Open Channel

by Joseph J. Carr

Large Loop Antennas

In this month's column, we will take a look at the large loop antennas such as the quad loop, delta loop, and bi-square loop. These loops share certain characteristics in common, such as the approximate pattern. First, let's take a look at the conventional quad loop antenna.

Quad Loop

Figures 1 and 2 show the basic quad loop antenna. The antenna has been likened to a folded dipole that has been "pulled open." The nice thing about this antenna is that a full performance antenna can be built in a limited space. The only thing required is at least a quarter wavelength at the operating frequency. This antenna has a maximum gain of 1.4 dBd (dB over a dipole) or 3.4 dBi (dB over isotropic). The antenna has a figure-8 pattern in and out of the page as you view Figures 1 and 2.

The quad antenna was originally built as a beam antenna (more later). It was created by engineers at radio station HCJB in Quito, Ecuador after they experienced losses to their Yagi antennas due to corona arcing off the ends. The thin air in Quito made the use of Yagis – or any half wavelength antennas – somewhat problematical because of the arcing at the high voltage tips of the antenna. The quad loop solves that problem by putting the current loops and voltage loops (which cause the trouble) in the center of the radiator element's vertical and horizontal sides.

The big loop antenna shown here consist of one wavelength of wire formed into a square, that is to say it is a quarter wavelength on a side. The dimensions of the antenna are:

$$A = \frac{251}{F_{MHz}} \quad (1)$$

Or, for the overall length:

$$Overall = \frac{998}{F_{MHz}} \quad (2)$$

where:
A and Overall are the lengths in feet (ft)
FMHz is the frequency in MegaHertz.

The overall length is four times the length of the individual sides.

Impedance Matching

The feedpoint impedance of the quad loop is around 100 ohms, with 140 ohms being given for the free space impedance. The impedance closer to the earth's surface is probably the smaller number, as is the impedance for antennas with a large length-to-diameter ratio. This is not a good match to either 75-ohm or 52-ohm coaxial cable, so some sort of impedance matching is needed. Perhaps the best approach is to use the quarter wavelength matching stub in series with the transmission line. The length of the quarter wavelength stub should be:

$$L = \frac{246\,V}{F_{MHz}} \quad (3)$$

where:
L is the length of the matching stub in feet (ft)
FMHz is the frequency in MegaHertz

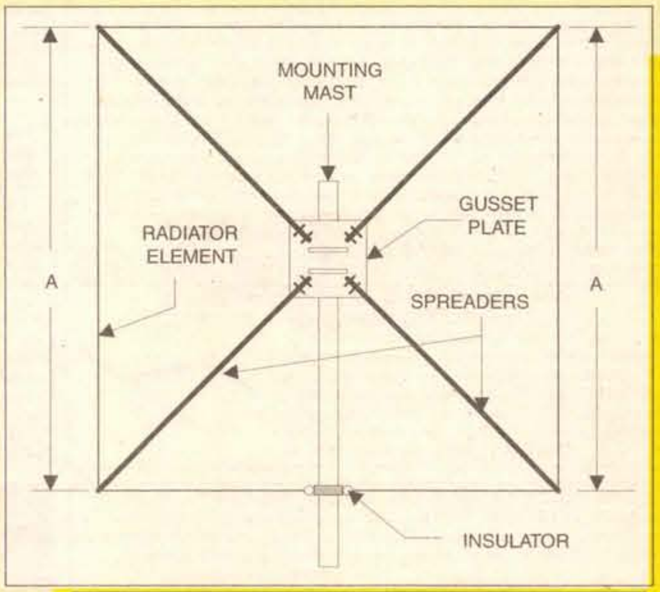


Figure 1 - Rotatable quad loop antenna.

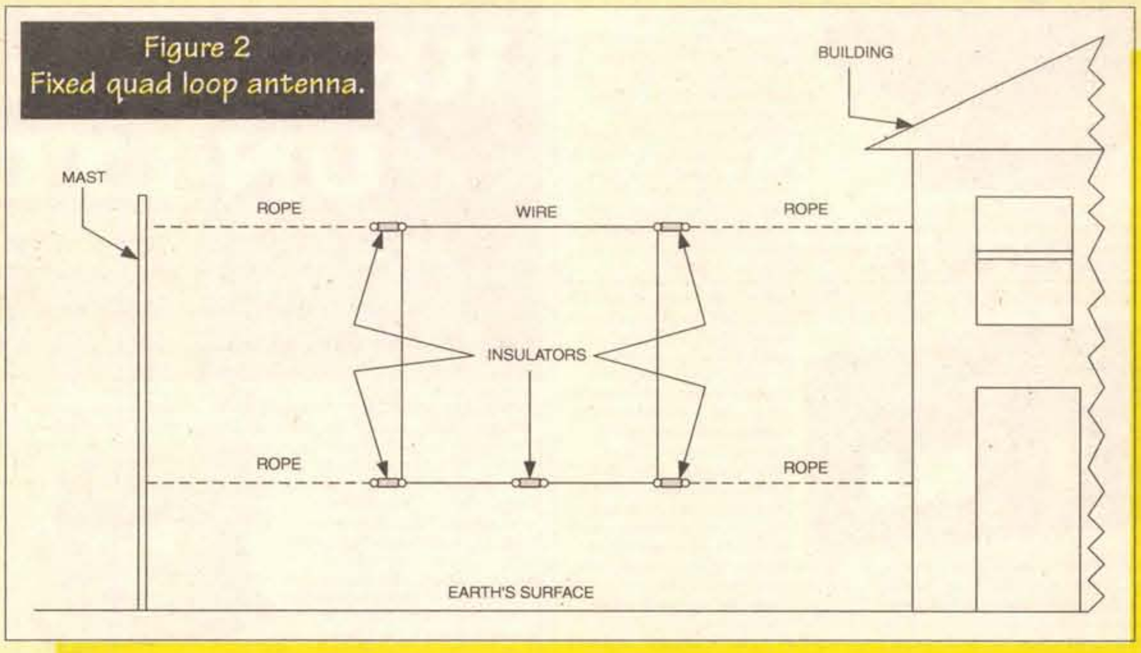


Figure 2
Fixed quad loop antenna.

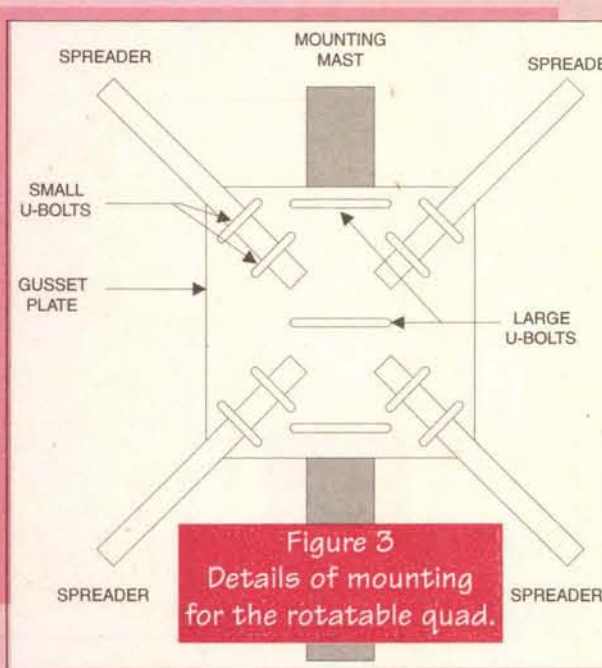


Figure 3 Details of mounting for the rotatable quad.

V is the velocity factor of the coaxial cable.

The term V in Equation 3 depends upon the type of coaxial cable that you use. You can use 0.66 for standard polyethylene coaxial cable, or 0.78 to 0.80 for polyfoam coaxial cable. Or alternatively, you can measure the velocity factor of the coaxial cable and use that number. I have seen substantial variation in the actual velocity factor, so prefer this latter method myself.

The impedance of the transmission line used for the quarter wavelength matching stub is found by taking the square root of the product of the impedances:

$$Z_1 = \sqrt{Z_O Z_L} \quad \textbf{(4)}$$

where:

Z1 is the characteristic impedance required of the matching stub

ZO is the impedance of the feedline to the receiver or the rig

ZL is the load impedance (i.e., the antenna feedpoint impedance)

Example

Take as our example the case where the feedpoint impedance is 140 ohms, and the receiver uses 52-ohm polyfoam coaxial cable with a measured velocity factor of 0.80. The frequency of operation is 14.25 MHz.

Overall Length:

$$Overall = \frac{998}{F_{MHz}} = \frac{998}{14.25} = 70 \textit{ feet}$$

Length of each side:

A = Overall/4 = 70/4 = 17.5 feet

Length of the matching stub:

$$L = \frac{246\,V}{F_{MHz}} = \frac{(246)\,(0.80)}{14.25} = 13.81 \textit{ feet}$$

Impedance of the matching stub:

$$Z_1 = \sqrt{Z_O Z_L} = \sqrt{(52)\,(140)} = \sqrt{7280} = 85 \textit{ ohms}$$

The impedance of the matching section is supposed to be 85 ohms. One can buy 90-ohm coaxial cable but, in practice, the user will be able to obtain 75-ohm coaxial cable far more easily. This cable forms a good match when used as the matching stub, especially considering the fact that the antenna will be used closer to the ground than the free space impedance value indicates. This means the impedance of the load will be closer to 100 ohms, and that translates into an impedance of SQRT(52 (100) = 72 ohms.

Construction

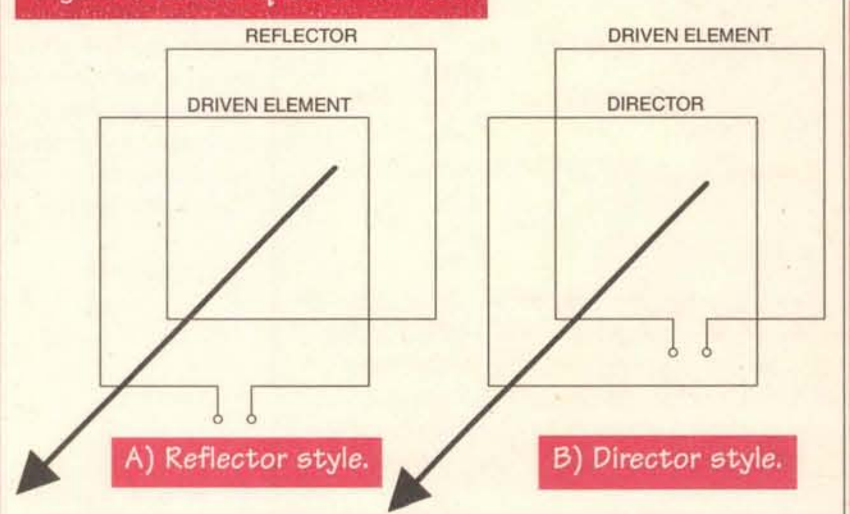
The quad loop antenna can be built in either a rotatable format such as shown in Figure 1, or it can be built fixed in a manner such as Figure 2. The advantage of the rotatable version should be obvious. One can send signals in any direction. More to the point, one can null interfering stations from any quarter.

The rotatable version shown in Figure 1 is mounted on a pole or mast that is, in turn, rotated either by hand or by an electrical antenna rotator. The antenna is built using fiberglass (or other insulating) spreaders connected to a gusset plate. The spreaders are connected to the gusset plate by a set or two or three U-bolts (Figure 3). The gusset plate is held to the mounting mast by larger U-bolts. The gusset plate is typically 10 to 24 inches square, and made of wood or fiberglass.

The mounting version shown in Figure 2 is fixed, but has the advantage of being able to be installed in an existing location, without the need for a rotatable mast. For example, the two supports shown in Figure 3 as a building and a mast, could be any combination of buildings, masts, trees, or other forms. Ropes are used to hold the antenna, which is about in the center of the distance between the supporting structures.

Although it is fed at the bottom in the case

Figure 4 Cubical quad antennas:



A) Reflector style. B) Director style.

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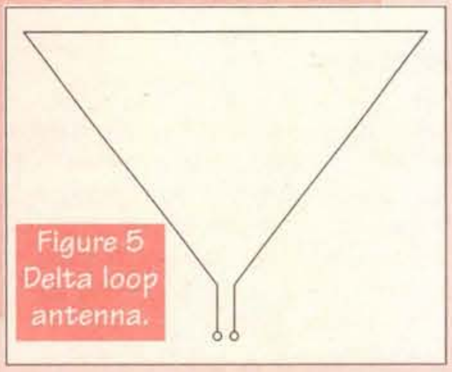

Figure 5 Delta loop antenna.

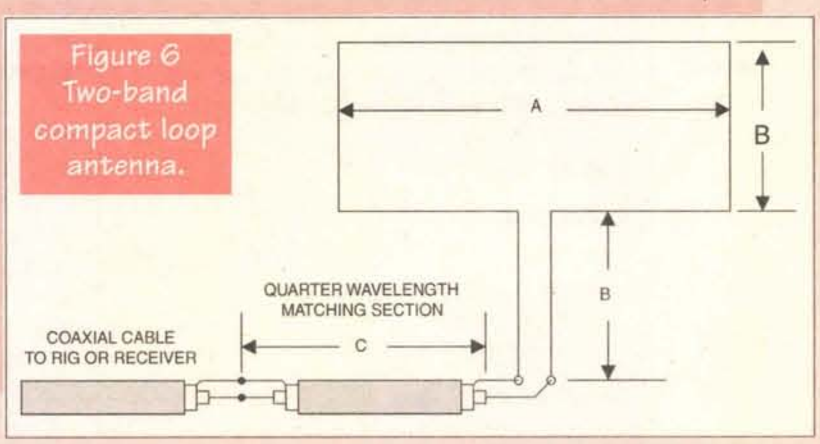

Figure 6 Two-band compact loop antenna.

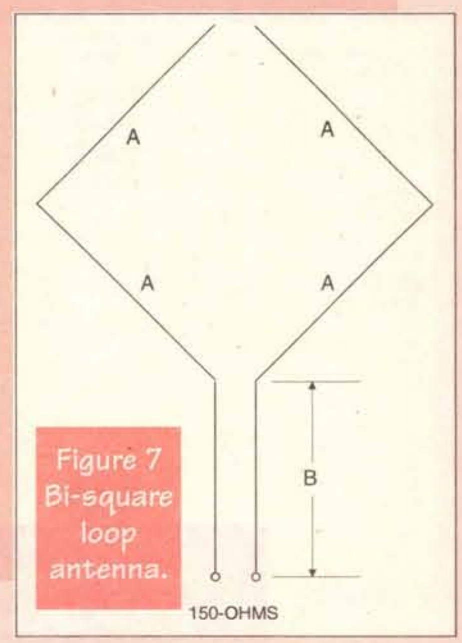

Figure 7 Bi-square loop antenna.

of Figures 1 and 2, giving it horizontal polarization, the antenna can also be fed along either vertical wire radiator segment for vertical polarization.

Quad Beam Antennas

The quad loop antenna can be formed into a beam antenna (Figure 4), giving a unidirectional pattern. The nice thing about the quad antenna is that close to the earth's surface it behaves better than a Yagi beam antenna. The antenna can be built in either of two ways: a driven element and either a reflector or a director. The driven element overall length is found from Equation 2, but the director and reflector element overall lengths are found from Equations 5 and 6:

Director:

$$Overall = \frac{976}{F_{MHz}} \quad (5)$$

Reflector:

$$Overall = \frac{1030}{F_{MHz}} \quad (6)$$

Spacing (0.13():

$$S = \frac{128}{F_{MHz}} \quad (7)$$

For a spacing of 0.13λ, the maximum gain of the two element quad beam antenna is 7.3 dBd, or 9.2 dBi. At a spacing of 0.13λ, the feedpoint impedance is about 60 ohms, which is a good match to either 52-ohm or 75-ohm coaxial cable (the VSWR when used with 52-ohm cable is only 1.15:1).

Delta Loop Antennas

The Delta loop antenna (Figure 5) gets its name from the resemblance to the Greek upper case letter "delta" Δ). The characteristic of this loop is that it is triangular shaped, which makes mounting and installation easier in some cases. Each side of the Delta loop is one-third of a wavelength (λ/3), but the overall length is found from Equation 2. The antenna can be fed at any corner. The antenna can also be inverted (sharp point up) and it will work approximately the same as for the case shown.

Two-Band Compact Loop

Most of the loops discussed thus far are basically monobanders, unless multiple loops are built on the same frame and fed in parallel. The loop in Figure 6, however, operates on two bands that are harmonically related to each other. For example, if FL is the lower band, and FH is the higher band, then FH = 2 X FL.

The overall length of the loop is half wavelength, but it is arranged not into a square, but rather a rectangle in which the horizontal sides are twice as long as the vertical sides, i.e., the horizontal elements are quarter wavelength and the vertical sections are one-eighth wavelength. The section lengths are:

Horizontal:

$$A = \frac{246}{F_{MHz}} \text{ feet} \quad (8)$$

Vertical:

$$B = \frac{123}{F_{MHz}} \text{ feet} \quad (9)$$

In both equations, the frequency is the center frequency of the lower band of operation.

The vertical stub is made of 600-ohm parallel open wire transmission line, although 450-ohm twin-lead could also be used. The length of the stub is found from the same equation (above) as the vertical segment if open wire line is used. If twin-lead is used, then multiply that distance by the velocity factor of the transmission line.

The coaxial line is a Q-section made of 75-ohm transmission line. It is cut to a quarter wavelength of the upper band, i.e., twice FMHz used in the calculations above.

The Bi-Square Loop

The bi-square loop in Figure 7 is twice as large as the quad loop. The overall length of the wire is two wavelengths, so each side is half wavelength long. The overall length is calculated from:

$$L_{Meters} = \frac{1919}{F_{MHz}} \text{ feet} \quad (10)$$

while each side is:

$$L_{Meters} = \frac{480}{F_{MHz}} \text{ feet} \quad (11)$$

The bi-square antenna can be used on its design frequency, and also at one-half its design frequency (although the patterns change). At the design frequency, the azimuthal pattern is a clover leaf perpendicular to the plane of the loop, and is horizontally polarized. At one-half the design frequency, the radiation is vertically polarized and the directivity is end fire.

The feedpoint impedance of the bi-square is on the order of 150 ohms. This means that some form of impedance matching will be needed to match the impedance to 52 or 75 ohms used by most receivers.

Conclusion

The large loop antennas offer gain over a dipole, and can be built on smaller sized lots than a host of other antennas. They are easy to build and use. **NV**

Connections ...

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