 X 4 1/2 inch 12 ga Aluminum, 1/4 inch Soft Aluminum Tubing, 3 inch Turn Spacing, Coupling Loop, QS1106-Portune09
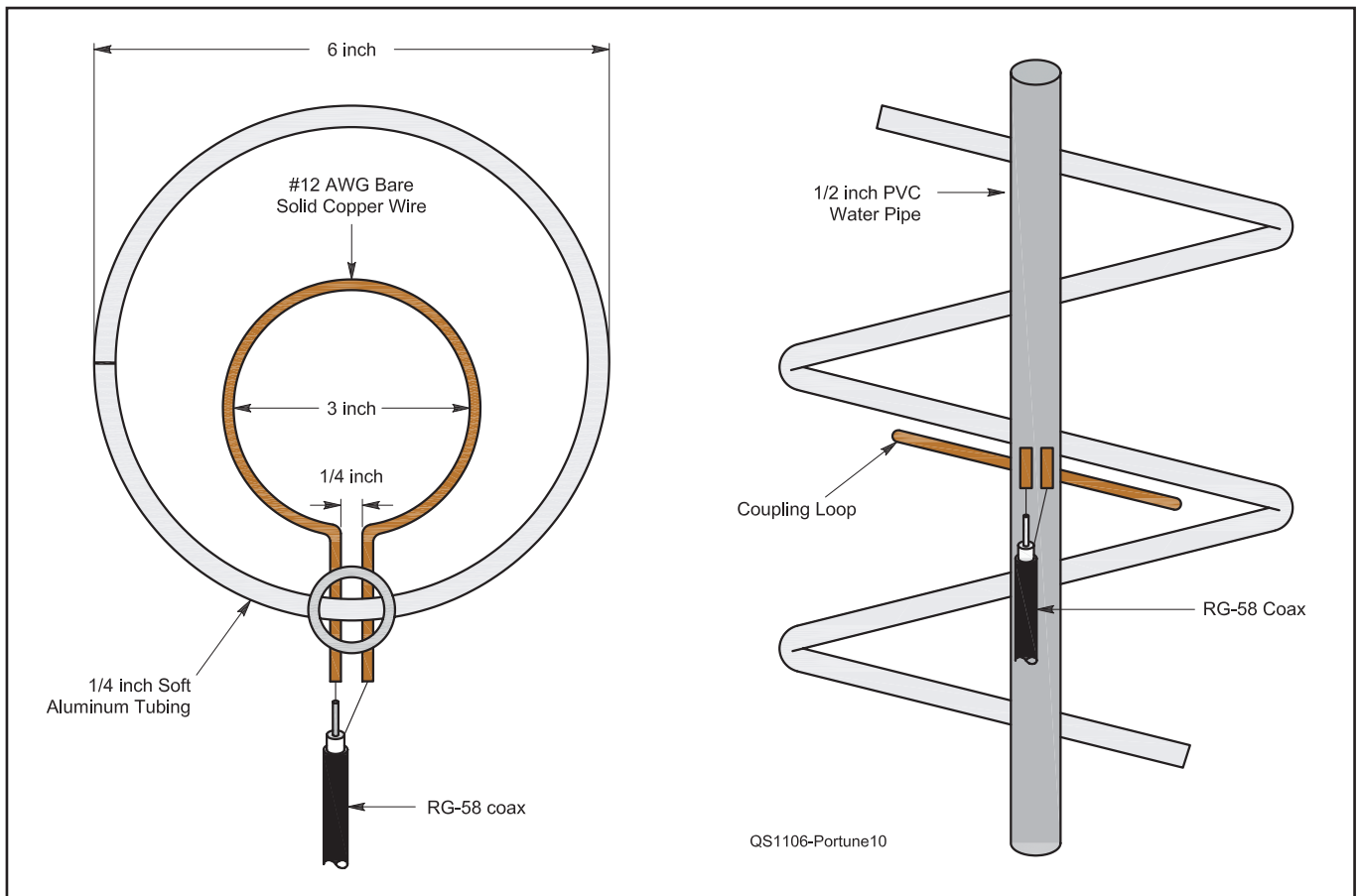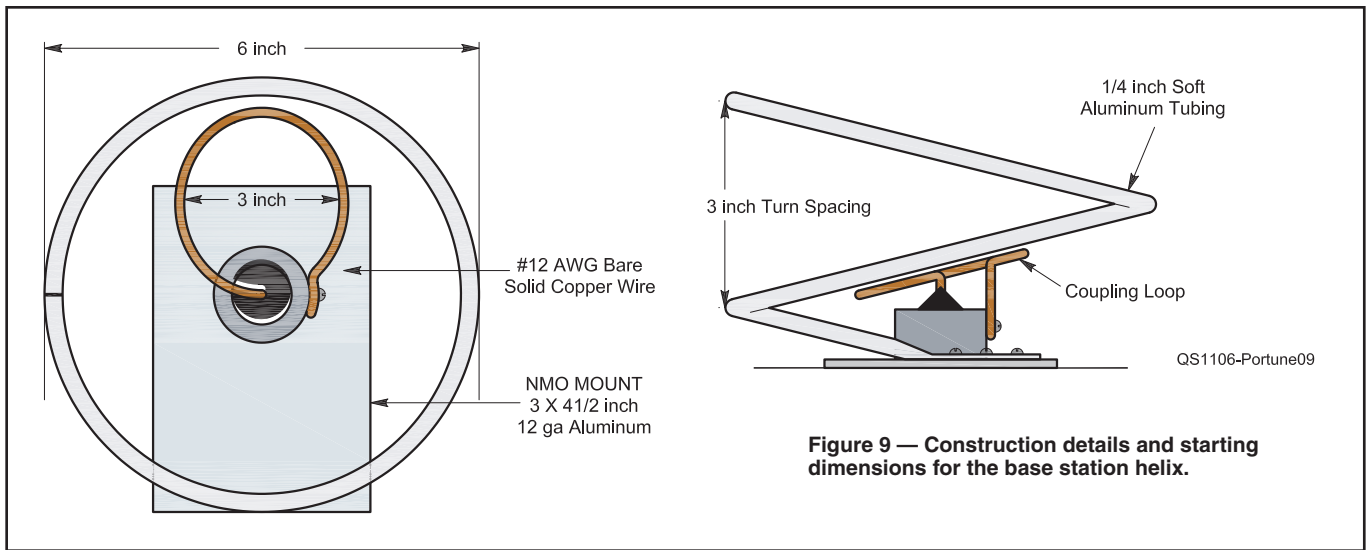
Figure 10 — Construction details and starting dimensions for the mobile helix.

Labels in figure: 6 inch, #12 AWG Bare Solid Copper Wire, 3 inch, 1/4 inch, 1/4 inch Soft Aluminum Tubing, RG-58 coax, 1/2 inch PVC Water Pipe, Coupling Loop, RG-58 Coax, QS1106-Portune10

other to accommodate the descending angle of the helix. For lower frequencies you might use black ABS DWV pipe, as it is less expensive and less visible than white PVC.

If you wish, you may wind the tubing around a cylindrical form. I found that I could easily just bend it into shape with my fingers. Again, cookbook precision is not required.

Constructing the λ/4 Mobile Helix

For the 2 meter mobile I modified an NMO mount and whip. See Figure 2. Other types will also work. Replace the stainless steel whip with solid copper wire for the coupling loop. See Figure 10. You must also ground the top end of the loop. I drilled and tapped 6-32 threads into the side of the mount for a grounding lug.

As illustrated in Figure 2, pop rivet the helix to a small 12 gauge rectangular aluminum plate (roughly 3 × 4½ inches). Make a ⅞ inch hole in it as shown. This permits you to
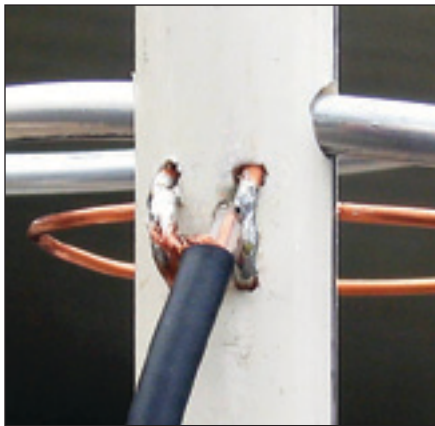
Figure 11 — Base station antenna connection from RG-58 coax to coupling loop. Weatherproof the connection.

slip the entire helix assembly over the threads of the NMO mount and secure it under the screw-on top portion. You might also put sealant under the aluminum plate. Tuneup and matching is the same as for the base station antenna.

It is not necessary to make an electrical connection between the base plate and the body of the vehicle. The plate and the car body form a capacitor through which the RF readily flows. Though if you are conveniently able, use as large a plate as you can. The bigger the better is true here.

Feeding and Matching

The easiest way I've found to match a helix (or a compact loop) to coax is a separate magnetically coupled feed loop as shown in Figure 10. Make it from solid bare copper wire (roughly #12 AWG) or small diameter soft copper tubing. A delta match or gamma match is also practical, but more difficult to build and adjust.

Notice that there is also no electrical connection to the helix. The coax attaches to the ends of the coupling loop only, via a couple

of extra inches of the same piece of wire that forms the loop. Pass the ends through holes in the support pipe and secure them in two additional holes. See Figure 11. Weatherproof the connection and the open coax end.

In case you are wondering how loop coupling works, visualize the main helix as a parallel L/C tuned circuit, with link coupling, in a receiver's IF or RF stage. The field around the link excites the tuned circuit, creating a single tuned RF transformer. The same principle is at work with the coupling loop and resonant helix.

Tuning and Matching

The first step is to put the helix on frequency. Only after that will you adjust the coupling loop for a good SWR match. Connect an MFJ-259 or similar antenna analyzer to the coax and first measure the helix's initial resonance, by sweeping the frequency on the analyzer. It is tuned to the frequency giving the lowest SWR. Do not be concerned that is not even close to 1:1 at first.

If the initial resonant frequency of the helix is low, move its turns farther apart on the side opposite the support pipe. Conversely, if it is too high, bring the turns closer together. If after you have tuned the helix to the desired operating frequency, say 146 MHz, and it has become too distorted, make a new longer helix or shorten the existing one.

Now, with the helix on frequency, you may adjust the match. You will discover that the area of the loop, its angle to the helix and the loop's location within the helix all influence the SWR. So again there are no cookbook dimensions. Merely begin with a round loop roughly ½ the diameter of the helix, mounted close to and parallel to the helix. See Figure 9. Adjust loop size and shape, or change its position and angle compared to the helix until you reach a good SWR. In any case always recheck the helix's resonant frequency after making any adjustment to the match. Keep it on frequency at all times.

Finally, a choke or balun is highly recommended for the base station antenna. You can create a choke using a few turns of the RG-58 feed coax wrapped around the support mast. See Figure 1. Secure it through four holes in the mast. Or you can use ferrite beads just below the antenna. See Figure 7. Note also that the coax loops away perpendicular to the helix. This helps keep the radiation pattern symmetrical.

My final conclusions, therefore, for small normal mode helical antennas are these. Except for a slightly smaller bandwidth and a minor reduction in gain, I have found their small size, low profile, stealth properties and circular polarization well worth the minor compromises, so I have several in service.

Notes
[1] J. Kraus, W8JK (SK), *Antennas*, 3rd edition, McGraw-Hill Education.
[2] Several versions of *EZNEC* antenna modeling software are available from developer Roy Lewallen, W7EL, at **www.eznec.com**.

ARRL Member John Portune, W6NBC, received a BSc in physics from Oregon State University in 1960, his FCC Commercial General Radiotelephone license in 1961 and his Advanced class amateur license in 1965. He spent five years in England as G5AJH and upgraded to Amateur Extra class in 1985. John retired as a broadcast television engineer and technical instructor at KNBC in Burbank and then from Sony Electronics in San Jose, California.

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