



L. B. Cebik, W4RNL (SK) (SK)

Having examined the low-band properties of the delta and rectangular loop, we next turn to the open-ended cousin of these SCVs: the half square. Although developed after its double-wide brother, the bobtail curtain, the half square is the more fundamental antenna.¹ As shown in Figure 1, it consists of two (roughly) 1/4 wavelength vertical legs connected by a (roughly) 1/2 wavelength horizontal wire. The horizontal wire functions as a phasing line between the verticals, although its radiation is imperfectly cancelled.

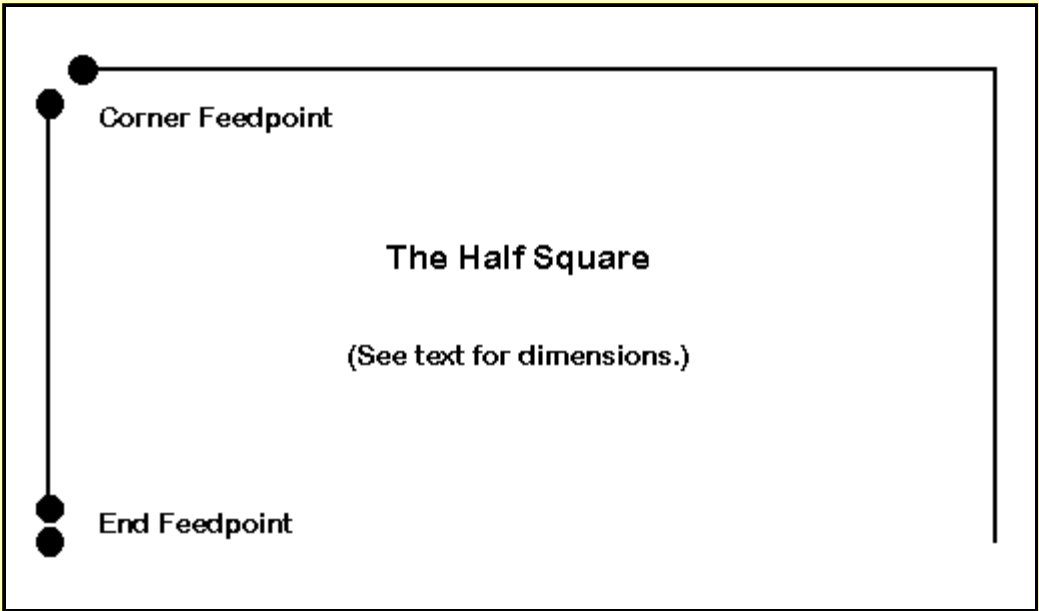


Figure 1. Basic outline of the half square antenna.

The first question often asked about the half square is whether it really belongs to the SCV family. Like the loops, the half square may operate without a ground plane--in fact, a small ground plane may reduce its gain and other desirable properties. Moreover, one may model the antenna in free space and make versions pointing either up or down for any frequency. For low band use, the down-pointing half square is favored because it places the high-current points at the corners at maximum achievable height.²

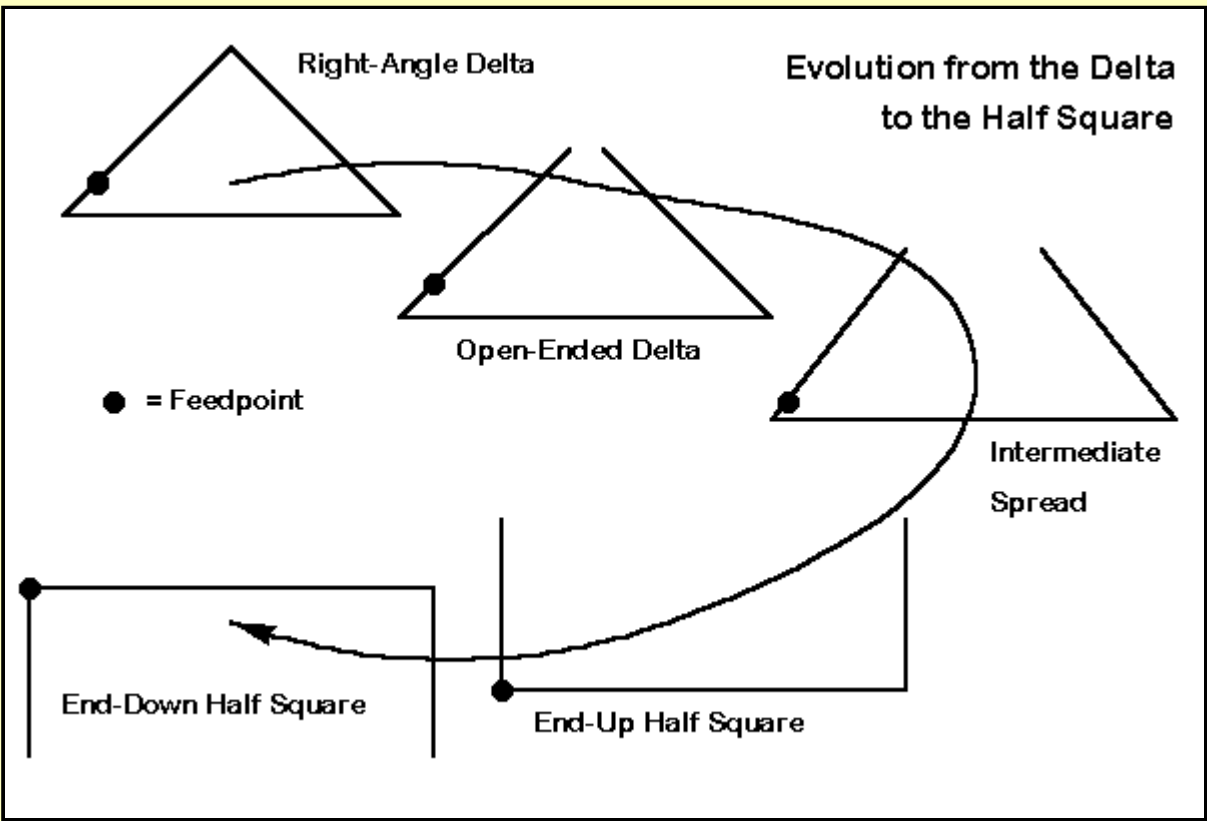


Figure 2. Evolution of the half square from the delta.

One can establish the SCV credentials of the half square by a simple free space modeling project. Begin with a right-angle delta, as shown in Figure 2. Separate the wires at the high-impedance apex point by a little. Then widen the separation, adjusting the model to maintain something close to resonance. Table 1 shows the first steps of this progression. In effect, nothing happens when the wires at the apex do not touch. By gradually, straightening the sloping delta wires toward the vertical and by lengthening the baseline until the feedpoint is in a corner, once evolves the half square. Finally, for low-band use, flip the antenna over so that the open ends point down. Of course, in free space, from which the figures in the table emerge, the flip is gratuitous, since there is no up or down.

Partial Evolution of a Right-Angle Delta to a Half Square

Antenna Description	Gain dBi	Feedpoint Impedance
	(R +/- jX Ohms)	
Right-angle delta:		
60.8' base; 30.4' height	3.31	51 + j 6

Right-angle delta: apex wires separated 0.2'	3.31	51 + j 6
Height increase to 30.41'; apex spread 0.4'	3.32	51 + j 7
Height increase to 30.7'; apex spread 2.0'	3.36	51 - j 1
Height increase to 31.1'; apex spread 4.0'	3.41	53 + j 5

Note: Frequency: 7.15 MHz; Wire: #12 AWG copper; model in free space.

Table 1. Partial evolution of a right-angle delta to a half square.

The more ideal separation between the vertical elements of the half square produces a sharper bi-directional pattern than the SCV loops develop. The side rejection will vary from 10 to well over 15 dB, for a familiar peanut-shaped pattern. An example appears in Figure 3. Whether the this pattern is an advantage or a disadvantage depends upon the oeprator's needs.

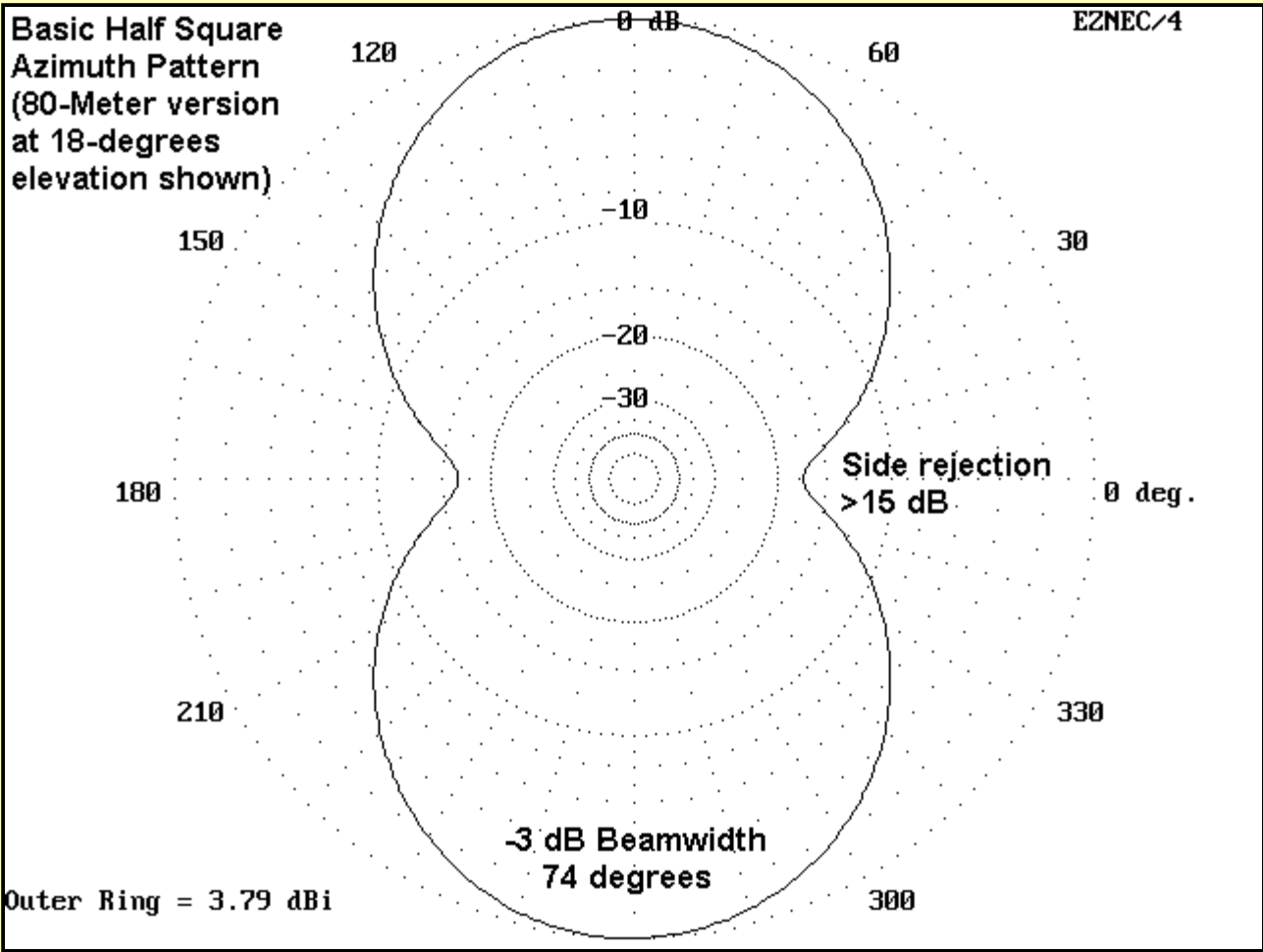


Figure 3. Basic azimuth pattern of the half square at the elevation angle of maximum radiation when the antenna is at the height of maximum gain.

Like the other SCVs, the half square has a ratio of horizontal to vertical lengths that yields maximum gain in free space (and over ground). However, that ratio appears to be independent of frequency, except for some residual effect of wire size. The ratio of horizontal length to vertical height for maximum gain is about 1.6:1.³

For most antennas, there is sufficient band-to-band variation that giving formulas for cutting wires can be more misleading than helpful. However, the relatively invariant relationship between the horizontal and vertical dimensions of the half square for a maximum-gain configuration tends to assure a good utility for such formulas here. Where H is the horizontal length in feet, V is the vertical height in feet, and f is the frequency in MHz,

$$V_{feet} = \frac{278}{f_{MHz}} \quad \text{and} \quad H_{feet} = \frac{447}{f_{MHz}}$$

80-Meter and 40-Meter Maximum Gain Half Squares

An 80-meter half square designed for maximum gain at 3.6 MHz requires a horizontal wire about 124.5' long and two vertical end wires, each 77' long, when all wires are #12 AWG copper. The maximum free space gain of this antenna is about 4.6 dBi. When the antenna is placed over ground at some achievable height, the free space gain cannot be realized until the soil is very much better than average.

80-Meter Half Square Over Various Soils at Various Heights

Soil Type	Bottom Height ft	Gain dBi	T-O Angle degrees	Feed Impedance R +/- jX Ohms
Very Poor (C=0.001, DC=5)	5	1.74	23	80 + j13
	10	1.92	22	74 + j 5
	15	2.05	22	70 + j 1
	20	2.14	21	67 - j 3
	25	2.21	20	65 - j 1
	30	2.27	20	63 - j 1
Poor	5	3.24	21	80 + j17

(C=0.002, 10	3.34	20	75 + j 7	
DC=13) 15	3.40	20	71 + j 2	
20	3.42*	19	68 - j 0	
25	3.42*	18	66 - j 1	
30	3.41	18	64 - j 2	
Average	5	3.75	20	81 + j19
(C=0.005, 10	3.79*	19	75 + j 8	
DC=13) 15	3.79*	18	71 + j 2	
20	3.76	18	68 - j 0	
25	3.71	17	66 - j 1	
30	3.63	16	64 - j 2	
Very Good	5	6.30	15	80 + j20
(C=0.0303, 10	6.36	15	75 + j 9	
DC=20) 15	6.40	14	72 + j 3	
20	6.42*	14	69 - j 0	
25	6.42*	13	66 - j 2	
30	6.40	13	64 - j 3	

Note 1. * = Height of maximum gain
Note 2. Dimensions of half square = 124.5' horizontal length, 77' vertical height. Construction: #12 AWG copper wire.

Table 2. 80-meter half square over various soils at various heights.

Table 2 shows the results of modeling the 80-meter half square over various soils. The listings can be quite short, since--for all but very poor soil--the half square reaches maximum gain when the vertical ends are quite close to the ground. Indeed, the most desirable height from the point of view of gain is lower for average soil than it is for either poor or very good soil. However, like the other SCVs, the half square shows a consistent pattern of feedpoint impedances for corner-fed models regardless of the soil type immediately beneath the antenna. The antenna is close to resonant in the vicinity of 70 Ohms, although very close proximity to the ground raises that number by as much as 10 Ohms.

A corresponding maximum gain half square for 7.15 MHz would be 62.45' horizontally and 39' vertically, using #12 AWG copper wire. Because the #12 wire is a larger fraction of a wavelength in diameter, the antenna's free space maximum gain is nearly 4.7 dBi. However, like the 80-meter model, the 40-meter half square does not achieve this gain over ground unless the soil is far better than average.

40-Meter Half Square Over Various Soils at Various Heights

Soil Type	Bottom Height ft	Gain dBi	T-O Angle degrees	Feed Impedance R +/- jX Ohms
Very Poor (C=0.001, DC=5)	5	2.41	23	73 + j 4
	10	2.72	22	67 - j 1
	15	2.94	21	64 - j 2
	20	3.13	20	62 - j 2
	25	3.29	19	61 - j 1
Poor (C=0.002, DC=13)	5	3.57	21	75 + j 6
	10	3.72	20	68 - j 1
	15	3.78	18	64 - j 3
	20	3.80*	17	62 - j 2
	25	3.78	16	61 - j 1
Average (C=0.005, DC=13)	5	3.40	20	76 + j 6
	10	3.46*	19	68 - j 1
	15	3.42	17	64 - j 3
	20	3.33	16	62 - j 3
	25	3.20	15	61 - j 1
Very Good (C=0.0303, DC=20)	5	5.50	17	76 + j 7
	10	5.51*	15	69 - j 2
	15	5.44	14	65 - j 4
	20	5.26	13	62 - j 4
	25	5.05	12	60 - j 2

Note 1. * = Height of maximum gain
Note 2. Dimensions of half square = 62.45' horizontal length, 39' vertical height. Construction: #12 AWG copper wire.

Table 3. 40-meter half square over various soils at various heights.

Table 3 shows the figures for 40-meter half square performance over various types of soil. Once more, the antenna shows maximum gain when the ends are fairly close to the ground, although that height varies with soil type. Unlike the 80-meter antenna, modeling suggests that the half square for 40 performs slightly better over poor soil than over average soil, although the difference is marginal, since the progression of take-off angles, or elevation angles of maximum radiation, is normal and decreases regularly with improvements in soil type. The progressions of feedpoint impedances is also quite normal to our expectations. Again, because the #12 wire is "fatter" on 40 than on 80, the resonant feedpoint impedance is a few Ohms under that of the corresponding 80-meter half square.

Although the tables flag a height (or two) as reflecting maximum gain heights for soils that are poor or better, the entries for very poor soil show no flags. The reason for the absence of a flag is that over very poor soil, half squares for 80 and 40 continue to show increases of gain with increases of height. Table 4 extends the 40-meter "very poor soil" set of values up to a height of 60' for the lowest point of the antenna. The continued increase in gain and lowering of the take-off angle are clearly apparent.

40-Meter Half Square Over Very Poor Soil at Various Heights

Soil Type	Bottom Height ft	Gain dBi	T-O Angle degrees	Feed Impedance R +/- jX Ohms
Very Poor (C=0.001, DC=5)	5	2.41	23	73 + j 4
	10	2.72	22	67 - j 1
	15	2.94	21	64 - j 2
	20	3.13	20	62 - j 2
	25	3.29	19	61 - j 1
	30	3.45	18	61 + j 0
	35	3.60	18	62 + j 1
	40	3.76	18	62 + j 1
	45	3.92	17	63 + j 1
	50	4.10	16	64 + j 1
	55	4.29	16	64 + j 1
	60	4.48	15	64 + j 0

Table 4. An extension of the 40-meter half square over very poor soil at various heights.

However, an illusion accompanies this progression, as shown in Figure 4. The elevation patterns in the figure are for antenna base heights of 10, 25, and 40 feet, respectively. As one raises the antenna, gain increases, but so too does a secondary high-angle lobe. In the process of acquiring more gain, the half square users also acquires high-angle radiation in the receive mode, thus decreasing the QRM and QRN filtering benefits of the half square. Whether there is a cut-off point to the height of the antenna over very poor soil--and where that point might be-- is a decision only the antenna builder can decide.

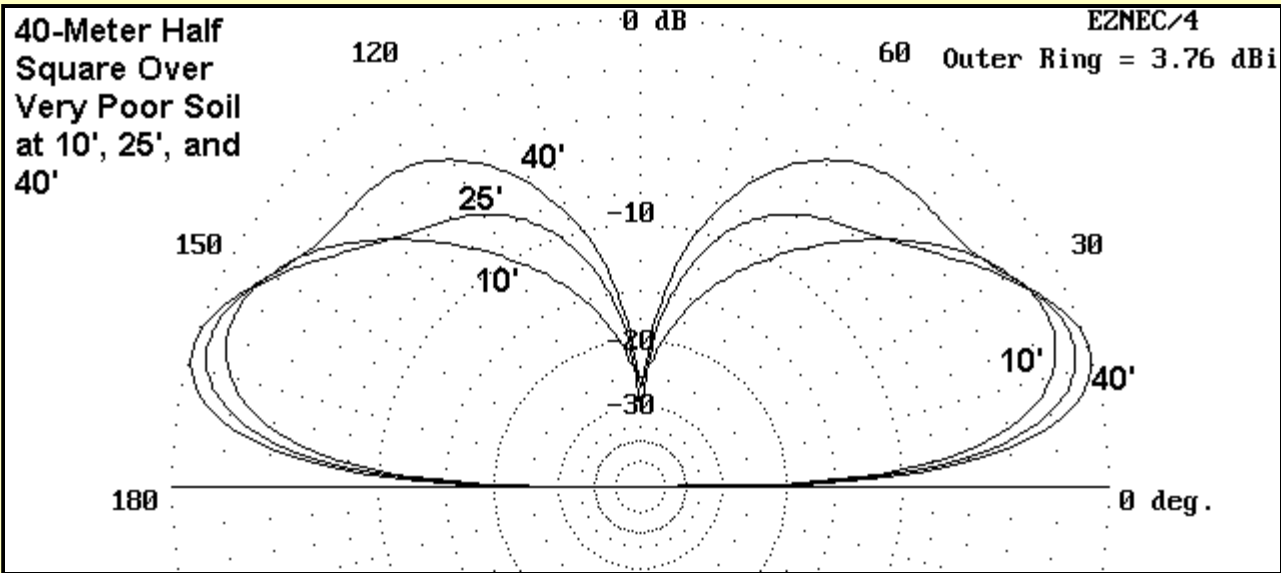


Figure 4. Elevation patterns of a half square over very poor soil for three heights. Note the increasing gain, but as well, the increasing high-angle secondary lobe.

In general, the half square over almost any soil type provides maximum gain at heights closer to the ground than is true of the other SCVs. Like its relatives, the half square elevation pattern begins to produce secondary high angle lobes as soon as it passes the height of maximum gain. Exceeding that height by very much may yield stronger reception to closer- in, high-angle signals and partially or wholly defeat the basic purpose in using an SCV in the first place.

80-Meter and 40-Meter 50-Ohm Resonant Half Squares

From the numbers in Table 3 and Table 4, it is clear that the feedpoint impedance of a maximum gain half square is somewhat distant from 50 Ohms. However, one of the benefits of using a corner feedpoint for the antenna is the ability to feed the antenna with standard 50-Ohm coaxial cable. Therefore, I redesigned the half square models to come somewhat closer to a 50-Ohm feedpoint impedance.

The 80-meter (3.6 MHz) model required horizontal stretching to 155' with the verticals shortened to only 60' to arrive at a 50-Ohm antenna in free space. This is a horizontal-to-vertical ratio of about 2.58:1, which is a considerable departure from the maximum gain ratio of 1.6:1. When subjected to the same systematic modeling over various soils as the maximum gain models, Table 5 emerged. All of the gain figures are down significantly from the maximum gain model, with the decreases growing worse as the soil type grows worse. Moreover, the heights for maximum gain also decrease, while the take-off angles increase. Whether these reductions in performance warrant the move to a 50-Ohm model is, once more, a user decision.

80-Meter 50-Ohm Resonant Half Square Over Various Soils at Various Heights

Soil Type	Bottom Height ft	Gain dBi	T-O Angle degrees	Feed Impedance R +/- jX Ohms
Very Poor (C=0.001, DC=5)	5	-0.29	25	66 + j 9
	10	-0.12	24	61 - j 1
	15	-0.02	24	57 - j 7
	20	0.03	23	54 - j10
	25	0.06	22	52 - j13
	30	0.08	21	51 - j15
Poor (C=0.002, DC=13)	5	1.61	23	61 + j16
	10	1.66*	22	57 + j 4
	15	1.66*	22	54 - j 3
	20	1.61	21	53 - j 7
	25	1.54	20	51 - j10
	30	1.46	19	50 - j12

Average	5	2.33*	21	60 + j21
(C=0.005,	10	2.30	21	56 + j 8
DC=13)	15	2.20	20	54 + j 1
	20	2.08	19	53 - j 4
	25	1.93	18	52 - j 8
	30	1.77	18	51 - j11
Very Good	5	5.27*	16	52 + j25
(C=0.0303,	10	5.17	16	51 + j12
DC=20)	15	5.04	16	50 + j 4
	20	4.89	15	50 - j 1
	25	4.73	14	50 - j 5
	30	4.58	14	50 - j 8

Note 1. * = Height of maximum gain
Note 2. Dimensions of half square = 155' horizontal length, 60' vertical height. Construction: #12 AWG copper wire.

Table 5. 80-meter 50-Ohm resonant half square over various soils at various heights.

Figure 5 shows the feedpoint resistance and reactance across the 80- meter band for the 3.6 MHz model. Across the band, the change in the resistive component is about 77 Ohms. With some redesign of the antenna, almost all of the band might be fit within a 2:1 SWR curve, assuming that the reactance can be compensated for at the feedpoint. However, the reactance varies by over 500 Ohms, suggesting that additional redesign for a remotely tuned series capacitor might still not yield full band coverage.

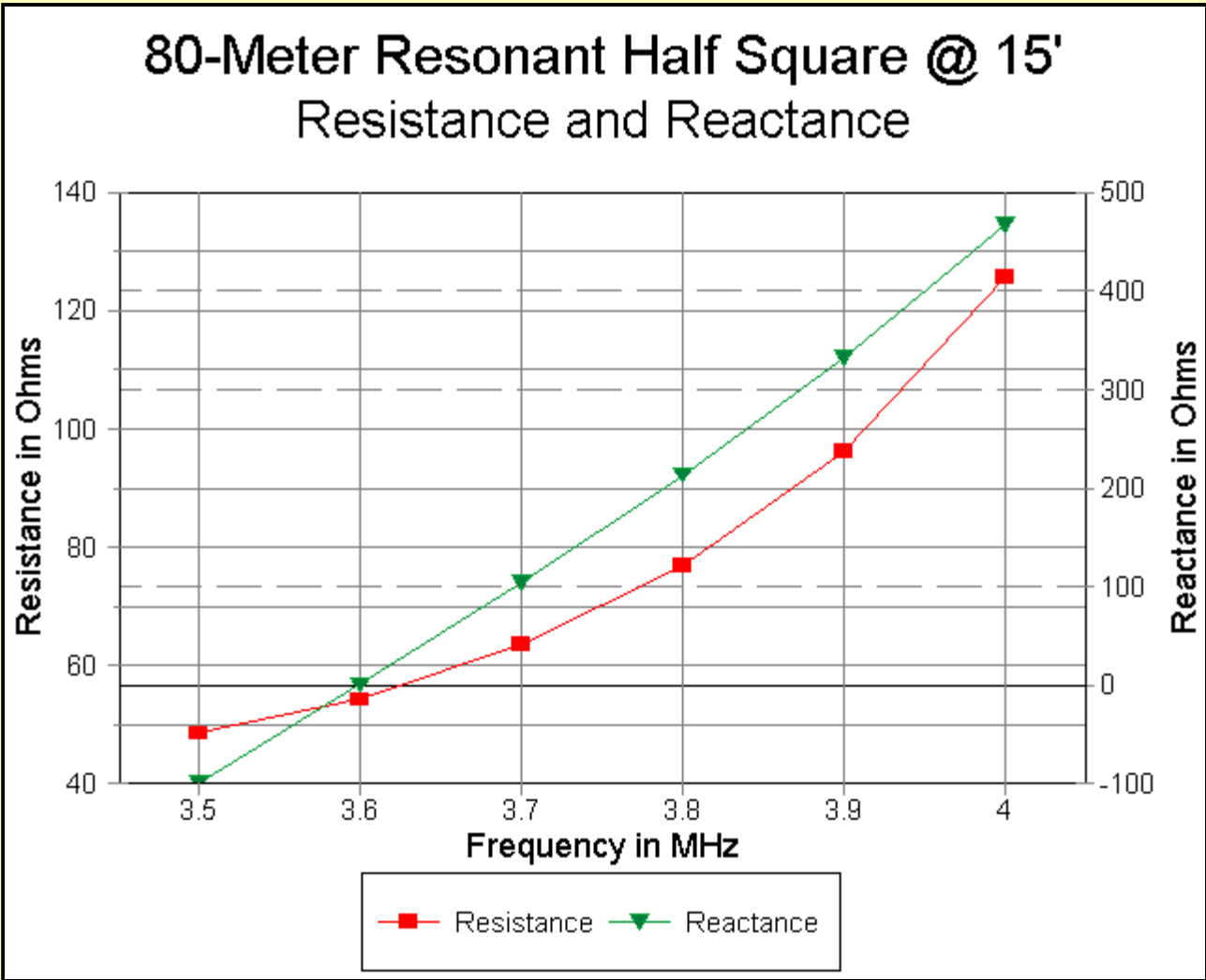


Figure 5. Feedpoint resistance and reactance of a 50-Ohm resonant 80-meter half square across the band.

40-meters presents fewer problems for a half square designed for 50- Ohm feed. The dimensions of the model used for 7.15 MHz, was 70.5' horizontally and 34.5' vertically (with #12 AWG copper wire). The horizontal-to-vertical ratio is about 2:1, which is much closer to the maximum gain ratio than the 80-meter version achieved. As shown in Table 6, the gain reductions for the 40-meter antenna are less severe than for the 80-meter model, and the heights needed for maximum gain are only slightly lower than those for the maximum gain model for each type of soil. Likewise, increases in the take-off angle are less severe. In general, then, a 40-meter half-square designed for 50-Ohm resonance may be more feasible than an 80-meter version.

40-Meter 50-Ohm Resonant Half Square Over Various Soils at Various Heights

Soil Type	Bottom Height ft	Gain dBi	T-O Angle degrees	Feed Impedance R +/- jX Ohms
Very Poor	5	1.85	24	58 + j 4
(C=0.001,	10	2.15	23	53 - j 3
DC=5)	15	2.34	21	50 - j 6
	20	2.51	20	48 - j 6
	25	2.68	19	47 - j 7
Poor	5	3.19	22	58 + j 8
(C=0.002,	10	3.30	20	53 - j 1
DC=13)	15	3.31*	19	50 - j 5
	20	3.28	18	48 - j 6
	25	3.23	17	48 - j 6
Average	5	3.06*	21	59 + j 9
(C=0.005,	10	3.06*	19	53 - j 0

DC=13)	15	2.97	18	50 - j 4
	20	2.83	17	49 - j 6
	25	2.68	16	48 - j 6

Very Good	5	5.34*	17	57 + j12
(C=0.0303,	10	5.24	16	52 + j 1
DC=20)	15	5.06	15	50 - j 3
	20	4.82	14	49 - j 5
	25	4.54	13	48 - j 6

Note 1. * = Height of maximum gain

Note 2. Dimensions of half square = 70.5' horizontal length, 34.5' vertical height. Construction: #12 AWG copper wire.

Table 6. 40-meter 50-Ohm resonant half square over various soils at various heights.

The feeding problem is also less severe on 40 meters. The resistive component of the feedpoint impedance, as shown if Figure 6, varies by only 6 Ohms or so, while the reactance varies by a little under 140 Ohms. Therefore, for a corner-fed 40-meter half square, a remotely tuned series variable capacitor becomes a viable option for full band coverage with direct coax feed--assuming the antenna is further optimized to present inductive reactance across the band.

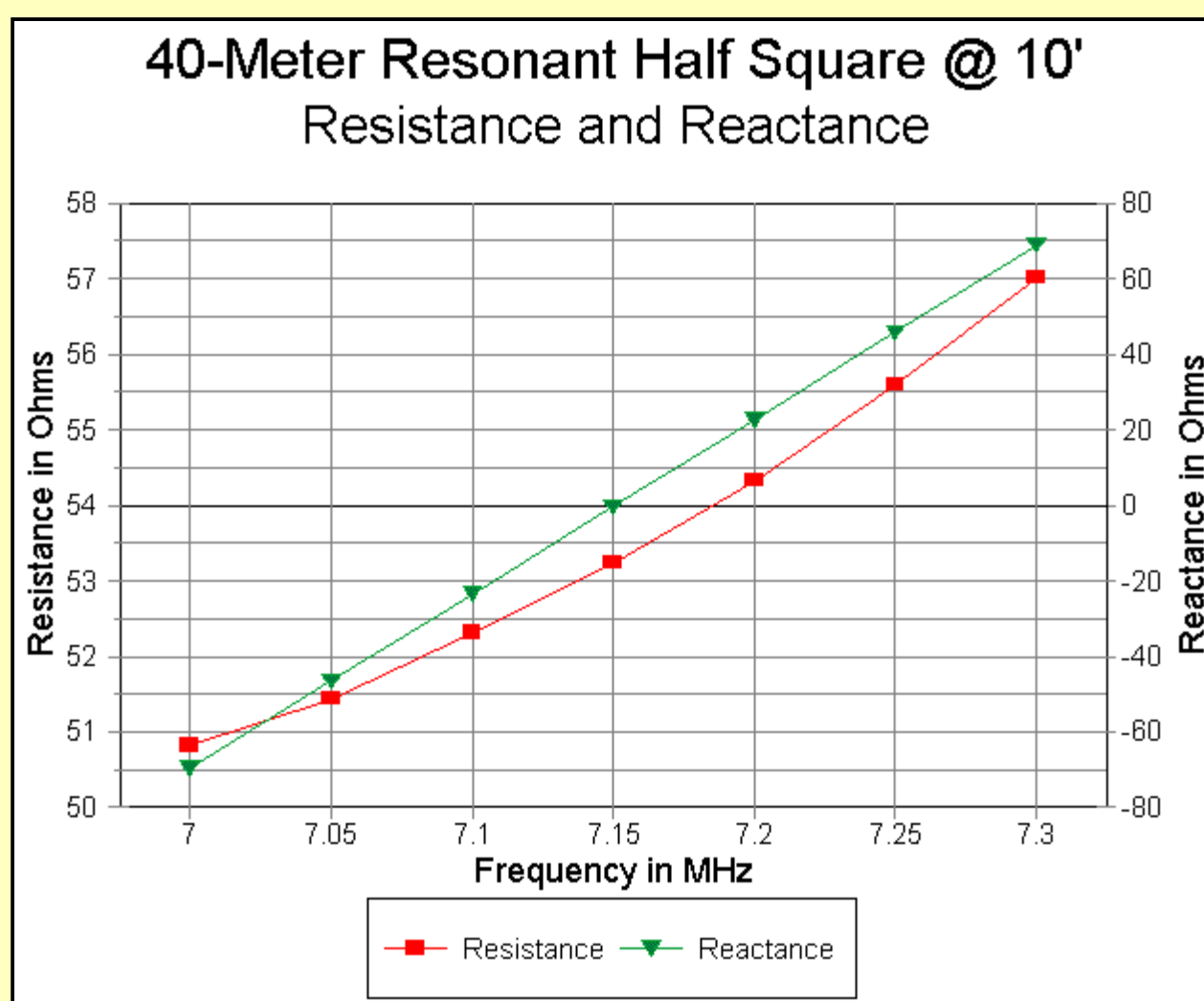


Figure 6. Feedpoint resistance and reactance of a 50-Ohm resonant 40-meter half square across the band.

End-Feeding the Half Square

Corner-feeding the half square eliminates in large measure the need for a more complex matching network when the antenna is used only on the band for which it is designed. Conversely, feeding the antenna in the most traditional manner--at the open end of one of the verticals--requires a parallel tuned circuit resonated on the band of choice. The coil is tapped for coaxial cable feed. An additional tap may be used near the top of the tank circuit to effect the most precise match possible.

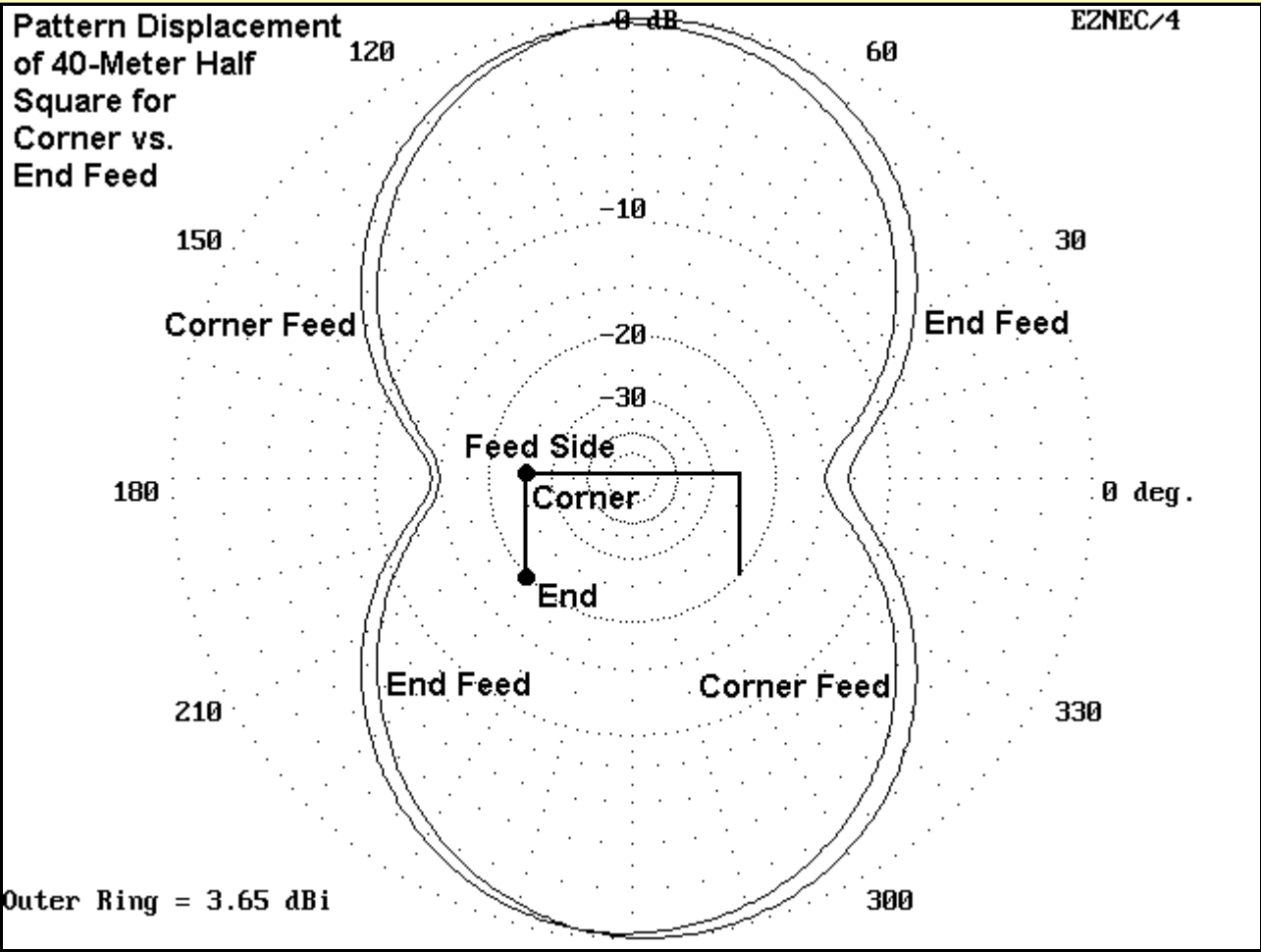


Figure 7. Comparison of azimuth patterns of a corner-fed and an end-fed half square. Except for the feedpoint location, the antennas are identical.

At the fundamental frequency for which the half square is cut, the use of end or corner feeding makes little difference to performance. Figure 7 shows the slight difference in pattern. With corner feed, the bi-directional pattern is closely symmetrical, with gain maxima at 90 and 270 degrees in the pattern shown. When end fed, the antenna shows a slight displacement of about 5 degrees in the maximum gain points, tilted away from the feed point. In practical terms, the user would be hard pressed to tell the difference.

End feeding is often recommended by those planning to use the antenna on more than one amateur band.⁴ If the matching network is remotely tuned, it might be pressed into service as a multi-band tuner. Likewise, there is no rule against feeding the corner with a parallel transmission line and using an antenna tuning unit in the shack for other bands.

Corner-Fed vs. End-Fed 80-Meter Half Squares at Higher Frequencies

Frequency Max. Gain T-O Angle Az. Angle of Feedpoint Impedance
in MHz in dBi degrees Max. Gain (R +/- jX Ohms)

3.6
a. Corner 3.79 18 90 71 + j 3
b. End 3.93 18 85 4100 - j4000

7.15
a. Corner 5.35 20 55 1400 - j 30
b. End 5.17 20 53 1900 - j3000

10.1
a. Corner 6.59 16 41 1000 - j 600
b. End 6.46 19 40 350 - j2000

14.1
a. Corner 6.78 33 31 600 - j 200
b. End 7.29 34 30 800 - j1000

Note 1. Dimensions of half square = 124.5' horizontal length, 77' vertical height. Construction: #12 AWG copper wire. Height 15' minimum.

Table 7. Corner-fed vs. end-fed 80-meter half squares at higher frequencies.

Table 7 hints at the anticipated results of using an 80-meter half square on 40, 30, and 20. By comparing corner and end feeding systems for a single model of the half square, we discover that there is no significant difference in the patterns. The slight differences in gain, as well as angles of interest, result from one or the other system yielding larger or smaller "bulges" in the pattern in various directions. The chief differences between the two feed point show up in the anticipated feedpoint impedances.

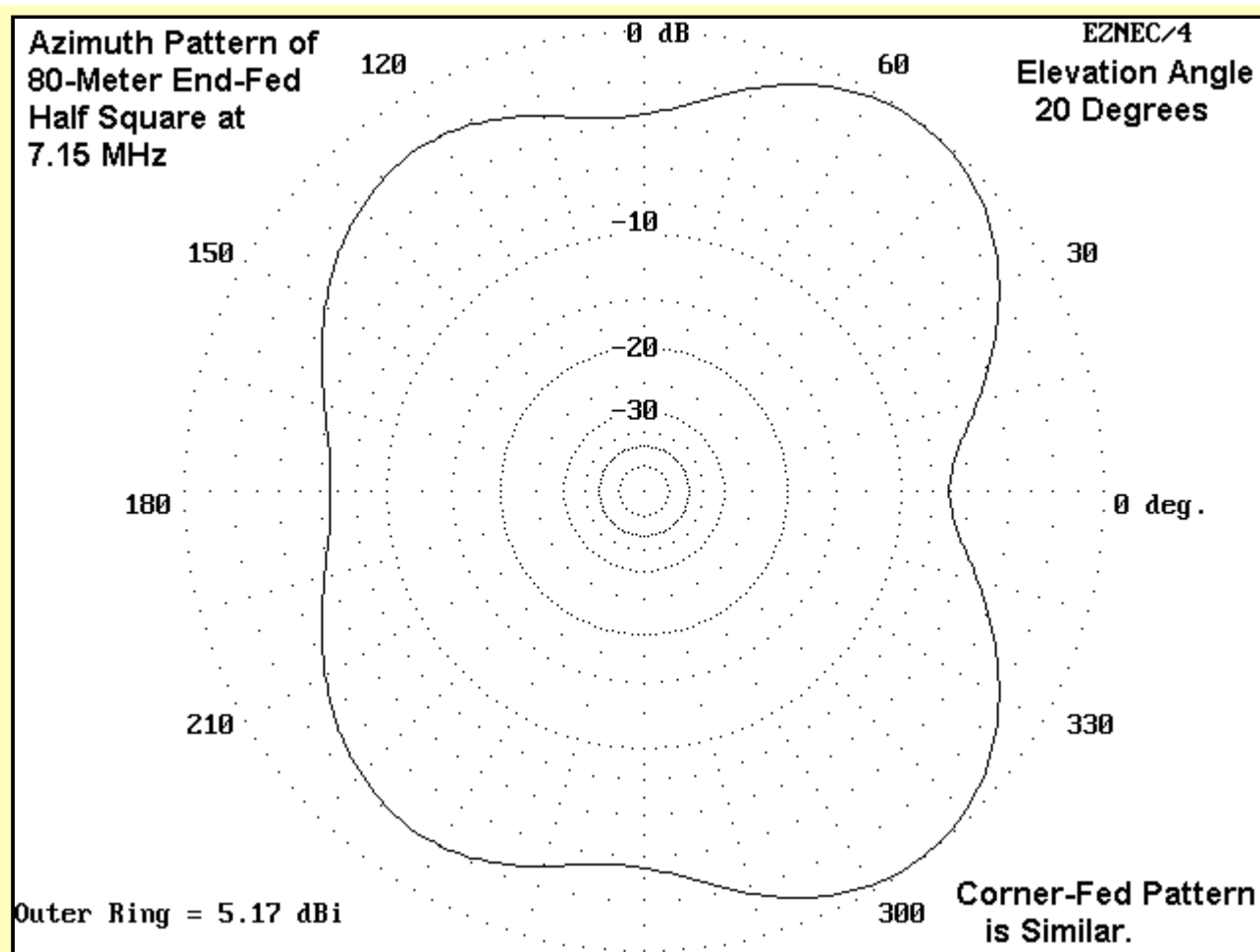


Figure 8. End-fed 80-meter half square azimuth pattern on 40 meters. The center-fed pattern is similar.

On 40 meters, the pattern is roughly square for both feed systems, as is evident from Figure 8. Maximum gain is toward the corners most distant from the feedpoint. In contrast, an 80-meter dipole would become something close to a full wavelength on 40, producing a strong bi-directional pattern approaching 9 dBi if the antenna is a half wavelength up on 40 meters. The half square substitutes coverage for gain.

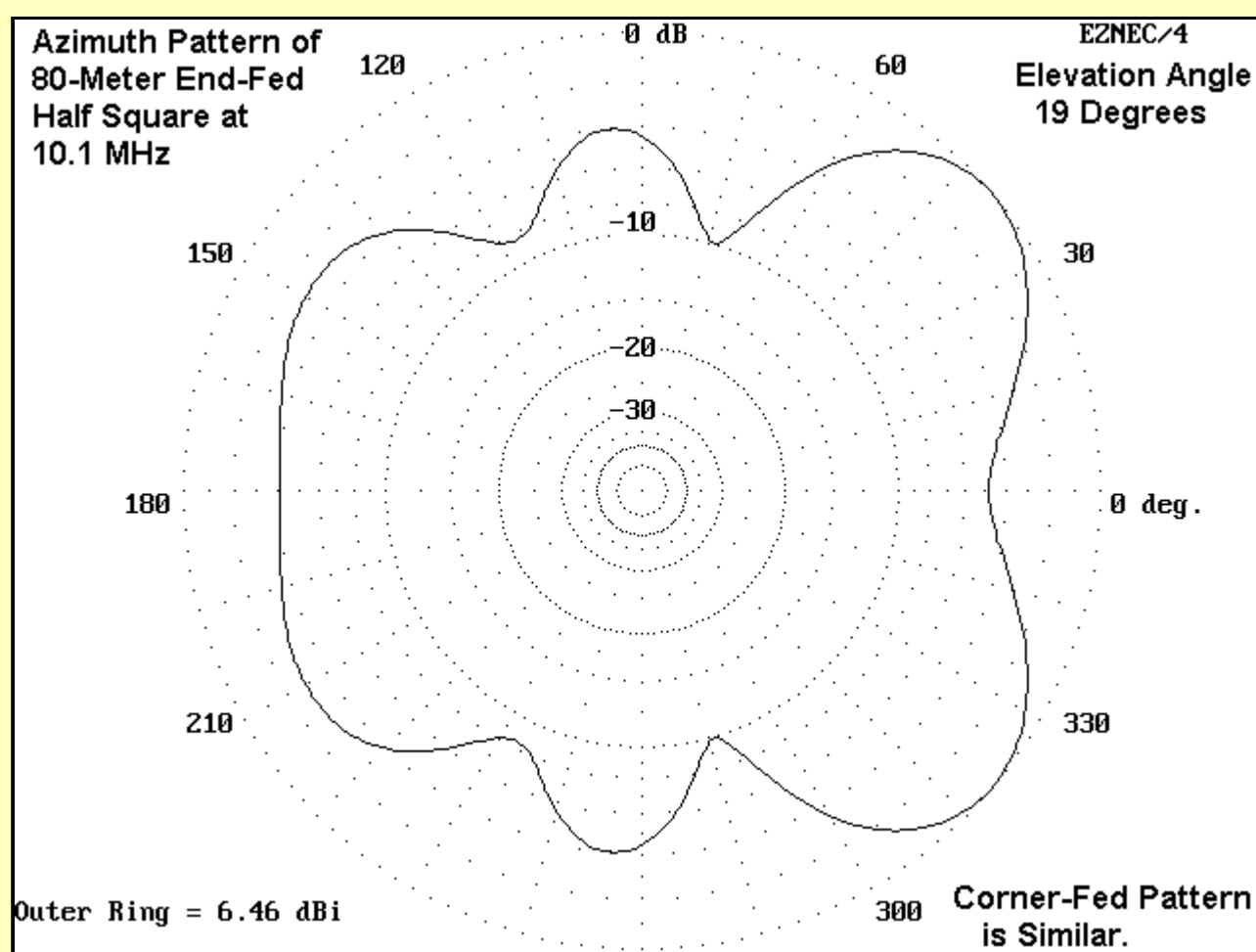


Figure 9. End-fed 80-meter half square azimuth pattern on 30 meters. The center-fed pattern is similar.

The patterns for the 80-meter half square on 30 and 20 meters are not too different from each other, as Figure 9 and Figure 10 make evident. The square becomes elongated, with further gain in the most favored directions. 20-meter use shows the disadvantage of a high-angle main lobe, although the lobe is very broad vertically. The feedpoint impedances for both bands require the use of a tuner with a considerable range of adjustment.

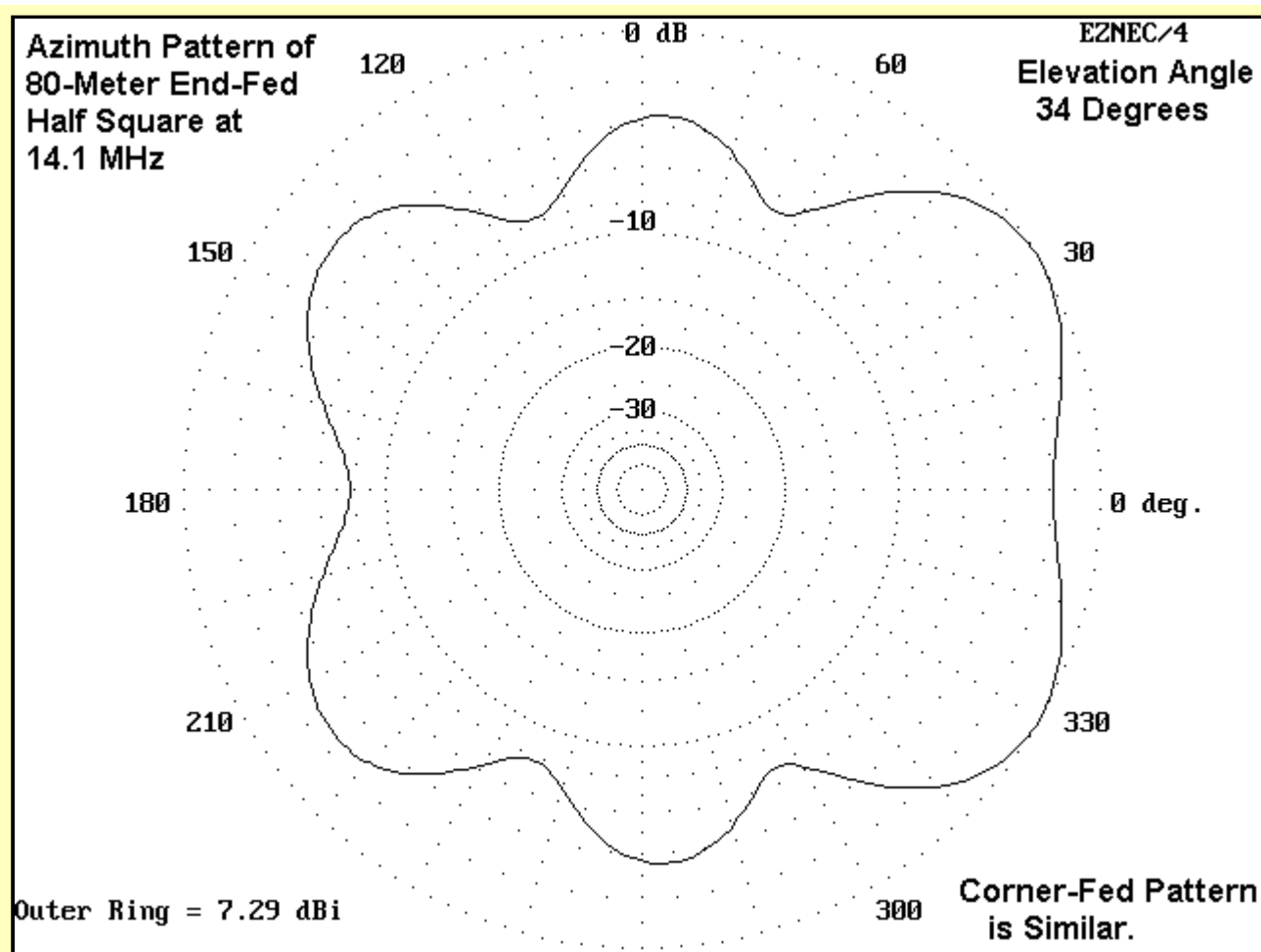


Figure 10. End-fed 80-meter half square azimuth pattern on 20 meters. The center-fed pattern is similar.

The patterns are certainly not those favored for DXing. However, they offer the contester and the general operator some advantages in coverage not offered by highly directional (including highly bi-directional) antennas. However, in some applications, the antenna tuner settings will be very sharp and require readjustment with small frequency excursions.

Although the half square can be pressed into multiband service, its principle use remains as a vertically polarized low-angle low-gain antenna that offers a fairly high signal-to-noise ratio for DX signals. Of the SCVs surveyed, it shows the strongest preference to be mounted as low as the structure permits for maximum gain over most soil types. However, a maximum gain 80-meter model would top out in the 90 to 100 foot level, while a 40-meter model also designed and installed for maximum gain would need to be 50 to 60 feet high. Except over very poor soil, further increases in height will likely not yield superior performance overall, when we combine considerations of both gain and the elevation angle of maximum radiation.

Moreover, unless one needs only a bi-directional pattern, full coverage may require two half squares at right angles to each other. However, with a little remote switching, it is possible to design the right angle array with a common feed vertical and to detune the unused wires. Of course, having the land on which to install such a system is a prior necessity.

So far in this series, I have not attempted to compare the various types of SCVs, although I have compared SCVs within each type. Because each type of SCV has its own installation requirements, "better" and "worse" become complex terms that measure not only the performance and feedpoint figures for the antennas, but as well, all of the mechanical properties and their relationship to the prospective user's land. Nevertheless, the prospective SCV user should remember that these antennas as a class are not general purpose antennas. Rather, when installed within the limits suggested for each type within the class, they provide low-gain, low-angle radiation free from higher lobes and thus forming a natural filter against QRM and QRN from closer sources. In some cases, users may want them for receiving purposes only and use a dipole or similar antenna for transmitting (in which application high angle QRM and QRN are not relevant).

Installing SCVs too high, especially half squares, can easily defeat the main functional advantage of the antennas. Designing them for 20 meters is a marginal enterprise, and above 20 meters, other antenna types will normally out-perform the SCVs. The SCVs do come into their own again until the VHF region, where they can be mounted many wavelengths above ground and their largely vertical polarization combined with a beamwidth around 60 degrees may be superior in some applications to Yagis turned on their side.

Except for these very general comments, I have avoided comparisons with other types of antennas. Although a thorough comparison would be useful, the amount of material there is to present on SCVs and the shortage of space within which to present it suggests that this must be (as they sometimes say in textbooks) "an exercise left to the reader."

In fact, there are a number of directly related SCV questions left to look at. Some hams have built shrunken SCVs. Others have built double wides (for example, the double-humped delta, the open double magnetic slot, and the bobtail curtain). Still others have managed some reversible SCV beams. We should take at least a brief look at each of these ideas in one last installment.

Notes

1 The half square antenna actually appeared after its larger sibling, the bobtail curtain. See Ben Vester, K3BC, "The Half Square Antenna," *QST* (March, 1974), 11-14. Additional notice appeared in *Radio Communications* for January, 1977 (p. 36). See also Robert Schiers, N0AN, "The Half-Square Antenna," *Ham Radio* (December, 1981), 48-50. All three of these early sources show the antenna as voltage-fed from one of the free ends. For the bobtail curtain, see Woodrow Smith, W6BCX, "Bet My Money on the Bobtail Beam," *CQ* (March, 1948), 21-23 and 92-95. See also Smith follow-up articles, "The Bobtail Curtain and Inverted Ground Plane," Parts 1 and 2 in *Ham Radio* (February, 1983), 82-86, and (March, 1983), 28-30. See also John Devoldere, ON4UN, *Antennas and Techniques for Low-Band DXing*, 2nd Ed. (Newington: ARRL, 1994), Chapter 12, "Other Arrays."

2 VHF half-square designs will appear in a forthcoming issue of *Communications Quarterly*. Unfortunately, some half square users have oversold the antenna, especially for upper HF use. See, for example, Hannes Coetzee, ZS6BZP, "A Visit to the Half Square Antenna," *Communications Quarterly* (Spring, 1998), 83-90. At normal heights (1/2 wavelength or more), a dipole will usually outperform the half square on the upper HF bands. Its use on the lower bands is, in concert with the other SCVs, to sacrifice gain for a low-angle bi-directional elevation pattern that suppresses high-angle QRM and QRN. Its most apt application is where elevating a horizontal antenna in its entirety above 1/2 wavelength is not feasible.

3 If expressed as a ratio of vertical to horizontal dimensions, the ratio is 0.62:1. Allowing for wire thickness effects, this is the Fibonacci constant:

$$k_F = \frac{\sqrt{5} - 1}{2}$$

(This equation yields a value of about 0.618034, which also yields an inverse ratio of about 1.618034. The numbers are decimally longer for those addicted to transcendental numbers). The reference to Fibonacci is incidental in this context; the basic ratio for the half square holds up at least throughout the HF region.

4 See, for instance, Joe Everhart, N2CX, "End-Fed Half-Wave Antennas," *QRPp* (Spring, 1998), 11-15.



[Return to Index](#)