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# Compact 40 Meter HF Loop for Your Recreational Vehicle

*Want something better than a mobile HF whip antenna while camping in an RV park? Try a tilt-up compact HF loop.*

John Portune, W6NBC

**H**ams with a motor home or a travel trailer know that achieving high efficiency in an HF RV antenna isn't easy. Most often we settle for a bumper mounted whip or screwdriver antenna. That's fine for on the road operating, but leaves room for improvement for operation while parked.

A survey of campground HF RV antennas will turn up a number of potential solutions. These include tilt-up home station type trapped multiband verticals, long wires shot over a nearby tree or pairs of mobile HF whips mounted horizontally on a mast and used as short dipoles. A much better solution, in my opinion, is to use a compact transmitting loop. They can be small enough to be easily mounted on an RV, but are more efficient than mobile HF whips. My version of such an antenna for 40 meters is shown in the title photo. I've provided design details for other bands at the end of this article.

Compact loops can also be a good choice for a home station operation if aesthetics or local rules prohibit more obvious antennas. I have a 20 meter loop hidden in a tree, a 40 meter loop on a rose trellis and a 2 meter loop disguised as a weather vane.<sup>1,2</sup>

A compact loop is just a dipole made short (less than  $\lambda/10$  long) then bent into an open-ended loop with a capacitor across the ends for tuning. Looking at it another way, a compact loop is a one turn parallel "tank circuit" big enough to radiate.

Why is it better than a typical electrical  $\lambda/4$  mobile vertical HF whip? Simply stated, a compact loop or other horizontal antenna, suffers far less from ground losses. This one, modeled at 70% efficiency, is only a bit less efficient than a full-size 40 meter dipole. Comparatively, an electrical  $\lambda/4$  mobile whip, such as a screwdriver antenna, for 40 meters may be only 5% efficient. Read a fuller explanation of this later in this article.

## Radiation Pattern

In free space, the radiation pattern of a compact loop is like that of a  $\lambda/2$  dipole lying

along the axis of the loop with its polarization rotated 90°, in this case to vertical. As with all antennas, the ground changes the radiation pattern. Figure 1 is an EZNEC plot of the loop over average soil (RV on the X axis). As you can see, at this height, the loop is more or less omnidirectional, but this is also true for many 40 meters antennas at this height.

Unlike a dipole, however, there is no specified size for a compact loop. With the correct tuning capacitor across the ends, one can resonate a loop to a wide range of frequencies. This loop is roughly  $\lambda/5$  in circumference. I intentionally made it larger than the classical  $\lambda/10$ , to improve the efficiency. In general, the bigger the loop, the lower the losses. On an RV, however, there is adequate room for a large loop. What's more, the extra size reduces the length of the coaxial tuning capacitor. The radiation pattern does skew a bit from the classical, but this is of no consequence at this height.

Do not mount the loop horizontally. If you do, losses may be severe. Loops do not like large objects, including the ground, broadside to the loop. Unless you can mount a compact loop high, keep it vertical.

## Mechanical Details

In addition to nearby objects, the other main cause of loss in a compact loop is the resistance of its conductors and connections. Hams rarely consider skin effect but in small antennas its influence is appreciable. Compact loop designers should always pay careful attention to both the conductor size and the material used in construction in order to achieve high efficiency.

As an aside, you can estimate the real world loss in an antenna by measuring the bandwidth wherever you intend to use it and then again at the same height, but now clear of all nearby objects. In free space this loop has a theoretical bandwidth of roughly 10 kHz. On my RV it is slightly broader, indicating that the rig and the ground are to some degree lowering the efficiency.

Large diameter high conductivity tubing is mandatory. Copper is best. I use common hardware store rigid copper water pipe.

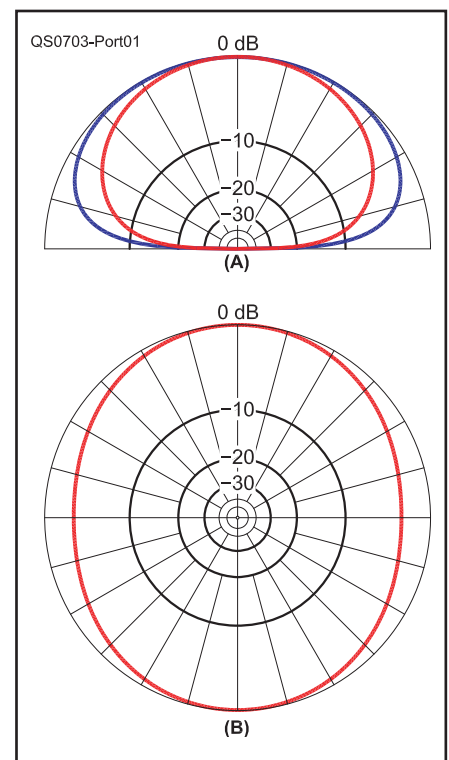


Figure 1 — EZNEC plots of the loop's pattern over average soil. At A, elevation plots in the plane of the loop (red) and at right angles (blue). At B the azimuth plot at 30° elevation.

<sup>1</sup>Notes appear on page 43.



**Figure 2 — View of the tilt-up hinges made from 1 inch PVC pipe, threaded elbow reducers and a ½ inch brass pipe nipple cut in half.**



Aluminum is noticeably poorer at nearly double the loss (roughly half an S-unit). Steel and stainless steel are terrible. Also, don't use flat strap. Skin effect in a strap pushes the RF mostly to the edges, increasing conductor resistance even more. Copper pipe, ¾ inches in diameter, is the best compromise considering strength, cost and weight. It results in an antenna having reasonable efficiency. The use of available plumbing fittings and ordinary solder, applied with a propane torch, makes for a satisfactory assembly method.

Make the tilt-up hinges from 1 inch PVC pipe, threaded elbow reducers and a ½ inch brass pipe nipple cut in half as shown in Figure 2. The cut ends slip into copper elbows at the bottom of the loop to act as bearings. The normal location of this loop is on top of my RV, but I decided also to make it the same size as the bed of my ¾ ton long bed pickup as shown in Figure 3.

Remember, a compact loop doesn't have to be a particular size. At a pickup bed size, it can be sized to mount directly in the truck's rear stake pockets. This gave me a convenient place to develop the loop as well as a way to operate it at home without the RV.

For installation on my RV, I permanently attached two 1½ × 6 inch galvanized steel pipe nipples, as shown in Figure 4, on floor flanges to the roof. These perform the same function as the stake pockets of my pickup.

## The Tuning Capacitor

I used 1¼ inch copper pipe and a 1¼ to ¾ inch reducer for the tuning capacitor as shown in Figure 5. This permits full legal power. You will need to drill through the small end of the reducer with a <sup>29</sup>/<sub>32</sub> inch drill so that the capacitor can slide on the loop. Also, drill a ¼ inch hole in the small side of the reducer and solder on a brass nut for a stainless steel locking screw. The tuning range with this capacitor is several megahertz.

The open ends of the main loop come within 3 inches of each other inside the capacitor. Maintain alignment by inserting a roughly 1 foot piece of ¾ inch acrylic rod into the open ends of the loop. Tape or heat shrink the rod to the ends of the loop. Several Internet providers supply acrylic rod.

You will also need to stabilize the open end of the capacitor with an assembly made from a PVC pipe cap. The cap requires a ⅞ inch hole drilled in the top. Glue the assembly together with ordinary PVC cement as shown in Figure 6. A PVC cap alone is not a good idea. If moisture gets in, a pathway for



**Figure 3 — The loop mounted on the bed of the author's ¾ ton long bed pickup.**

arcng will exist along the cap from the loop to the end of the capacitor. The voltage here is thousands of volts even at 100 W of transmit power. After tuning the loop, weatherproof both ends of the capacitor with tape or heat shrink tubing. The ½ to ¾ inch bushing helps you accomplish this. You should not need to readjust the capacitor after initial tuneup. Refer to the tuning section later in this article.

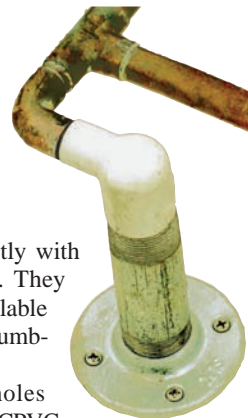
## Feeding the Loop

There are several ways to connect to a compact loop. My preference is a tap match as shown in Figure 7. It resembles a gamma match, but is actually more like tapping an RF coil. It can be made of small diameter wire, but for rigidity I prefer ½ inch pipe and fittings.

By experiment, I discovered that the location of the matching section isn't critical. A good match can be achieved at many places on the loop. Changing the position mostly affects the loop's radiation null. I found by modeling with EZNEC that the best compromise is the bottom corner opposite the capacitor.

The matching section must be open at one end to permit connection to the feed coax. Use a CPVC plastic coupler as shown in Figure 8 for this. CPVC is not ordinary PVC. These special fittings are made of high strength, high temperature plastic to allow

**Figure 4 — Details of the galvanized steel pipe nipples mounted on floor flanges on the RV roof.**



them to mate directly with copper water pipe. They are commonly available at hardware and plumbing supply stores.

Drill <sup>5</sup>/<sub>64</sub> inch holes near the ends of the CPVC coupling through the matching section pipes for 6-32 stainless steel connection screws. Solder brass nuts inside the pipes. Use a stainless steel screw to hold the brass nut in place while soldering. Make the actual connection with a short coax pigtail fitted with ring terminals on one end and a PL-239 connector on the other. Weatherproof the pigtail.

You must also slip HF ferrite beads (roughly 50) over the feed coax near the loop to form a coaxial choke. Without the choke, currents on the outside of the coax make matching nearly impossible. Secure the beads with heat shrink tubing. I prefer a W2DU style ferrite choke balun for this. Several Internet vendors offer these.

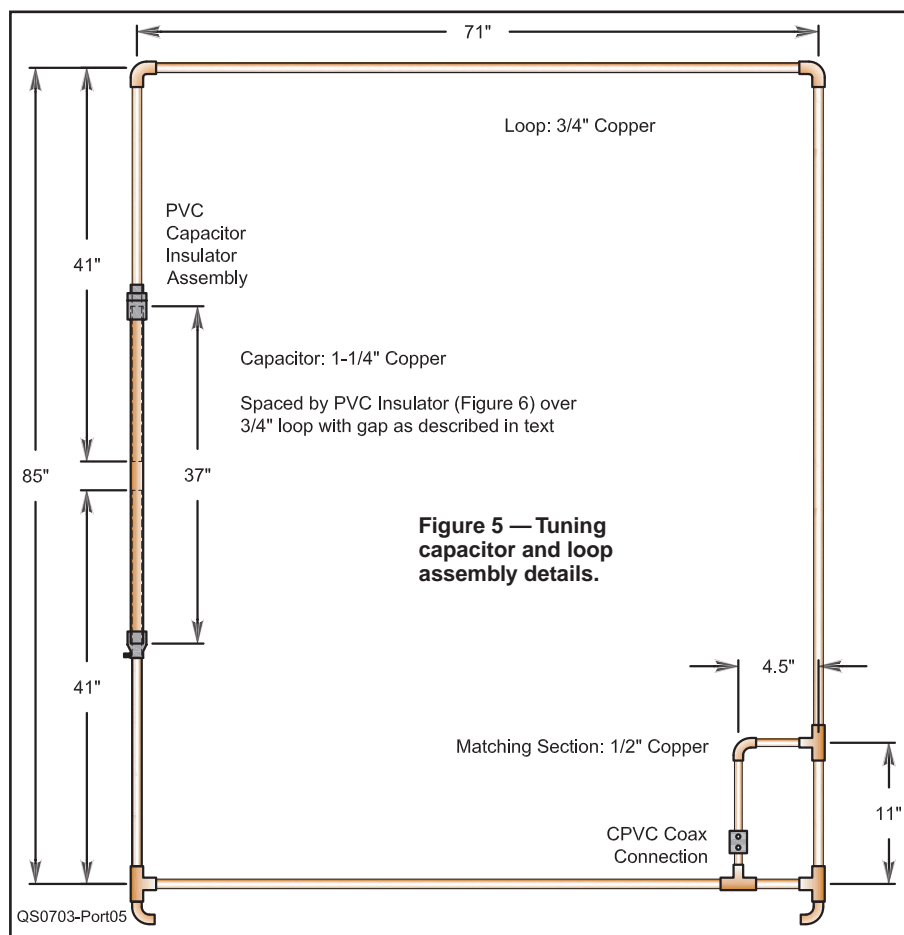
## Tuning the Loop

The best tool for tuning the loop is an MFJ-239 or similar SWR analyzer, but you can also tune it with an ordinary SWR bridge and your transceiver (at low power). Simply adjust the capacitor for the lowest SWR. The dimensions shown in Figure 5 for the matching section provide a good match over the entire 40 meter band. In a different location, such as an attic or a tree, you may need to lengthen the matching section. By experiment I have found that the closer the loop is to other objects the longer the matching section needs to be. The capacitance is changed by sliding the 1¼ inch tubing up and down.

## Tuning While Operating

A big difference between a compact loop and a full-sized dipole is bandwidth. The loop is sharper. Most shortened antennas have inherently high Q. Therefore, some form of remote tuning while operating is desirable. My preference is an antenna tuner at the operating position, leaving the loop tuned to the center of the band. Some purists may object to this because the SWR on the feed line increases as one moves off center frequency. Actually, the loss is small. To be sure, I made signal strength tests to determine how much actual loss there is. With a tuner and 25 feet of RG-8X, I can not discern any appreciable difference in the transmit or receive signal strength over the entire 40 meter phone band. Subsequent on air experience has confirmed this.





**Figure 5 — Tuning capacitor and loop assembly details.**

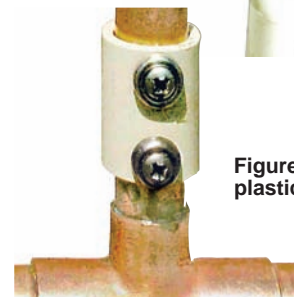
**Figure 6 — Cover for open end of capacitor made by gluing together a 1 1/4 inch coupling, a 1 1/2 inch pipe cap and a 1 x 3/4 inch reducing bushing. Before gluing, drill a 7/8 inch hole through the top of the pipe cap and through the reducing bushing. A 1 inch coupling may be substituted for the reducing bushing.**



**Figure 7 — Details of the tap match used to couple to the antenna.**



**Figure 8 — CPVC plastic coupler.**



## Ground Plane Loss in $\lambda/4$ HF Whip Antennas

Let's now take a closer look at ground plane or soil loss. First of all, a  $\lambda/4$  antenna is not a complete antenna. A resonant antenna needs to be at least  $\lambda/2$  long. A  $\lambda/4$  whip is, therefore, only half an antenna.

So how then does a  $\lambda/4$  whip work? Visualize, if you will, a  $\lambda/4$  whip mounted vertically on a metal mirror. What would you see looking at its reflection in the mirror? An upside down whip, of course. Well, that reflection acts as the other half of the antenna. It literally makes the whip into a  $\lambda/2$  antenna. Therefore, a ground plane is essential for a  $\lambda/4$  whip. What's more, that ground plane needs to be highly conductive — metal in most cases.

Not only this, but the ground plane should extend at least  $\lambda/4$  in all directions from the base of the whip. When, for example, you use a 19 inch  $\lambda/4$  2 meter whip on your car, the metal body is able to provide an adequate ground plane. It is large enough on 2 meters. On HF, however, it isn't. A vehicle's metal body on HF is usually too small to provide a complete ground plane. Instead the soil under the mobile rig carries significant current. The ground, and the resistance of any connections or wires in loading coils, adds significant resistance to the equivalent circuit. The result is that the resistive part of a typical HF vertical antenna is perhaps 35  $\Omega$ , in series with a

radiation resistance, the part of the equivalent circuit that results in radiation, of only a few ohms, depending on the band in use.

To illustrate why this is a big problem, consider a full length 32 foot  $\lambda/4$  vertical antenna on 40 meters. Theory predicts a radiation resistance of roughly 36  $\Omega$  in series with any soil resistance. The soil resistance can easily equal the radiation resistance; if so, about half of the transmitter's power is heating the soil. This is why we often use radials on a vertical antenna. They reduce the ground resistance.

Let's now shorten the whip to 8 feet, the average length of a mobile HF antenna. Now the radiation resistance will be roughly 2  $\Omega$ . In series with 35  $\Omega$  of soil resistance a typical 8 foot long mobile whip on 40 meters has an efficiency of roughly 5%. Worms get 95% of your transmitter's power.

In contrast, a compact loop has high efficiency because the soil resistance is no longer in series with its radiation resistance. That's why this loop consistently outperforms my conventional 40 meter HF mobile whip by as much as 2 S-units.

## Loops for Other Bands

You can build a compact loop for almost any HF or VHF band. To do so, download a copy of the handy *Excel* compact loop spread sheet from AA5TB's Web site: [webpages.charter.net/aa5tb/loop.html](http://webpages.charter.net/aa5tb/loop.html) (scroll down for

loop cal.xls). It dynamically calculates all the needed parameters. Using it, I have successfully constructed compact loops on several HF and VHF bands. For the matching section, you can essentially just scale the dimensions shown here by frequency. Try one — you won't be disappointed.

### Notes

<sup>1</sup>J. Portune, W6NBC, and F. Adams, WD6ACJ, "A Weather Vane Antenna for 2 Meters," *QST*, Aug 2005, pp 35-38.

<sup>2</sup>Feedback, *QST*, Oct 2005, p 35.

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*John is active on many bands and modes, predominantly from his HF RV mobile station. He has written various articles in ham radio and popular electronics magazines and remains active as a VE team leader, ham license teacher and Web site designer. You can reach John at 1095 W McCoy Ln #99, Santa Maria, CA 93455, or at [jportune@aol.com](mailto:jportune@aol.com). More information on loops can be found on his Web site at [www.w6nbc.com](http://www.w6nbc.com).*

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