Notes on the Modified Half-Loop

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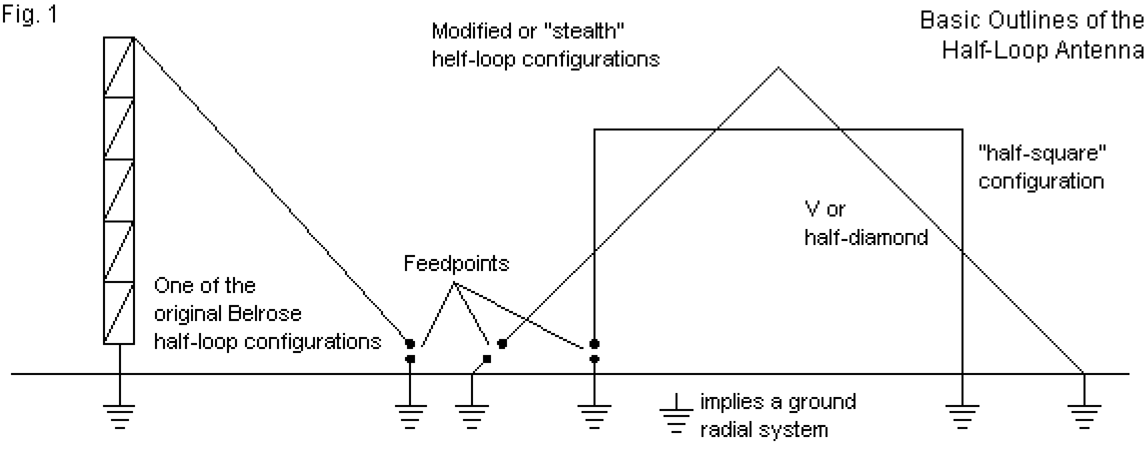
Many hams in the suburbs have modest yards, often with some trees. The yards are often not large enough to handle a lower-HF half-square, and the height of a full monopole might scare neighbors or violate covenants. These homeowners wish to work 40 meters effectively, but cannot support a dipole at a height that gives a reasonably low take-off (TO) angle. So the challenge they face is to come up with a moderately effective 40-meter antenna that is inconspicuous.

In 1982, Jack Belrose, VE2CV, introduced (in both *Ham Radio* and *QST*) the half-delta. As shown on the left in **Fig. 1**, the original version of the antenna (and the sketch shows only 1 of several configurations) made use of an existing tower as one leg of the antenna, with a sloping wire forming the other leg. (For further information on the various configurations of Belrose's antenna, see the *Ham Radio* and the *QST* CDROM archives, available from ARRL, or Chapter 11 of ON4UN's *Low-Band DXing*, 2nd Edition.)

Fig. 1



The total antenna length is about 1/2-λ. If a ham does not have a tower, then he might construct the entire antenna from wire. Two versions of the antenna evolved, as shown in the overlapping sketches on the right in **Fig. 1**. One version is a square half loop, while the other version is a delta, V, or diamond half-loop. In all cases, the feedpoint is at ground level at one end of the wire. The earth-ground symbols indicate that the antenna requires a ground radial system at each intersection of the wire with the ground.

Recently, I have received a number of questions about the half-loop--mostly from users. What is it, that is, into what category of antenna should we place the antenna? How well does the antenna perform? How does the half-loop compare to other antennas we might construct in a suburban backyard? As a result of these questions, I have taken a small look at the antenna and put together a few notes. The notes do not advance the art of the half-loop to any degree, but they may prove useful to some folks in showing how to reach answers for the kind of questions that we shall address.

What is a Half-Loop?

One way to arrive at an answer to the question of what kind of antenna the half-loop may be is to model the antenna and then to look at the current distribution. Therefore, I modeled the square and the diamond versions of the antenna to arrive at the EZNEC current distribution graphics in **Fig. 2**. With a ground level and wire-end feedpoint, both versions of the antenna show maximum current at ground level, with minimal current magnitude at the high center point. The graphics also indicate the relative current phase angle. The current phase reverses at the antenna center point. The voltage also reverses its phase angle at the same point, so the two points of intersection with the ground are in phase with each other. The sketch does not show the ground radial system beneath each end of the wire.

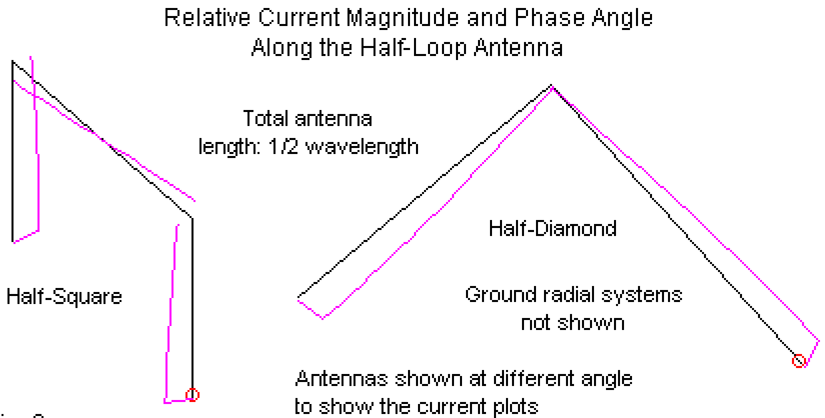


Fig. 2

The current distribution along the antenna should immediately remind us of another antenna: the quad loop. **Fig. 3** shows both square and diamond loops with a side feedpoint. If we examine only the upper half of each antenna, we find the same current distribution that we saw in **Fig. 2**. Although the models are in free space, over ground, we would find that they are vertically polarized (with only a remnant of horizontal polarization). Essentially, both configurations place two vertical dipoles in phase with each other at an effective quarter-wavelength distance. One-quarter wavelength is not ideal to maximize gain from a pair of dipoles in phase, but it is sufficient to show a significant gain increase over a single dipole.

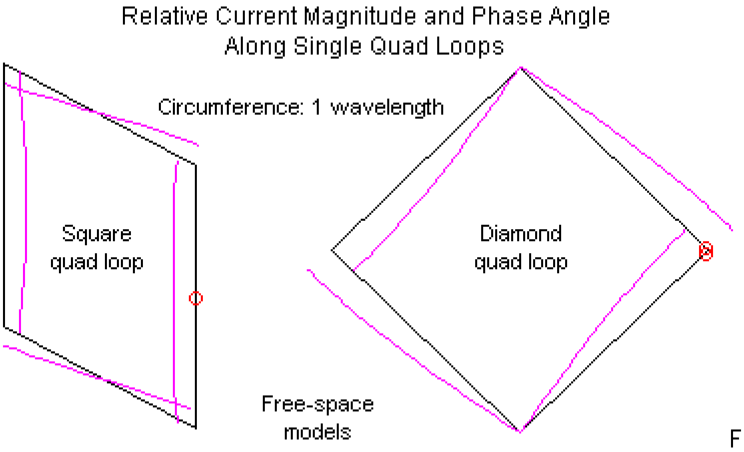


Fig. 3

Essentially, then, the half-loop is one half of a quad loop, with the ground substituting for the missing lower half. A single quad loop has about 1.1 to 1.2 dB gain over a dipole, and over perfect ground, the half-loop has about 0.5-0.6 dB gain over a monopole. Unfortunately, unless we can construct a half-loop over an ocean (a good sea will do), we cannot obtain near-perfect-ground performance. Therefore, we shall have to satisfy ourselves with whatever the antenna will yield over dry ground.

We shall require a ground radial system at each end of the antenna. Some users have buried chicken wire beneath the lawn as a substitute, although this type of ground is best laid down before adding topsoil and grass seed. For modeling purposes, we shall use radials.

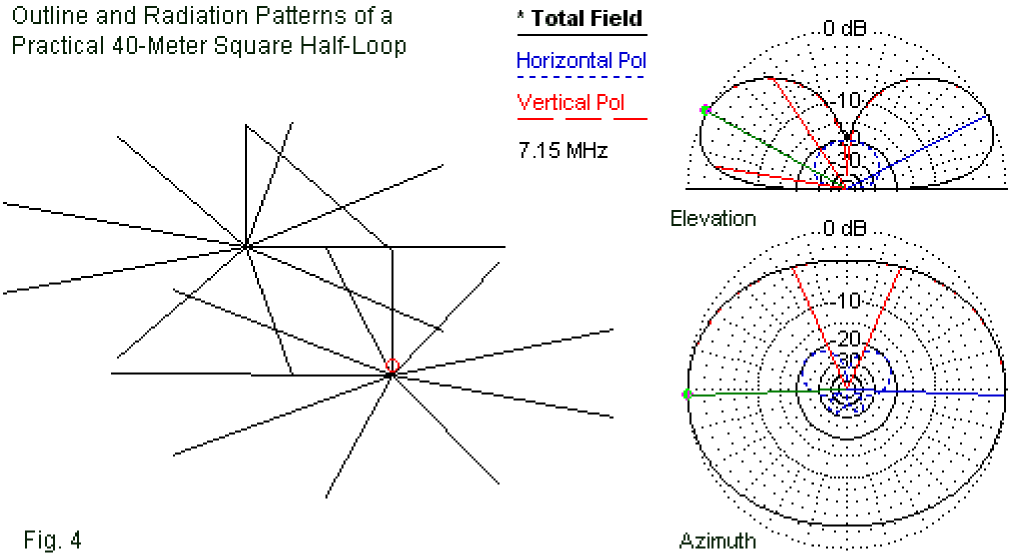


Fig. 4

Fig. 4 shows the outline of one of the models, using the square version of the antenna. For our initial examination, we shall not use many radials: the outline shows 9 radials per end. The use of 9 radials, rather than the traditional 8, results from the fact that some configurations of the antenna result in distances between wires ends that are less than 1/4-λ. An even number of radials would have resulted in an unwanted wire intersection, even though the radial systems are vertically offset by 0.2'. Using an odd number of radials prevents the unwanted wire intersection.

The patterns on the right confirm that the polarization of the antenna is predominantly vertical. In both the elevation and the azimuth patterns, we can find the small horizontal component that is 20 dB lower than the maximum gain shown in the patterns. The vertical component is co-terminal with the total field except at the very center of the elevation pattern.

The half-loop, then, is half of a quad loop with the ground replacing the missing half. Now we can turn to the question of how well the antenna performs.

What Performance Can I Expect from a Half-Loop?

The performance that one can expect from a half-loop does not depend on whether one chooses the square or diamond configuration. Far more important to performance are four factors.

1. The quality of ground beneath the antenna;
2. The number of radials beneath each end of the antenna;
3. The proximity of "RF-eating" ground clutter; and
4. The distance between the antenna ends.

The half-loop consists of two 1/4-λ, ground-mounted monopole either bent or tilted toward each other. Like any ground-mounted monopole, the performance will vary with the ground quality for any set number of radials. Let's use some fairly standard soil quality categories for a brief survey. Very good soil has a conductivity of 0.0303 S/m and a relative permittivity of 20. Average soil values are 0.005 S/m and 13. For very poor soil, we find 0.001 S/m and 5. Most soils on the continental U.S. fall within this range. I surveyed one 40-meter model of the square half-loop over each of these soils. Each model was identical in using 9 radials per wire end. **Table 1** shows the modeled data.

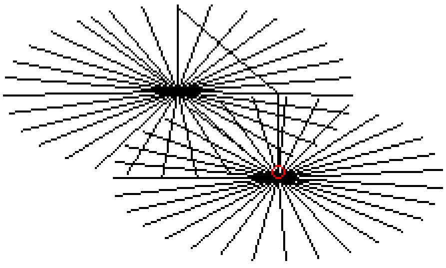
Table 1. Relative performance of a square half-loop over 3 soil types AWG #12 copper wire and 9 radials per wire end (see **Fig. 4**)

Soil Type	Max. Gain dBi	TO angle degrees	Source Impedance R +/- jX Ω
Very good	1.58	23	77.7 - j11.7
Average	-0.40	28	86.6 - j6.9
Very Poor	-1.25	31	93.8 + j21.9

Just as we would find with a ground-mounted monopole, the gain increases with improving soil quality. Accompanying that gain increase is a reduction in the TO angle. Equally important is the fact that the feedpoint or source impedance also changes. The resistive component rises with decreasing soil quality. The reactive component becomes more capacitive as we improve the soil.

The test purposely used only 9 radials per wire end. The number roughly corresponds to what we might expect homeowners to install before fatigue ends the enterprise. However, the number of radials may have a profound effect on performance. I increased the number of radials per wire end to 31. Once more, the odd number prevents an unwanted wire intersection. The model underwent no other changes. The resulting model has the outline shown in **Fig. 5**.

Fig. 5



The Square Half-Loop with 31 Radials per Wire End

With the larger radial field, I obtained the results shown in **Table 2**.

Table 2. Relative performance of a square half-loop over 3 soil types AWG #12 copper wire and 31 radials per wire end (see **Fig. 5**)

Soil Type	Max. Gain dBi	TO angle degrees	Source Impedance R +/- jX Ω	Gain Increase over 9 radials
Very good	2.38	2	65.9 - j16.1	0.80 dB
Average	1.15	28	61.9 - j14.7	1.55
Very Poor	0.36	31	52.4 - j14.9	1.61

Increasing the number of radials by a factor of between 3 and 4 has several noteworthy effects. Most antenna enthusiasts will immediately note the increase in the gain relative to the smaller radial fields. However, note that the gain increase diminishes as we improve the soil quality. That fact may have an influence on how much larger we make each field according to the law of diminishing returns for the effort expended. Nevertheless, the gain increase is significant.

Equally significant is what happens to the source impedance of the antenna. As we increase the size of the radial fields, the impedances become less dependent on the soil quality and begin to form a tightly clustered group of values. With 31 radials per wire end, it is likely that other installation variables will have a greater effect on the source impedance than the soil quality.

Finally, let's not neglect what does not happen as we increase the radial field size. The TO angle does not change for each soil quality. The TO angle is largely a function of ground reflections that occur beyond the limits of the radial field. Hence, improving the radial system has almost no effect on the elevation angle of maximum field strength. While we are looking at the TO angle numbers, we should note in passing that many potential half-loop users might be dismayed by the relatively high values. However, if you refer to **Fig. 4**, you will see that the vertical beamwidth (between half-power points) exceeds 45°, extending from under 10° elevation to more than 50°. Within the limits of the antenna structure, considerable low-angle energy (and reception sensitivity) exists for effective operation. If we find any drawback, it lies in the high-angle sensitivity to noise sources at less than remote distances. However, the half-loop shares this feature with many ground-mounted antennas.

Models do not adequately deal with the third factor in our list of conditions that may have an effect upon half-loop performance. Any vertical antenna interacts--usually in unwanted ways--with any other close vertical structure that is either conductive or semi-conductive. All that I can do here is to list some of the usual advice. Keep the wires as far from metal or wooden vertical objects as the yard layout permits. Some antenna builders with 2 good trees will run a rope between elevated limbs and hang the antenna from the rope, thus maximizing the distance between the wire and the trees.

Many newer antenna builders often mistakenly believe that trees are wood and wood is an insulator. More correctly, kiln-dried lumber thoroughly coated to prevent moisture absorption is a fairly good insulator. However, raw lumber and especially living trees contain a vast array of ionized salts that can absorb and dissipate RF as heat. (Experiments have shown that trees may be conductive enough to serve as a lossy but usable emergency antenna.) Because the degree of ionization may change with the season and the short-term weather, antenna performance may also change if the wires are too close.

While we are looking at ways to maximize performance in the backyard, note the azimuth pattern in **Fig. 4**. The gain broadside to the plane of the wires is about 3 dB better than the gain edgewise to the wires. If feasible, you may wish to orient a half-loop broadside to your most significant target communications areas.

The final factor affecting performance involves the exposed part of the antenna itself. Suppose that we wish to obtain a feedpoint impedance that is close to resonant. We shall use this desire as a premise, although it may not be as significant a factor as most folks might surmise. Due to the many site and installation variables, we are unlikely to obtain a direct match to a coaxial cable (usually 50 Ω). Hence, a half-loop is a good candidate for a remote weatherproof (more properly, a weather resistant) automatic antenna tuner. The impedance excursions of the half-loop with changing weather and pruning inaccuracies are unlikely to drive the tuner networks into regions of high inefficiency.

Nevertheless, the premise of resonance gives me a place to note some interesting aspects of the half-loop. Let's continue to use the 40-meter square half-loop as our subject antenna, placing it over average ground. We can achieve resonance with numerous combinations of vertical height and end-wire separation. **Table 3** lists 3 combinations that will work.

Table 3. Some near-resonant dimensions for a square 40-meter half-loop AWG #12 copper wire, average ground, 9 radials per wire end

Vertical Height feet	Separation feet	Max. Gain dBi	TO angle degrees	Source Impedance R +/- jX Ω
20.5	28	-0.53	27	120.1 - j1.8
18.5	32	-0.49	27	103.5 - j7.3
16.5	36	-0.39	28	86.6 - j6.9

A common misconception by newer antenna enthusiasts is the idea that any antenna benefits from height. Although this sound bite is generally true of horizontal antennas, it does not apply to the array with which we are dealing. The half-loop is a pair of monopoles fed in phase by virtue of the bent structure. Vertical monopoles and dipoles obtain maximum gain when fed in phase at a distance of just over 1/2 λ. With our connected structure, we cannot possibly obtain ideal spacing for maximum gain. (Incidentally, in-phase fed verticals show their maximum gain broadside to the plane of the antenna pair, which coincides with the direction of maximum gain shown in the azimuth pattern in **Fig. 4**.) But we can widen the separation beyond the shape of a pure half square.

As we shorten the antenna and stretch the separation, we see a slow but steady rise in the maximum gain. At the same time, we see a considerable reduction in the resistive component of the source impedance. Both trends suggest that further separation might be even more beneficial. However, note the TO angle. As we continue to shorten the array, the current in the horizontal section near the corners increases, thus increasing the TO angle. Hence, we encounter a limit as to how much we may shorten the array and increase gain before that gain goes straight upward instead of at a desired lower elevation angle.

Except for the source impedance, the actual performance differences shown in the table are not significant enough to be matters of concern. Hence, for the average builder, there is plenty of room to fit a half-loop within a variety of spaces and still obtain virtually the same performance.

So far, we have appeared to ignore the diamond or V version of the half-loop. With 9 radials per wire end, its outline and patterns over average soil appear in **Fig. 6**.

Outline and Radiation Patterns of a Practical 40-Meter Diamond Half-Loop

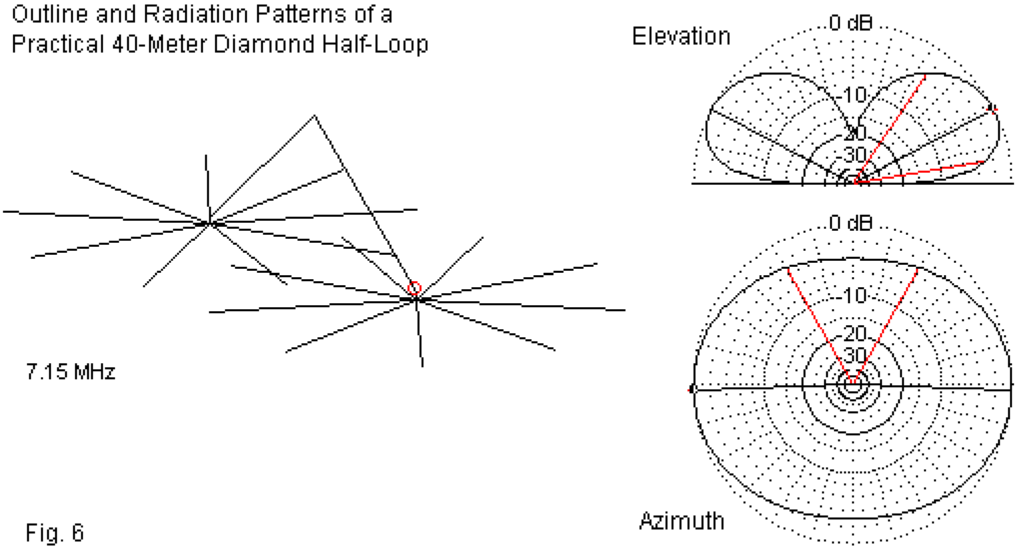
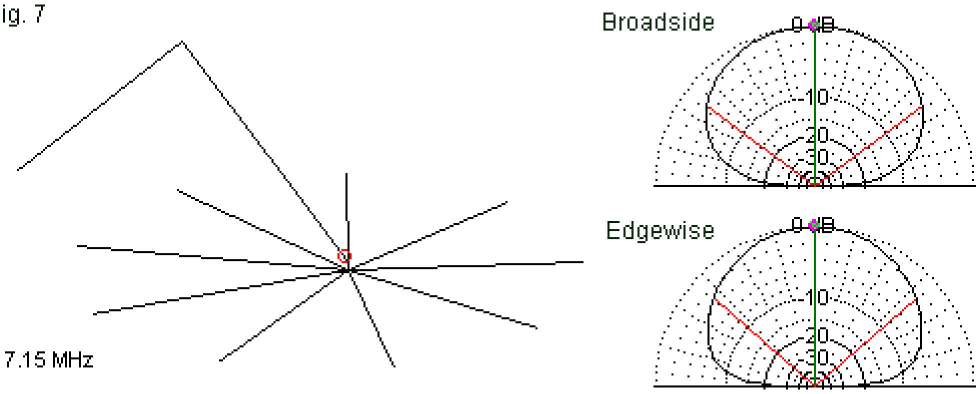


Fig. 6

Actually, when we analyzed the performance of the square version, we also analyzed the performance of the diamond version. The gain levels for the two antennas are within about 0.2 dB of each other, and the elevation angles are identical for both. The version of the diamond shown in the outline has a horizontal dimension of 50' and a height of 23.5' at the center. These two dimensions are about 1.4 times the horizontal and vertical dimensions of the square loop with the widest footprint. The diamond version shows a source impedance of 87.3-j1.8 Ω, almost identical to the source impedance of the corresponding square version. (Square and diamond quads in free space show similar relationships.) The overlaid sketches in **Fig. 1** show that the height and width average out to virtually the same values.

Whether using a diamond or a square half-loop, one mistake not to make is to omit the radial field at the far end of the wire, relative to the feedpoint. To simulate this condition, I eliminated that set of radials and raised the loose wire end 0.2' above ground (about 2.4"). The results appear in **Fig. 7**.

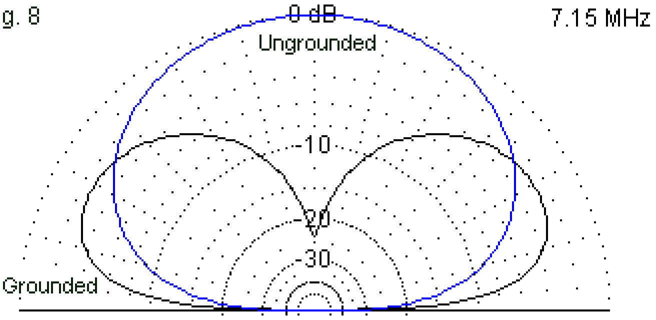
Fig. 7



Outline and Radiation Patterns of a Half-Loop with One End Ungrounded

The antenna is no longer a half-loop. The current is maximum at the center and decreases toward each end. Essentially, the antenna is a horizontally polarized very low inverted-V that we are end feeding, in contrast to the normal center-feedpoint. The feedpoint impedance approaches 2000-j2000 Ω. The maximum gain is 2.03 dBi over average ground. Although the maximum gain seems to be a vast improvement over the diamond half-loop, maximum gain occurs directly overhead. **Fig. 8** overlays the patterns for the antenna with and without radials at the far end. The gain at low angles that favor normal DX skip angles is higher for the half-loop than for the end-fed V.

Fig. 8



Comparative Elevation Patterns: Diamond Half-Loop with and without Far-End Radials

Although the low end-fed V may seem to be a reasonable NVIS antenna, it falls far short of the performance that we can obtain by raising the V to a top height between 0.15 λ and 0.2 λ above ground. Hence, the ungrounded version of the half-loop is not optimal for anything but emergency service--in which case, almost any wire that will radiate is suitable for service.

How Does the Half-Loop Compare to Other Suburban Backyard Semi-Stealthy Antennas?

The motivation behind our last question emerges from a more general consideration: should I go to the trouble of building one of the half-loops? We shall assume that the backyard situation precludes an effective horizontal dipole, that is, a dipole at least 3/8 and preferably at least 1/2 λ above ground. Below such levels, the dipole becomes a NVIS antenna with a pattern similar to the end-fed V pattern shown in **Fig. 7**. We are also assuming that the goal is long distance communications. The final assumption that we shall make is that we can only use wire. Our comparative models will use the same material that we used for the half-loops, namely, AWG #12 copper wire.

Using some of the construction advice given for the half-loop, we can construct some simple wire monopoles for 40 meters. Two candidates appear in **Fig. 9**. One is a full-length 1/4-λ monopole. The second is a half-length monopole with a T-top, that is, 2 symmetrical wires acting as a simple top hat to bring the monopole to resonance. In each case, each antenna uses 8 radials, close to the number we used at each end of the half-loop.

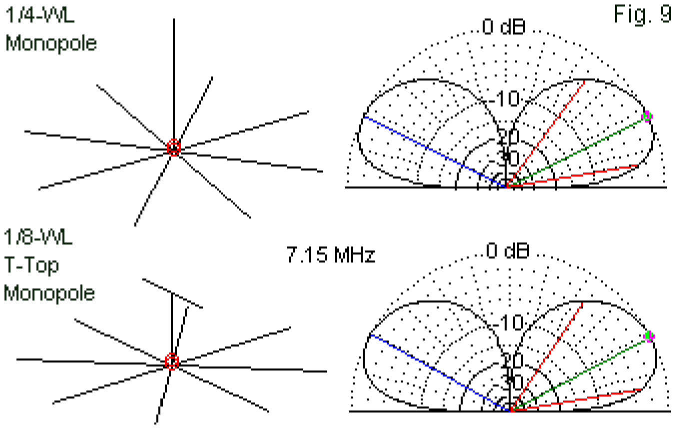


Fig. 9

Outlines and Elevation Patterns of a Full-Size Monopole and a Half-Size Monopole with a T-Top

Table 4 catalogs some of the characteristics of these two antennas, along with a representative half-loop of each type.

Table 4. Comparative data for two monopoles and two half-loops
All antenna are AWG #12 copper wire over average ground

Antenna	Height feet	Width feet	Max. Gain dBi	TO Angle degrees	Source Impedance R +/- jX Ω
1/4-wl monopole	32.75	---	-2.05	26	56.1 + j2.5
1/8-wl T-top	16.5	21.2	-2.99	28	38.6 + j1.0
Square half-loop	16.5	36	-0.40	28	86.6 - j6.9
Diamond half-loop	23.5	50	-0.58	28	87.3 - j1.8

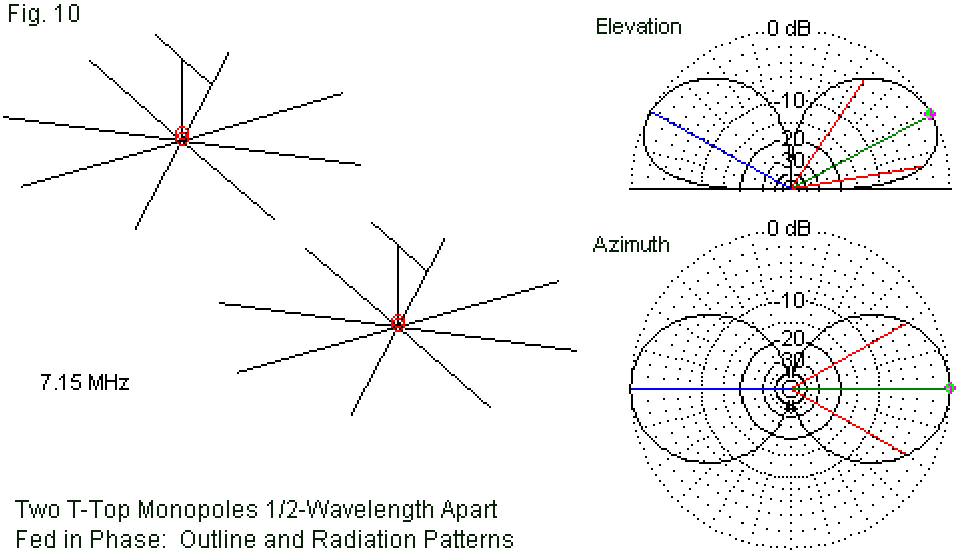
If the full-length monopole is too tall to support, then the T-top shortened version is a good alternative. A rope supporting the wire monopole between trees may also support the T-top wires. By reducing the monopole length by half, we lose less than 1 dB of gain, while retaining an easily matched feedpoint impedance.

However, both half-loops easily outperform the monopoles in the favored directions. (Of course, the circular patterns of the monopoles will outperform the half-loops in the non-favored directions, that is, edgewise to the half-loops.) Since the TO angles are comparable throughout the table, the half-loop gains its advantage largely by reshaping the circular monopole pattern into a broad oval.

The decision to use a half-loop rather than a monopole, then, arises out of two considerations. Do I have favored communications directions that suggest the use of the half-loop azimuth pattern over the circular monopole pattern? Can I fit the antenna within my suburban yard?

Of course, nothing prevents us from obtaining further gain and directivity by setting two monopoles 1/2-λ apart and feeding them in phase. Let's suppose that we cannot support two full-length monopoles. Still, we can set up two T-top monopoles about 80' feet apart. The antennas will look like the outline in **Fig. 10**.

Fig. 10



Two T-Top Monopoles 1/2-Wavelength Apart
Fed in Phase: Outline and Radiation Patterns

If the width of our yard brings the T-wires too close to the neighbor, we can always turn them 90° to the plane of the two monopoles with no harm whatsoever. **Table 5** compares the performance of 1 T-top to 2 T-tops.

Table 5. Comparative data for one and two T-top monopoles
All antenna are AWG #12 copper wire over average ground

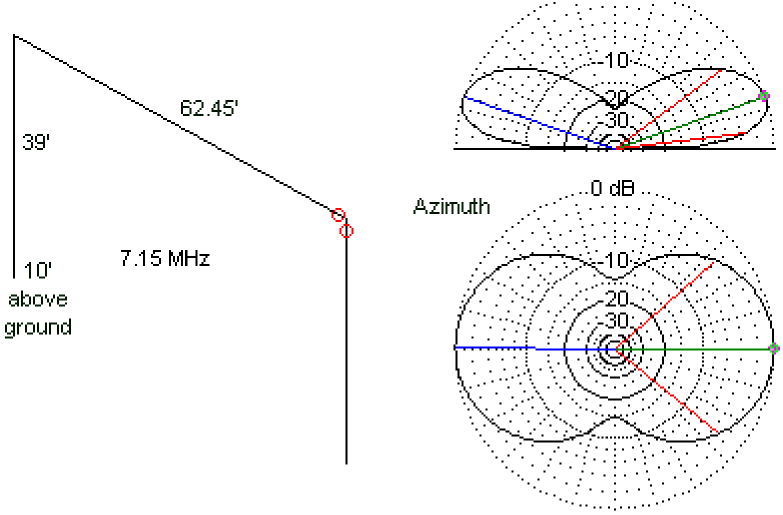
Antenna	Height feet	Width feet	Max. Gain dBi	TO Angl degrees	Source Impedance R +/- jX Ω
One 1/8-wl T-top	16.5	21.2	-2.99	28	38.6 + j1.0
Two 1/8-wl T-tops	16.5	101.2	0.76	28	32.2 - j1.6 x2

The width dimension does not take into account the space required by the buried ground-plane radials. Most notably, the use of 2 T-top monopoles improves the gain (broadside to the plane of the two monopoles) over a single monopole by 3.75 dB--assuming that we use 8 radials for each monopole. The gain figure is also more than a full dB higher than the gain of a half-loop with 9 radials per end wire. The azimuth pattern in **Fig. 10** shows why: the deep side nulls of the phase-fed monopoles provide additional energy for the main lobes, given that the elevation patterns for the two antenna types are so similar.

For many arrays, phase feeding is a complex matter. However, for in-phase fed broadside arrays, we only need to assure that both arrays are fed at the same current phase angle. Equal lengths of 50-Ω coaxial cable that are an odd multiple of 1/4-λ will assure this condition for a pair of T-top monopoles and yield a 77-Ω junction impedance. The 38-Ω parallel impedance that results from joining the two lines is compatible with coaxial cable. For greater precision, one might use one of the series matching systems to arrive at 50 Ω on the design frequency.

Before we finish, we should examine briefly one other antenna that looks like a half-loop but is not. **Fig. 11** outlines a half-square array. As the dimensions suggest, this antenna is self-contained, elevated above ground, and has a total length of about 1 λ. Each vertical section is 1/4-λ, with an approximate half-wavelength line between. (A 5:8 ratio between the vertical and horizontal sections tends to maximize gain with standard wire sizes.)

Fig. 11



Outlines and Radiation Patterns of a Half-Square Array

The half-square array requires more height than any of the arrays that we have examined in these notes. However, it does not require the width of a pair of monopoles or T-tops fed in phase. Despite its greater exposed size, the half-square requires less total wire, since the array does not need any ground-plane radials. The upper-corner feedpoint places the high current region at the top of each vertical section, leaving a low-current (but sometimes lethally high voltage) point at the lower end of each vertical section. **Table 6** compares the performance of a half-square array with the two half-loop configurations.

Table 6. Comparative data for the half-loop and the half-square
All antenna are AWG #12 copper wire over average ground

Antenna	Number of Radials	Height feet	Width feet	Max. Gain dBi	TO Angle degrees	Source Impedance R +/- jX Ω
Diamond half-loop	9/wire end	23.5	50	-0.58	28	87.3 - j1.8
Square half-loop	9/wire end	16.5	36	-0.40	28	86.6 - j6.9
Square half-loop	31/wire end	16.5	36	1.15	28	61.9 - j14.7
Half-square array	none	39 (10-49)	62.45	3.46	19	68.4 - j1.4

The half-square array data and the patterns in **Fig. 11** show the benefits of the increased array size. (Note that size alone is not the determining factor. Rather, the array's two phased bent dipoles produce the performance and also dictate the larger size.) The elevated feedpoint position and the use of full size elements contribute to the bi-directional gain and the relatively low elevation angle of the antenna.

Conclusion

The half-loop antenna is 1/2 of a full quad loop using the ground to complete the missing half. Each wire end contacts ground and requires a radial system for effective performance. The chief advantage of the half-loop is its simplicity and relative stealthiness above ground, although the size of the radial fields will have a profound effect on performance.

The half-loop provides a slightly directional signal and yields gain over a ground-mounted monopole in the favored directions. Hence, it is a highly useful antenna in many suburban situations, where antenna invisibility is a desirable trait. Nevertheless, it falls short of the performance of even two T-top monopoles when they are 1/2 λ apart and fed in phase. As well, it does not reach the performance level of the larger (and therefore more visible) half-square.

Whether the half-loop is the proper antenna for lower-HF use depends on many circumstances that only an individual operator can evaluate. However, in the search for a serviceable vertical antenna for 80 or 40 meters, we should not overlook VE2CV's "half-delta," however much we may modify it for greater invisibility.