John Portune, W6NBC, and Fred Adams, WD6ACJ

A Weather Vane Antenna for 2 Meters

VHF incognito! Here's a 2 meter antenna your neighbors won't recognize.

Figure 1—The completed weather vane antenna. Can you find the loop?

Keeping a homeowners' association happy isn't easy. Many hams burdened with CC&Rs often live with badly compromised antennas. Why not combine a compact magnetic loop with a functional weather vane and put high-performance right out in full view? A neighbor even asked me where I got mine, so she could get one, too.

Compact loops, often called magnetic loops, have been around for years. They're tiny open-ended ring radiators, always less than roughly 1/10th wavelength in diameter. Recently we've seen them mostly on HF where their small size is of great appeal. But they work very well on other bands too; here on 2 meters. Remarkably, this VHF version achieves an efficiency of 93%, yet radiates as if it were a full-sized dipole or a J-pole, but from a space only 7 inches square. What's best, it is disguised as a nice-looking weather vane. Your neighbors won't guess that your rooster has a call sign.

What makes a magnetic loop so easy to camouflage besides its size is its radiation pattern. It may surprise you, but a horizontal compact loop radiates as if it were a full-sized half-wave dipole on the vertical axis of the loop. Yet, here it looks like nothing more than the support for the weather vane's direction letters (Figure 1).

There is a restriction, however. Compact loops require low conductor resistance as compared to full-sized dipoles. (See the technical discussion later in this article.) This requires that we use copper water pipe for construction. Also, compact loops have narrow bandwidth (BW)—in this case, a theoretical BW of 600-700 kHz. Practically, however, the BW is wider. Figure 2 shows an actual SWR plot of my loop.

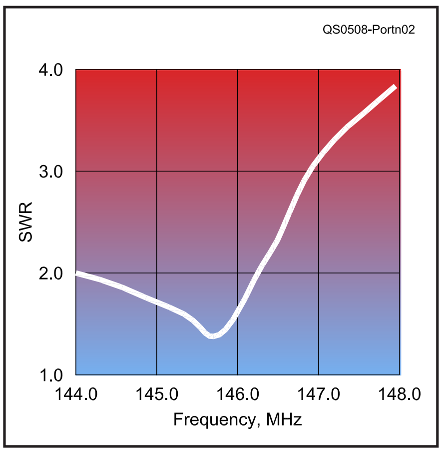

Figure 2—An SWR plot of the completed loop. A 1:1 match at the resonant frequency is possible by compressing or expanding the feed loop.

Table 1
Relative Room Temperature Conductivity of Common Metals

Silver	100
Copper	95.2
Gold	68.3
Aluminum	60.3
Steel	9.5
Stainless Steel	2.4

On the positive side, a magnetic loop's narrow bandwidth increases the received signal-to-noise ratio (SNR). In a noisy environment a compact loop will better discriminate than a dipole or J-pole. [While horizontal loops do better in noisy situations because that local noise tends to be mainly E-field oriented, the perceived SNR improvement of a narrowband antenna is principally due to the reduction in out-of-band signals that cause IMD, rather than any reduction of the receiver noise floor.—*Ed.*] They also tend to work better close to the ground or near other objects.

Construction

All materials (Figures 3A and 3B) are common hardware store items. I recommend a tubing cutter for cutting the pipe, copper and PVC. Also, a different brand of copper fittings may require slight adjustments to the cutting dimensions shown. But, don't worry; high precision isn't required. The loop will tune up easily if you are roughly within 1/8 inch of these dimensions.

The only part of this design that requires special attention is the 3/4-1/2 inch reducer that acts as a tuning capacitor across the open ends of the loop. Drill or file the inside so that it will slide freely on the pipe (21/32 inch, roughly). Otherwise you will not be able to tune the antenna easily. As purchased, stock pipe fittings are too tight. Also, cut the slot shown for a securing screw.

Important Note: Do not cut the two end pieces at first. Instead, cut just one piece the same size as the opposite side. Later, after soldering, you'll cut a gap in center. This assures good alignment of the tuning capacitor.

For soldering, clean all joints thoroughly and apply a little flux. Use a propane torch and common solder, not silver solder (Figure 4). Also, solder sparingly. It isn't necessary to make watertight connections—tack soldering is fine. At RF frequencies, skin effect makes low dc resistance at the joints completely unnecessary. Keep the loop flat on a heat-resis-

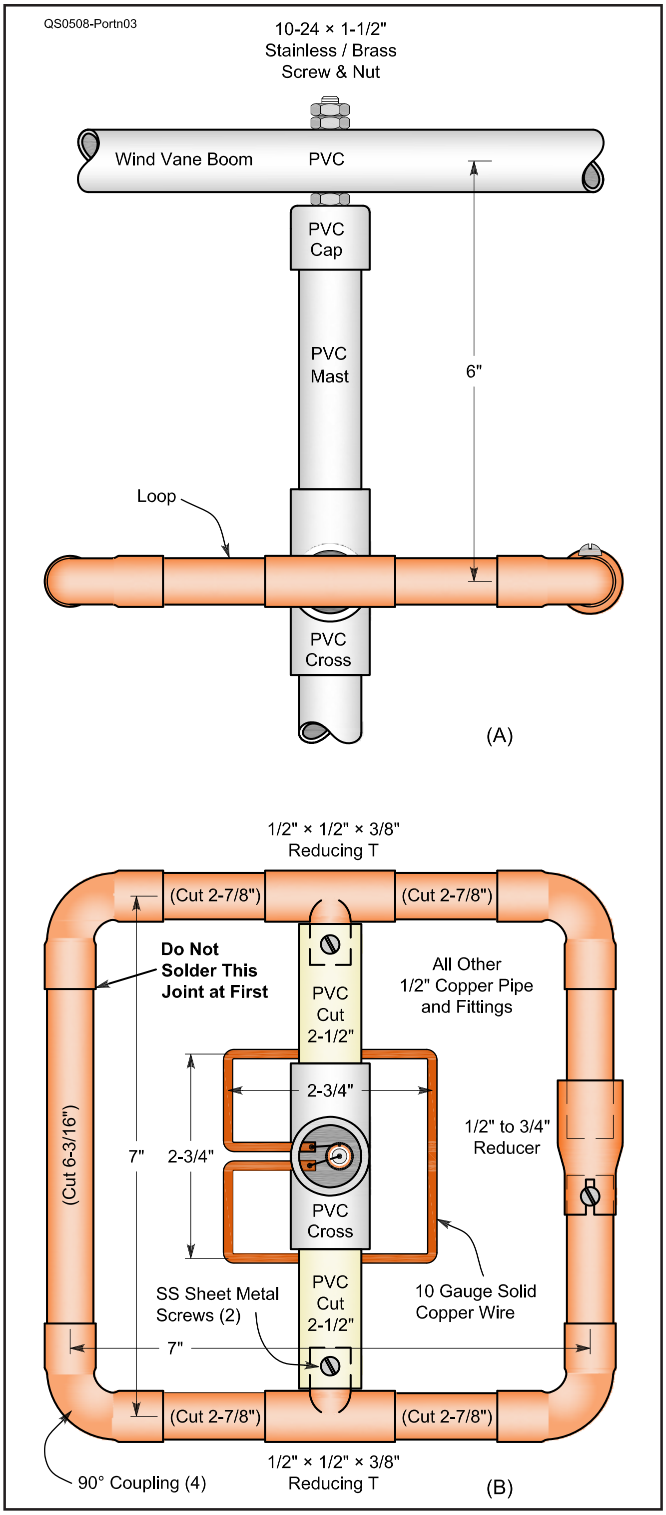

Figure 3—Parts and assembly details for the 2 meter loop are shown in (A). Note that most material is 1/2 inch copper pipe and fittings, except as noted. The inductive feed loop is made of 10 gauge solid copper wire. Basic details of the PVC weather vane support are shown in (B).

tant surface while soldering.

Important Note: Do not have the tuning capacitor installed while soldering. You will put it on later. Also, be very careful not to solder the one joint indicated (Figure 3A). Otherwise you will not be able to assemble the antenna.

After soldering, cut a 1/2 inch gap in the center of the copper pipe on the tuning capacitor side of the loop. Also, make a hole for a sheet metal screw to secure the tuning capacitor. Then cut the two short PVC center support arms. Note that the copper T-fittings are of the reducer type. The arms of both are 1/2 inch, but the necks are 3/8 inch. Also, add two more sheet metal screws (Figure 3A) to keep the loop from rotating.

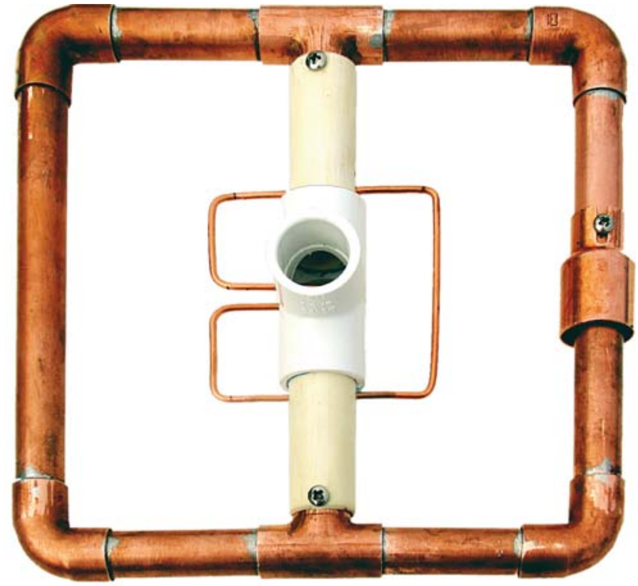

Figure 4—The copper pipe 2 meter loop. Note the inductive feed loop at the center.

Next, install the tuning capacitor, glue the PVC support arms to the center PVC cross, put all the parts together, and then finally solder the one remaining copper joint, again keeping the loop flat. For the final solder joint, wrap wet rags around the T-fittings and PVC pipe to prevent damage to the PVC.

The Feed Loop

For matching to the coax, I prefer an inductive loop, as shown. To me, this is the easiest technique for feeding a compact loop. Other methods also work, such as a gamma match, but are generally more difficult to fabricate. I only had to make a couple of trial loops during the prototype stage to find the correct size. Loops seem to normally need a coupling loop that is roughly 1/3 the size of the main loop. The dimensions will yield a good match without any further experimenting.

You can, however, after final tuning, make minor adjustment to SWR by squeezing or stretching the feed loop. Fabricate the feed loop from bare 10 gauge or 12 gauge solid copper wire. Drill holes in the PVC pipe, then thread the coupling loop through, progressively bending the corners as you go.

For weather protection, solder the coax to the coupling loop inside the PVC cross fitting. Ideally, the loop should have a balun. In practice, however, I have experienced no discernable difference with or without it. But if you prefer, heat-shrink several small VHF RF torroidal cores over the coax, inside the PVC cross, to form a feed line choke.

The Weather Vane

I cut the decorative parts of the vane (Figure 4) with tin snips from an inexpensive heavy-duty plastic storage tub. The Web contains a wealth of wonderful weather vane designs, or you may use the one shown. You are obviously free to be innovative here. Do *not*, however, use metal for any of the pieces. This will detune the antenna.

For the rotating arm, keep two things in mind. First, the tail end must have more wind surface than the head end so that the

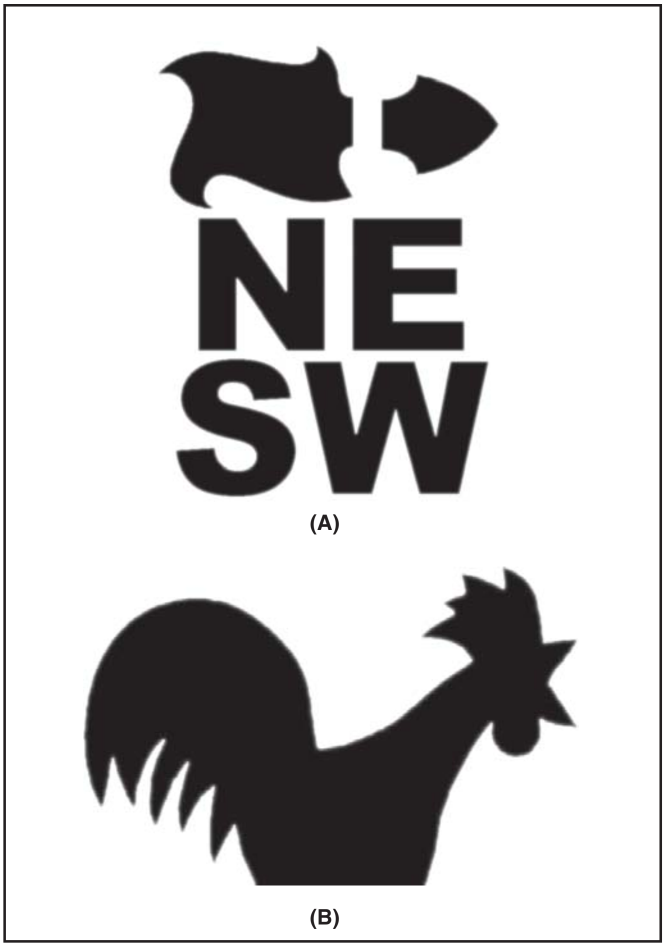

Figure 5—(A) The weather vane "head" and "tail" cutouts and compass points. (B) The rooster cutout. These examples are not to scale—use your imagination!

vane will point into the wind. Therefore, the head end must be weighted. I used six-ounce fishing sinkers, silicone glued inside the boom. To hold the head and tailpieces on the arm, cut slots in the ends and use a little more silicone glue. Second, the pivot hole must be drilled at the balance point. Otherwise the arm will not rotate easily. The length of the vane is not critical. Mine is roughly 16 inches long.

Attach the rooster (Figure 5), or whatever "critter" you choose, with plastic cable clamps and some additional glue. Punch two small appropriately-located holes in the direction letters and attached them with wire ties. Finally, give the entire structure a coat of black outdoor spray paint. This will give the impression that your weather vane is made of wrought iron, a final touch for the disguise.

Tuning

For tuning, you'll need no special tools, only a VHF SWR bridge and a 2 meter transceiver. In the design phase, I did use a FET dip oscillator to get the prototype in the ballpark. Subsequently I've only needed an SWR bridge and a handheld transceiver to tune up a new vane.

The basic tuning technique is simple. Begin with the tuning capacitor as far away from the $^1/_2$ inch end gap as the securing screw will permit. Apply low power with your transceiver and measure the SWR at the top and again at the bottom of the 2 meter band. Write down the difference. With the capacitor all the way out, the SWR should be worse at the low end. That's because the loop is tuned too high in frequency. Remember, always keep the securing screw tight when making the SWR measurements. Also, at first, both SWR readings will be poor. Only the difference between high and low matters.

Progressively move the tuning capacitor inward, in small increments, again taking high/low readings. As you reach the desired operating frequency, high and low readings should become equal. Still, they won't necessarily be low. If you go too far, the SWR will become better at the low end, the reverse of above. Your objective is to find the position where both readings are equal and lowest. To obtain a final 1:1 match you may need to squeeze or stretch the feed loop a little. Generally, I have not had to bother with the dimensions given. Adjusting the tuning capacitor alone has yielded an adequate SWR.

A Technical Discussion

Theoretically, a compact/magnetic loop antenna is a par-allel-tuned LC "tank" circuit. The variable capacitor across the ends ($^1/_2$-$^3/_4$ inch reducer) resonates the inductance of the loop to the frequency of operation. A multi-turn inductor can't radiate because of its small size. But, with a large single-turn inductor, such as a compact loop, good radiation characteristics can be achieved.

A compact loop, however, *must* be smaller than about 0.1 wavelength in diameter and 0.35 wavelength in circumference. This causes it to radiate in a unique way. The classical RF bible, *Electronic and Radio Engineering* by F. Terman, states that: "The directional pattern of a small loop is identical with that of an elementary doublet (dipole). The only difference is that *the electric and magnetic fields are interchanged*." A small horizontal loop, therefore, radiates as if it were a vertical dipole.

If we make the loop larger than 0.1 wavelength in diameter, the radiation pattern will slowly take on the more familiar form. A full half wavelength dipole, for example, folded into a loop, radiates horizontally. This is the popular "halo" antenna, once common during the early days of 2 meter mobile.

On the other hand, within limits, a compact loop may be made much smaller. A tiny loop compared to wavelength is easily implemented by merely increasing the capacitor across the loop's ends. In this way, lower frequencies or even multiple bands can be achieved. This technique is often used on HF, for example, and several good small multi-band HF compact loops are currently on the market for hams with limited space.

Radiation Resistance

There is, however, a practical limit to how small a loop can be made, due to another important characteristic of all small antennas—radiation resistance. Radiation resistance is not resistance in the usual sense. It is a kind of virtual resistance created by the actual loading of space on an antenna. Said another way, radiation resistance is a measure of how well an antenna couples to space.

But, as far as your transmitter is concerned, radiation resistance looks just like an ordinary resistor at the end of the coax. But instead of converting transmitter power into heat, which an actual resistor would do, radiation resistance does what we want, and converts RF power into a radio signal. Therefore, radiation resistance is the kind of resistance we want in an antenna. And, here's why.

In free space, a full-sized dipole has moderately high radiation resistance, roughly 72 Ω. Smaller antennas like compact loops have a radiation resistance that is much lower. The bigger the antenna, the larger a piece of space it captures, and the higher the radiation resistance. Specifically, as the size of an antenna decreases, the radiation resistance decreases—roughly as the square of size. Our weather vane is less than $^1/_{10}$ wavelength in diameter. It has an actual radiation resistance of only 1.7 Ω.

But, as long as we correctly match the transmitter's output impedance (normally 50 Ω) to the radiation resistance of the antenna, efficient radiation will take place. Hence, a compact loop with a very low radiation resistance can theoretically radiate just as well as dipole or a J antenna with a much higher radiation resistance.

There is a fly in the ointment, however—conductor resistance. That's because conductor resistance is in series with radiation resistance. And both forms of resistance must share the power from the transmitter. The power the conductor resistance (a real resistance) receives is wasted as heat. The power the radiation resistance (a virtual resistance) receives makes useful radio waves.

Therefore, in a dipole, with a relatively high radiation resistance of 72 Ω, conductor resistance isn't of much concern. Even for a thin wire of poor conductance, conductor resistance is only a small fraction of the radiation resistance. Thus it shares very little of the transmitter's power. But for a compact loop, where the radiation resistance may be very low, conductor resistance can easily waste significant power. That's why we should construct small antennas with large diameter conductors, not thin wire. This is also one of the reasons why mobile HF whip antennas are characteristically low in efficiency.

Metal Conductivity

Also for a small antenna, the kind of metal can be important. Table 1 illustrates how poorly conductive some common metals are, and why copper is really the only good choice for a compact loop. Two interesting points to note are that gold is a poorer conductor than either silver or copper. Gold is used on electronic connecters not because it is the best conductor, but because it does not corrode. Also, notice that stainless steel is 40 times poorer than copper, and that aluminum is about 60% as good.

Bandwidth

The final theoretical limitation of a small antenna, as mentioned earlier, is its low bandwidth. Bandwidth is a function of an antenna's natural LC ratio. In a dipole, this ratio is low. That is, the native self-inductance of a straight wire is relatively small compared to its self-capacitance. Q, therefore, is low, and bandwidth high. For a compact loop the opposite is true. A one-turn coil has high L compared to C. Hence, Q is high and bandwidth low. This is equally true for a loaded mobile HF whip. The large loading coil is very inductive, giving the antenna high Q and low bandwidth.

So, as an overall guideline, if we use large copper conductors and can live with a small bandwidth, a compact loop is a high efficiency choice for a small space. It is also easier to camouflage. My 40 meter rose trellis loop is also rarely noticed.

Designing a Loop

And, in case you would like to try your hand at a compact loop on another band, I have placed on **www.w6nbc.com/loop.html** the loop design equations and an excellent little Basic program that quickly calculates all parameters, including efficiency, of compact loops of almost any size and frequency. It is one of the many freeware programs for compact loop design available on the Web. It is a simple DOS program, but emulates well on a modern computer running *Windows XP*.

My Operating Experience

I have had two of the weather vane loops in service for several months now, one on my mobile home and the other at a friend's house. At my location I also have a comparison J-pole antenna (basically a full-sized dipole) at the same height, and I can detect little difference. Also, the weather vanes have experienced significant wind and weather exposure during that time and show no tendency to detune. Give one a try. They've been an "undercover" winner for me.

Photos by the authors.

John Portune, W6NBC, first received his Advanced class amateur license in 1965, but has held an FCC First Class General Radiotelephone commercial license since 1961. He spent the first five years in Amateur Radio in England, as G5AJH. John upgraded to Amateur Extra in 1985. He is active on all bands through 440 MHz and has written articles for various ham and electronics journals. John is a retired TV broadcast engineer (KNBC, Burbank, California) and technical instructor (Sony Electronics, San Jose, California). He is currently an active VE team leader and participates in Central California ARES/RACES activities. You can reach him at 1095 W McCoy Ln, #99, Santa Maria, CA 93455 or **jportune@aol.com**.

Fred Adams, WD6ACJ, was first licensed as WN6AIH in 1961. Fred says that he was interested in CB radio prior to that time and that his career has mainly been in the mechanical engineering area. He advised and collaborated with W6NBC on this antenna—principally in the area of construction. Fred says he's built many antennas, but this design was a new concept to him. You can reach him at **fredeadams@verizon.net**.

NEW PRODUCTS

AUTOMATIC ANTENNA TUNER FOR LOW-POWER TRANSCEIVERS

◊ Elecraft offers a 160 through 6 meter automatic antenna tuner (ATU) that's not much larger than a deck of cards. The T1 is a stand-alone ATU that can be used with any low-power transceiver.

The tuner consists of a seven inductor, seven capacitor L-network that is said to provide a wide matching range and is specified to handle of up to 20 W SSB or CW and 10 W for AM, FM or digital modes. Antenna matching can be initiated with the application of a constant carrier, SSB voice, or a CW keyer.

The tuner uses Elecraft's multi-stage tuning algorithm that aims for the lowest possible SWR, not just a result below some threshold. The T1 saves many previous matches in EEPROM, so most re-tunes are said to take one to two seconds.

An optional T1-FT817 remote control cable is available. This "smart" cable provides instant recall of per-band ATU settings on any band change at the transceiver, without the need to transmit. Full details on remote control are provided in the owner's manual, so users of other commercial or home-built transceivers may be able to make use of these capabilities.

Green, yellow and red LEDs are used for power and SWR indications with combinations indicating intermediate values. The three LEDs thus function as a five element bargraph providing metering for QRP transmitters without power or SWR measurement capability.

The internal 9 V battery is said to provide a year or more of service. The T1 checks the battery on every power-up, and provides a low-battery indication.

The T1 is 4.4×2.5×0.9 inches in size making it particularly useful for backpacking and travel. All controls are labeled, and a quick-reference guide is included on the panel.

The T1 is priced at $159, factory assembled and tested, or $135 for the kit version. The T1-FT817 remote control cable is $49, assembled. To order, see **www.elecraft.com** or call 831-662-8345.