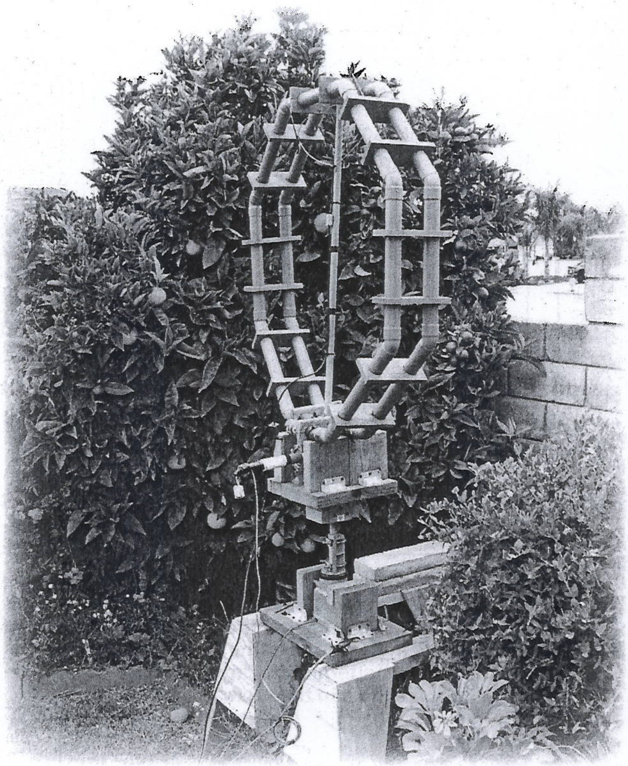
An Antenna Idea for Antenna Restricted Communities

Dress up your garden and neighborhood with antennas that look like lawn sculptures.

Cristian Paun, WV6N

For a number of years I used a various mobile antennas while operating from home on all bands between 3.5 and 30 MHz. My score of 264,922 in the 2010 CQ World Wide DX contest using low power (272 out of 14,765 entries) shows just how good such an antenna can be, if used in a permanent installation with appropriate ground radials.[1]

Still, I wanted something that would work even better on the lower HF bands and at the same time be unobtrusive to my neighbors. What antenna could possibly come close to the performance of a full size vertical and not be as visible?



The Small Loop Antenna versus the Competition

The small loop antenna, often called a magnetic loop, has been around for a long time. While some have had good luck with such an antenna, many others have been disappointed. I suspect they suffered from losses in loop conductors and in their interconnection method that can make such antennas much less efficient than expected. I recommend that the reader start with some useful references on this topic.[2-4]

The following will attempt to show that a properly constructed small loop antenna can perform almost as well as a properly installed elevated vertical. Since different readers will have different available space and other requirements, I have not attempted to provide detailed construction information. However, many of my design details are available on the QST-in-Depth website for those who are interested.[5]

An Elevated Vertical Monopole

Figure 1 is the elevation pattern of a 40 meter elevated vertical monopole antenna with the base 30 feet above average ground (conductivity 0.005 S/m, dielectric constant 13). At 15° elevation, a good yardstick for DX operation, the signal intensity from this vertical is about –0.41 dBi. While that doesn't sound too great, it is a lot higher than what a short mobile antenna can do. The azimuth pattern is omnidirectional, as one might expect.

Unless fed with a tuner, or traps or other schemes are employed, in its simplest form it is a single band affair.

The Horizontal Dipole at a Height of ½ Wavelength

A dipole at this height has a significant performance advantage over a monopole due to both the ground reflection and the restricted azimuth pattern that focus its radiation in the broadside direction. The azimuth pattern at 15° elevation is shown in Figure 2 and the elevation at the azimuth peak is shown in Figure 3. Note that while the main peak is at around 30°, the intensity at 15° elevation is a respectable 6.8 dBi, 7 dB greater in its preferred direction than from the monopole.

The dipole's disadvantages are that for the lower bands it is hard to rotate. To get worldwide coverage, it takes three of them, although two at right angles can come reasonably close. Each requires a half wave support pole on each end, although at least one could be shared. While traps can be used to operate on multiple bands, a coax fed dipole is basically a single band antenna. If fed with window line and a tuner, it will operate on all bands at frequencies higher than its half wavelength. The pattern at the higher frequencies is complex, however, and it is difficult to cover all directions with just two such antennas.

The Small Loop Antenna

An ideal small loop at a height of 10 feet has azimuth and elevation patterns as shown in Figures 4 and 5 respectively. The improvement in performance compared to the vertical monopole is notable — 5.47 dBi at 15° elevation versus –0.41 dBi at the same angle for the monopole. That is almost exactly 1 S-unit, similar to the gain of a small Yagi over a dipole. The comparison above assumes 100% efficiency, which is not quite attainable in practice. More about that later.

The same loop at a height of 5 feet above ground has slightly less gain, 4.08 dBi at 15° — still a lot better more than the vertical.

Building the Small Loop

I wanted my loop to be tunable from 3.5 to above 11 MHz, thus covering the 80, 40 and 30 meter bands, as well as our 60 meter

[1]Notes appear on page 37.

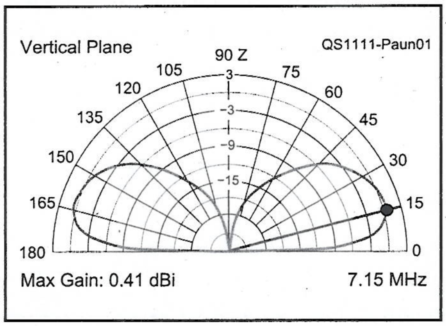


Figure 1 — The elevation pattern of the elevated ¼ wave vertical antenna 30 feet above average ground. Note the intensity of –0.41 dBi at 15° elevation. The data for all plots is from *4NEC2* simulation software.[6]

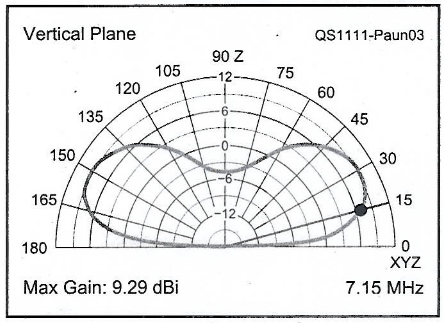


Figure 3 — The dipole elevation pattern at the peak azimuth. Note that while the main peak is at around 30°, the intensity at 15° elevation is a respectable 6.59 dBi, more than 7 dB greater than the monopole.

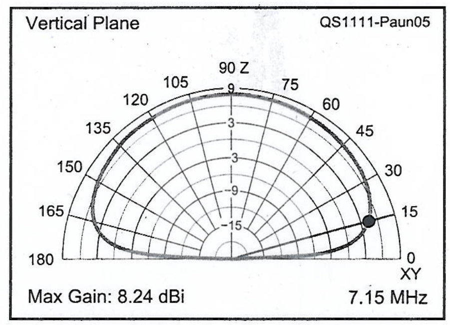


Figure 5 — The small-single-turn loop elevation pattern on 7.15 MHz at peak azimuth. Note that while the directivity is dipole-like, the loop's radiation is vertically polarized.

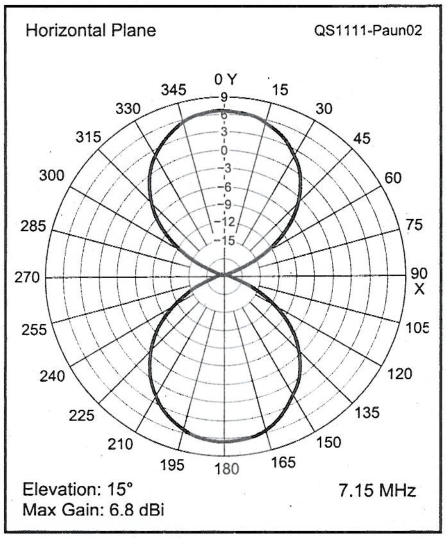


Figure 2 — The half-wave-high dipole azimuth pattern on 7.15 MHz at an elevation angle of 15°.

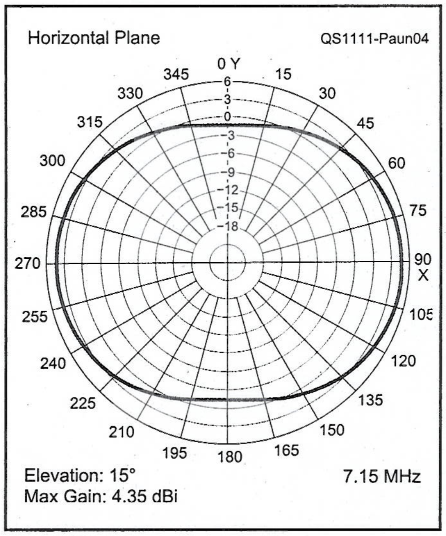


Figure 4 — The small single turn loop azimuth pattern on 7.15 MHz at an elevation angle of 15°. Note that the maximum radiation is in the plane of the loop perpendicular to the pattern of the more familiar large loop such as in the quad antenna.

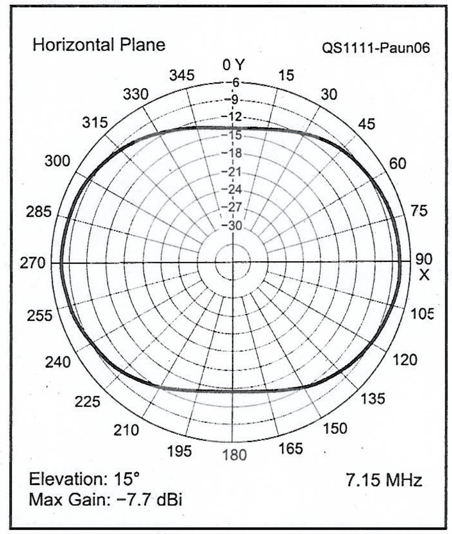


Figure 6 — The 3.3 foot diameter two turn loop azimuth pattern on 7.15 MHz at an elevation angle of 15°.

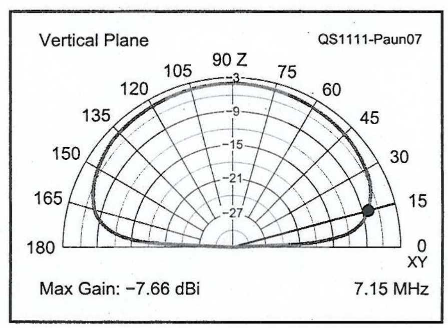


Figure 7 — The 3.3 foot diameter two turn loop elevation pattern at the peak azimuth.

channels. I started with the spreadsheet from Steve Yates's website.[7]

The distributed capacitance would make tuning at 14.2 MHz rather difficult if not impossible. A 6.6 foot diameter loop has a calculated efficiency of only 20% at 3.5 MHz but that is quite a bit better than most commercial mobile antennas. The predicted (*4NEC2*) efficiency is significantly higher on the 7 and 10 MHz bands. All said and done, that size loop is not going to be easily hidden, especially considering the directivity of this antenna and the need to make it rotatable.

Well, since the antenna is essentially a large one-turn coil resonated by a variable capacitor, I will get the same equivalent inductance by halving the diameter but using two turns instead of one. This will require approximately the same length of copper pipe that I used to minimize loss. This is particularly important because the radiation resistance will be reduced by a factor of four in the process.[8] I took this change into account in my assessment by inserting additional series resistance into AA5TB's spreadsheet calculator. Azimuth and elevation patterns are shown in Figures 6 and 7, respectively.

An additional price to pay for the convenience is the added distributed capacitance, which could make tuning difficult at the upper limit of the frequency range. Enough design margin can take care of that, though. With the above design data, I started to build a two turn loop, about 3.3 feet in diameter, made out of off-the-shelf, commercially available 1.5 inch copper pipe. I tuned it with a motor driven 12-500 pF, 15 kV vacuum variable capacitor. The rotator is a simple TV antenna unit.

The octagonal shape was an obvious choice because the 45° fitting pieces are also readily available. The vacuum variable capacitor is controlled remotely via an electric motor with planetary reduction gear. The supporting hardware is mostly homebrew with some wooden stands that were purchased for convenience. The two turns are 5 inches apart. This antenna has been in service at WV6N since April 11, 2010.

Over the air comparison between this antenna and the vertical, with help from my friends Jim, K6JRF and Randy, WB6MMJ, showed that it delivered 1 S-unit improve-

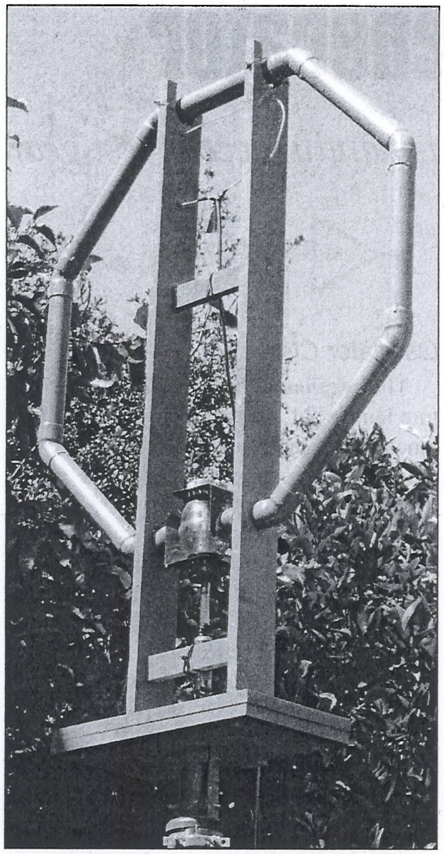


Figure 8 — The 3 foot diameter single turn loop for 14-30 MHz. Note the coupling loop used for excitation in both loop designs.

ment over my best mobile vertical on 75 meters. Once that orange tree grows taller, I may be able to raise this loop another 2 to 3 feet higher.

On to Higher Bands

After a couple of months of testing this loop, it was time to build one for the higher frequency bands. I again used the AA5TB spreadsheet calculator. I wanted this version to tune from below 14 MHz all the way to past 30 MHz.

For good design margin, a 5-100 pF, 25 kV variable capacitor was selected. I used the same type of motor with planetary reduction gear and the same antenna rotator as the lower frequency version. The vacuum variable capacitor tuning shaft is hot with RF, so the coupling between this shaft and the motor has to be able to withstand the very high voltages predicted by AA5TB's spreadsheet. The resulting antenna is shown in Figure 8. This second loop tunes as intended and it can take 1500 W with the use of the 25 kV capacitor.

All the wooden parts, the stand, the frame and the mast are home brew. I chose the octagonal shape again for convenience.

Hamspeak

Dipole antenna — A type of antenna consisting of a single element, often, but not always, approximately 1/2 wavelength long. This antenna is often used as a reference for gain comparisons and is frequently encountered in center-fed form on the high-frequency amateur bands. Multiple dipoles are often used in combination as directive antenna arrays.

Vacuum variable capacitor — Capacitor consisting of two electrodes, often concentric cylinders within an evacuated glass envelope. One is moved in and out with respect to the other by a lead screw running through a sealed bushing to change the capacitance.

Vertical monopole — Single vertical antenna element, typically a quarter or more wavelengths long. Often used as a transmit and receive antenna, singly or in combination with other similar antennas.

Conclusion

Small or magnetic loops turn out to be a viable choice for those hams living in restricted areas. Depending on the efficiency of the loop, they can come close to the performance of a full size dipole at a height of ½ wavelength. They don't quite look like antennas and will outperform an elevated vertical installed at the same height and with comparable efficiency. They radiate well at low angles for DX contacts as well as at high angles for short skip communications.

The thicker the copper pipe the more efficient they will be, and the higher voltage rating of the capacitor the more power they can take. These loops are narrow band and they exhibit directivity which could be a great advantage on receive. I used to get great reports from DX stations on 20 meters with the vertical while I was barely hearing them. It had to do with the local noise being captured by the antenna and with the take-off angles at each end. Not so with the loop. They hear me well and I hear them equally well.

The designs presented here are good compromises between performance and cost. They can handle significant power, at least 1 kW for the low bands (1.5 kW if 18 kV or higher rating capacitors are used) and 1.5 kW for the upper bands. Note that with high power levels and heights potentially near people, it is particularly important that an RF safety assessment be conducted in combination with methods of keeping people far enough away to be safe.

Notes

[1]**www.cqwpx.com/claimedcall.htm**

[2]For a good introduction to the basics of the magnetic loop, see **en.wikipedia.org/wiki/Magnetic_loop**.

[3]Practical information regarding the building of the magnetic loops is available at **www.standpipe.com/w2bri/**.

[4]This article makes extensive use of the *EXCEL* calculator that Stephen Yates, AA5TB, makes available on **www.aa5tb.com/loop.html**.

[5]**www.arrl.org/qst-in-depth**

[6]*4NEC2* is available to amateurs by Arie Voors without cost at **home.ict.nl/~arivoors/Home.htm**.

[7]See Note 4.

[8]The radiation resistance of a small multiturn loop can be shown to be $R_R = 31{,}171 \times (n \times A/\lambda^2)^2$. See, for example, J. Kraus, *Antennas* (New York: McGraw Hill, 1950), p 167.

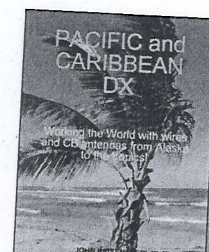
Photos by the author.

ARRL member and Amateur Extra class operator Cristian Paun, WV6N, has been interested in ham radio for many years, He started as a short-wave listener in 1983 and then became licensed as YO3FMY. He moved to Australia and there became VK3MS (still an active call sign). He now lives and works in California and operates as WV6N.

He holds an MS degree in Electrical Engineering. While living in Australia he was employed by Codan and Winradio. He now works as an RF engineer, designing radios and antennas for a large corporation. Cristian holds a number of US and European patents for antennas. You can reach Cristian at 904 Aster Ln, Lompoc, CA 93436-3241 or at **wv6n@arrl.net**.

New Book

PACIFIC AND CARIBBEAN DX BY KL7JR



◊*Pacific and Caribbean DX* by John Reisenauer Jr, KL7JR, includes stories of KL7JR's adventures working the world with wire and CB antennas from Alaska to the tropics. *QST* readers are familiar with some of John's radio exploits, and here are more stories for your enjoyment. 48 pages, 8.5 × 11 inches. Price: $12.99. Available from **www.lulu.com/product/paperback/pacific-and-caribbean-dx/16247513**.