If you have limited space and don't mind limited bandwidth, KM5KG suggests you check out building a spiral dipole for your favorite HF band.

A Small Spiral Antenna

BY GRANT BINGEMAN,* KM5KG

The advantage of an electrically small, spirally wound antenna is the fact that resonance occurs in a compact package. However, you don't get something for nothing, and the bandwidth of such an antenna is limited. I built one to operate on the 15-meter band. It consists of two dipole arms: One is 20 inches long and the other is 30 inches long. Yes, this is an asymmetrical dipole. Since I chose a turn spacing of 1 inch, the overall length of the antenna is 50 inches. This is formed on a 2×4-inch pine board, with 20 turns of 16 AWG wire on one side of the balun, and 30 turns on the other side. See photo A.

In this case, the short arm uses about 17 feet of wire, and the long arm uses about 26 feet of wire. Each turn is a little longer than the sum of the four sides of the 2×4 lumber (10 inches). I temporarily mounted the antenna on a ladder, which puts it 48 inches above the concrete, lying on the plastic top step. As you can see, I made no special attempt to lay out the spiral perfectly. This antenna is easily tuned by adjusting the spacing and the overall lengths of the dipole arms. Impedance is also adjustable by changing the height above ground, or by adding copper-wire ground radials beneath the antenna.

Note that the short arm is a quarter wavelength, or 90 degrees long at 14.5 MHz, and the long arm is 90 degrees long at 9.5 MHz. This is not your classic half-wave dipole at 21 MHz. The input impedance at 21 MHz is 32.2 + j90 ohms.[1] If we feed this dipole in its center and trim one turn off each end, the 21-MHz input impedance becomes 18.9 + j19 ohms. The point is to start with a little more wire than you expect you will need.

Photo A– Spiral antenna atop fiberglass ladder.

This is not a high-gain antenna by any means, but can easily be erected in a small room from a coil of wire. Being small, it can be oriented in many directions to take quick advantage of its directional properties.

Using Bob Clunn's AIM4170 impedance box[2] and a calibrated 6-foot length of RG52A coax with a 1:1 current balun, the antenna impedances shown in Table I were measured when the antenna was 4 feet above ground. Note that the antenna is series resonant below the 15-meter ham radio band (21.0 through 21.45 MHz). A Smith chart plot[3] of these impedances when resonated with a 166-pF capacitor is displayed in fig. 1.

A simple L network can match the center band to a 50-ohm transmission line per fig. 2. The overall bandwidth of the antenna and the matching network is then described in Table II and fig. 3. Clearly, this is not a wideband antenna, but that is the price you pay for its compact size.

MHz	Za (ohms)	Z resonated
21.0	18.9 + j19	18.9 – j27
21.05	20.3 + j25	20.3 – j20
21.1	20.9 + j29	20.9 – j16
21.15	22.4 + j35	22.4 – j10
21.2	22.8 + j39	22.8 – j6
21.25	24.5 + j45	24.5 + j0
21.3	25.0 + j49	25.0 + j4
21.35	26.7 + j55	26.7 + j10
21.4	27.1 + j59	27.1 + j14
21.45	28.9 + j65	28.9 + j20
21.5	30.0 + j70	30.0 + j26

Table I– The antenna impedances shown here were measured when the antenna was 4 feet above ground.

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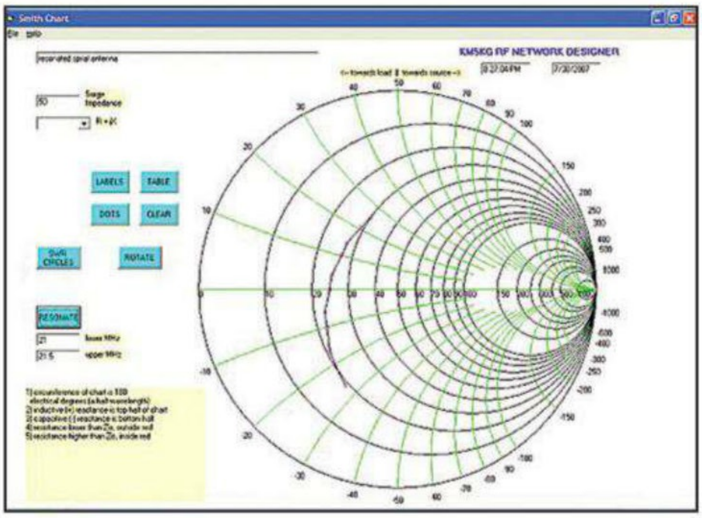

Fig. 1– Smith chart of resonated spiral antenna.

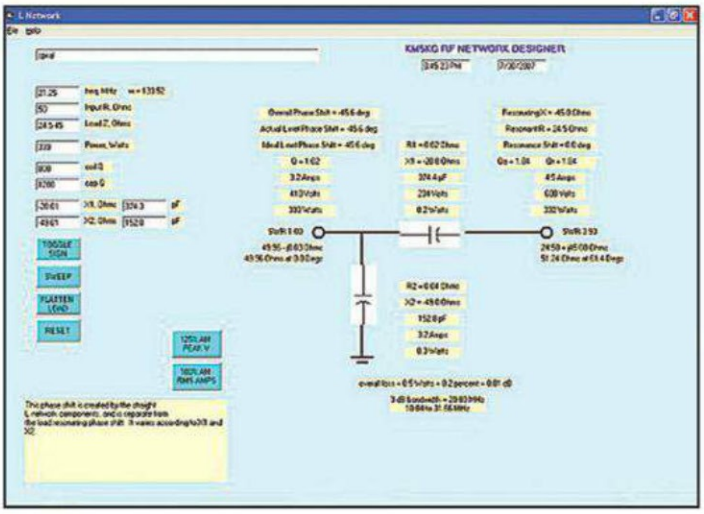

Fig. 2– A simple L network.

Please note per fig. 3 that the impedance bandwidth of the antenna itself is shown in blue, while the overall characteristic, including the effects of the L network, is shown in red. In this case, the L network additionally reduces bandwidth.

Improving Bandwidth

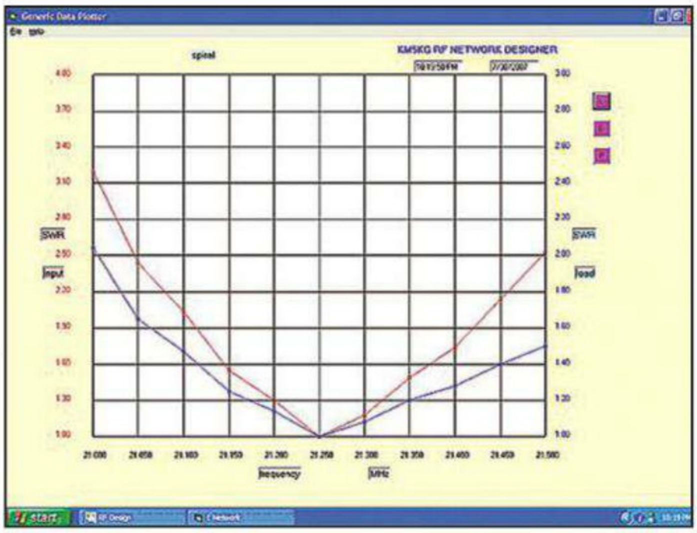

Fig. 3– Narrow bandwidth is the tradeoff for compact size.

We can build two of these dipoles, mount them orthogonally to one another (forming a right angle), and feed them in quadrature to obtain elliptical polarization and a much broader bandwidth. The quadrature phasing simply requires that we insert 90 degrees of phase shift in one of the two antennas' feed lines. It is probably easiest to do this with about 7.6 feet of RG58A. I was able to obtain better than 1.7 SWR across the entire band after summing the two antenna feeds. This is quite a bit better than the 3.2 worst-case SWR shown in fig. 3. Note that the amount of coupling between the two antennas will affect the outcome, but this is generally quite small when the dipoles are mounted orthogonally.

Baluns

I want to emphasize the importance of isolating the transmission feed line from the antenna in order to avoid undesired RF currents and unpredictable radiation patterns. A balun such as shown in photo B must operate correctly at the desired frequencies. Some baluns have self-resonant conditions at higher frequencies where they may become very lossy. The simple choke balun shown here consists of two ferrite beads on a short length of RG58A, and it works well at 21 MHz. I had to replace the toroidal balun shown in photo A with the photo B balun when I discovered the former was not performing as a 50-ohm 1:1 balun at 21 MHz, although it worked fine on the lower frequencies.

If you plan to keep this antenna beyond the experimental

Photo B– An HF choke balun is essential for this type of antenna.

phase, I recommend that you put a couple of coats of spar varnish on the 2×4 support before winding the wire onto it. Better yet, a plastic mailing tube or PVC pipe might reduce losses compared to a wooden form. In any case, this is a very cheap antenna, and very easy to maneuver. If you want to stand it up vertically, you can use a longer form such that the active portion of the antenna is a fair height above ground. You can guy it with three nylon strings and stakes. If you leave the antenna too close to ground, you may incur extra losses.

Notes

1. See sidebar, "What Does That 'j' Mean?"
2. Available from Array Solutions at <www.arraysolutions.com>. Also see <www.W5BIG.com>.This impedance-measuring device is the most convenient I have used. I particularly like the feature that allows the user to calibrate a random length of feedline and a balun, and make them *invisible,* regardless of line losses and surge impedance. This transparency reduces time and aggravation during antenna tests. A personal computer is required to generate the displays.
3. RF Network Designer software demo available at <www.qsl.net/km5kg>.

What Does That 'j' Mean?

You often will see formulas for calculating impedance with a number such as "32.2 + j90 ohms." This is the mathematic representation of a *complex* number. It consists of a *real* component (resistance) and an *imaginary* component (reactance). In electrical engineering this complex number is called a *phasor.* The j operator is the square-root of minus one, hence the term *imaginary.* Equations 1 and 2 show how to convert from rectangular to polar impedance form. The polar form can be considered a vector of magnitude |Z| and bearing θ.

$$|Z| = \sqrt{(R^2 + X^2)} \qquad \text{Eq. 1}$$

$$\theta = \text{atan}\,(X/R) \qquad \text{Eq. 2}$$

As an example of complex number arithmetic, let us calculate the voltage at the input to the 21-MHz spiral antenna. The impedance is 18.9 + j19.0 ohms, which in polar form is 26.8 ohms at 45.2 degrees. If we are operating at 10 watts, the input current is

$$\sqrt{(10/18.9)}\text{, or 0.73 amps}$$

and the *absolute* input voltage is $I|Z|$ = $0.\underline{73}(26.8)$ or 19.5 volts RMS. which is 19.5 $\sqrt{2}$, or 27.6 volts PEAK. In other words, you must multiply the current times the absolute value or magnitude |Z| of the impedance, not times the resistance. After all, we are dealing with AC here (we call it RF at this frequency), not DC.

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