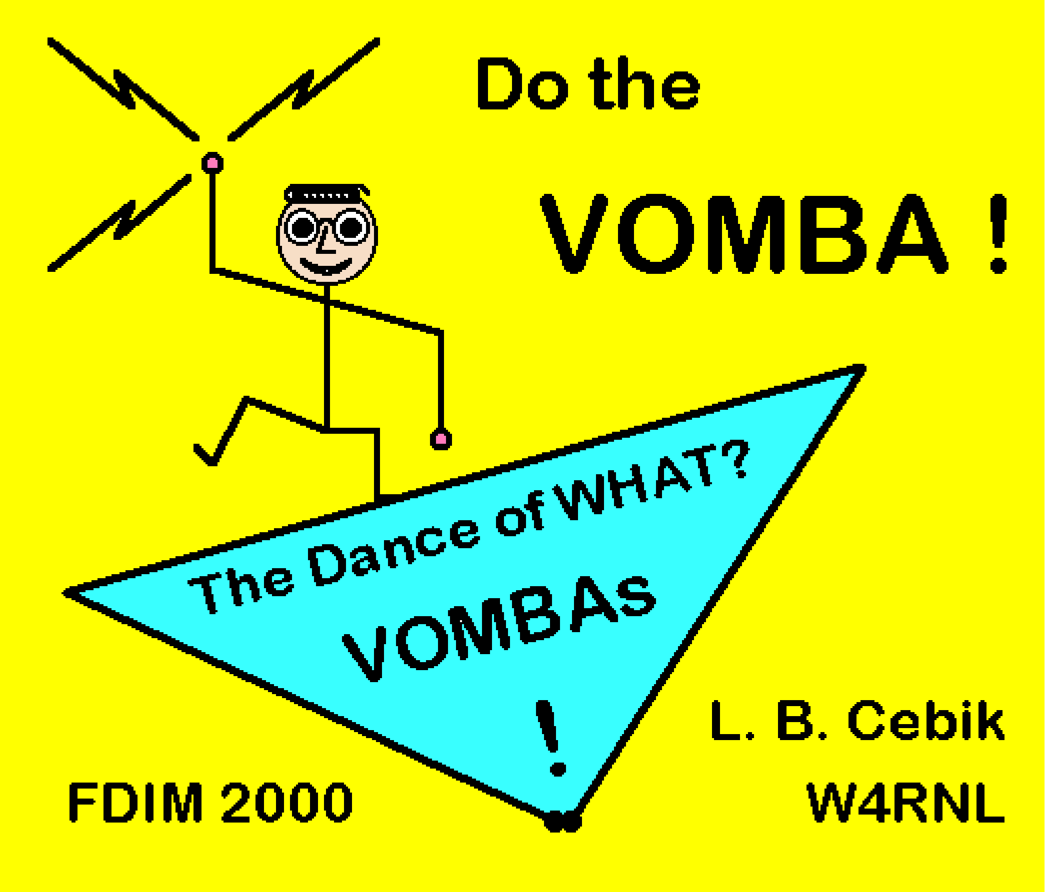
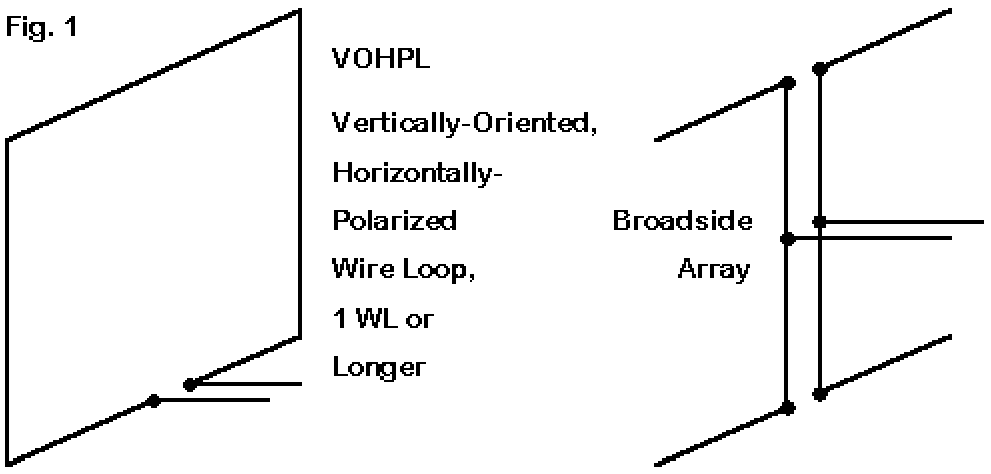


(This talk, on the basics of vertically oriented multi-band antennas, was originally prepared for the 2000 Dayton FDIM Symposium.)

Do the VOMBA!
Vertically Oriented Multi-Band Antennas

Among the more popular antennas used by QRP enthusiasts is the VOHPL, the vertically oriented, horizontally polarized loop, consisting of about 1 wl of wire at the lowest frequency used. Within this group of antennas are the delta--both equilateral and right-angle--the square and diamond quad loop, and the rectangle. When vertically oriented, we must feed them at the top or bottom center to make sure they are horizontally polarized. **Fig. 1** shows just one of the many VOHPL configurations.

Fig. 1



Two Types of VOMBAs

Fig. 1 also shows a second vertically oriented array: the Lazy-H. One of a number of in-phase-fed arrays, the Lazy-H is also horizontally polarized. In traditional terms, this is a broadside array, since radiation is strongest perpendicular to the plane defined by the two radiating wires. (In contrast, a Yagi is an end-fire array, since radiation is in the plane of the elements.)

We often operate either type of antenna on more than one band. Hence, we obtain a bigger category of antennas: the VOMBA: the vertically oriented multi-band antenna.

We can also feed the loops on their sides and arrive at vertically polarized antennas (VOVPLs), but they tend not to be good performers on bands other than the one for which they are cut. Yet, we still have an interesting question. Suppose that we take a loop and move the feeder to the corner. It is not at the center of a horizontal wire, so it is not purely horizontal. It is not up the antenna side, so it is not purely vertical. So what is it? It is a hybrid with the properties of both a horizontal and vertical antenna. Before we are finished, we shall look at one especially interesting version of this hybrid: the W6RCA right triangle.

The next question is a simple one. What do we want to accomplish in our exploration of VOMBAs? Essentially, we want to know which--if any--of the many types of VOMBAs makes the best multi-band antenna. We have to have a baseline, and I shall arbitrarily select 40 meters for that reference point. Except for a couple of specific antennas, we shall cut the VOMBAs for 40 meters and see how they do on bands above 40 meters.

Why 40 meter? A wavelength at 40 meters is about 140' long. We can make rectangles and triangles with top heights of 35 to 70 feet and still squeeze most of the loop into the space below. Since space is at a premium in most urban and suburban station locations these days, 40 meters is the most common loop we would discover in a survey.

Here is we shall proceed. First, we shall look at the most tempting antenna group--the loops. Then we shall take a quick look at the 40 meter doublet as a standard of comparison by which to judge the loops. Third, we shall examine the W6RCA corner-fed triangle to see how it differs from the loops and the doublet. Finally, we shall explore the expanded Lazy-H to see if a phase-fed array can compete with the loops.

Along the way, as is my habit, I shall present a lot of information in the form of antenna model patterns and tables of modeled output data. In all cases, the antennas are perfectly amenable to modeling, since their structures do not come close to the limits of NEC or MININEC. The one major limitation is the average ham's cluttered environment. Models usually use a clear horizon, but we hams live in object-filled yards. The end result is always a slight adjustment to the numbers when you actually build a VOMBA.

The VOHPL on Many Bands

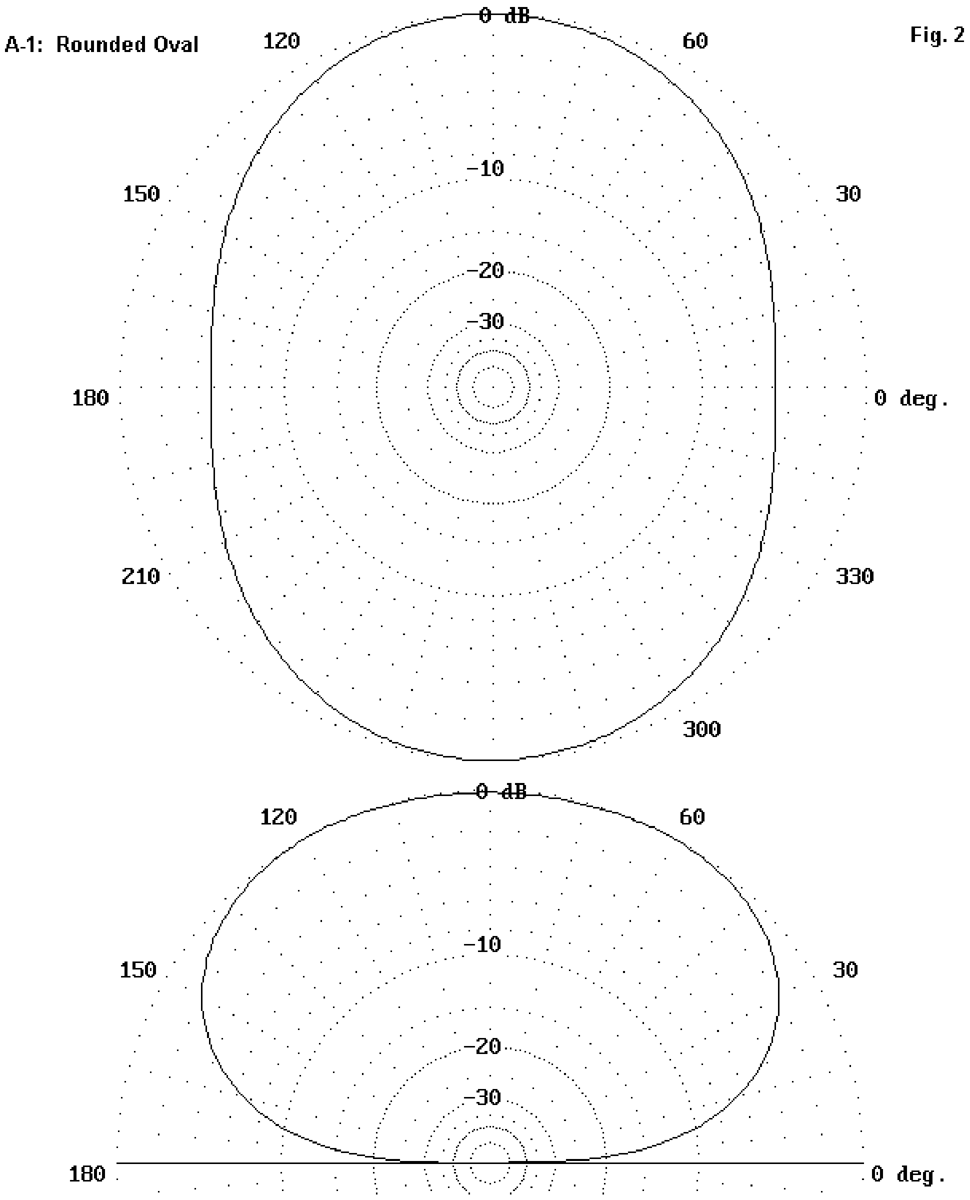
Many would-be loop builders want to use VOHPLs on frequencies above their fundamental. With parallel transmission line and an ATU, multi-band operation is certainly possible. The key question is this: what do we get for our trouble? And how does the VOHPL stack up against other possible multi-band antennas. Patterns and performance data for the 135' center-fed antenna, the 102' center-fed antenna, the 135' end-fed Zepp, and the 135' off-center-fed antenna have been presented in past FDIM sessions, and a complete set of patterns for all of the HF bands are available at my web site. The compendiums of patterns for these antennas will make excellent comparative references for you as you try to decide which multi-band wire to build. Developing this reference library of patterns and data is one of the reasons for the web site and for the series of articles in Low Down called "Antennas From the Ground Up."

For the VOHPLs, we shall vary the procedures that I have used for the other antennas. For most antennas, I have simply presented each antenna, its pattern, and its data. Among VOHPLS, there are simply too many variants to analyze one pattern at a time. Therefore, we shall begin with a collection of types of patterns that occur on various bands with the VOHPLs, labeling each with a letter. Then, we shall tabulate the modeling results for each type of VOHPL on each band, referring to a pattern by letter (if one exists in our collection). We shall also list other data, such as maximum gain, elevation angle of maximum radiation, and approximate feedpoint impedance.

All antennas in the VOHPL collection will have a maximum top wire height of 66' as representative of a maximal backyard ham installation. All of the modeled data emerge from EZNEC (using NEC-4.1, although NEC-2 is perfectly adequate to modeling these antennas). The modeled antennas are constructed of #14 copper wire over average ground (conductivity = 0.005 S/m; permittivity [also called relative dielectric constant] = 13). Since these antennas are all horizontally polarized, the actual ground or soil quality will have minimal affect on performance.

Let's begin our catalog of antenna pattern types.

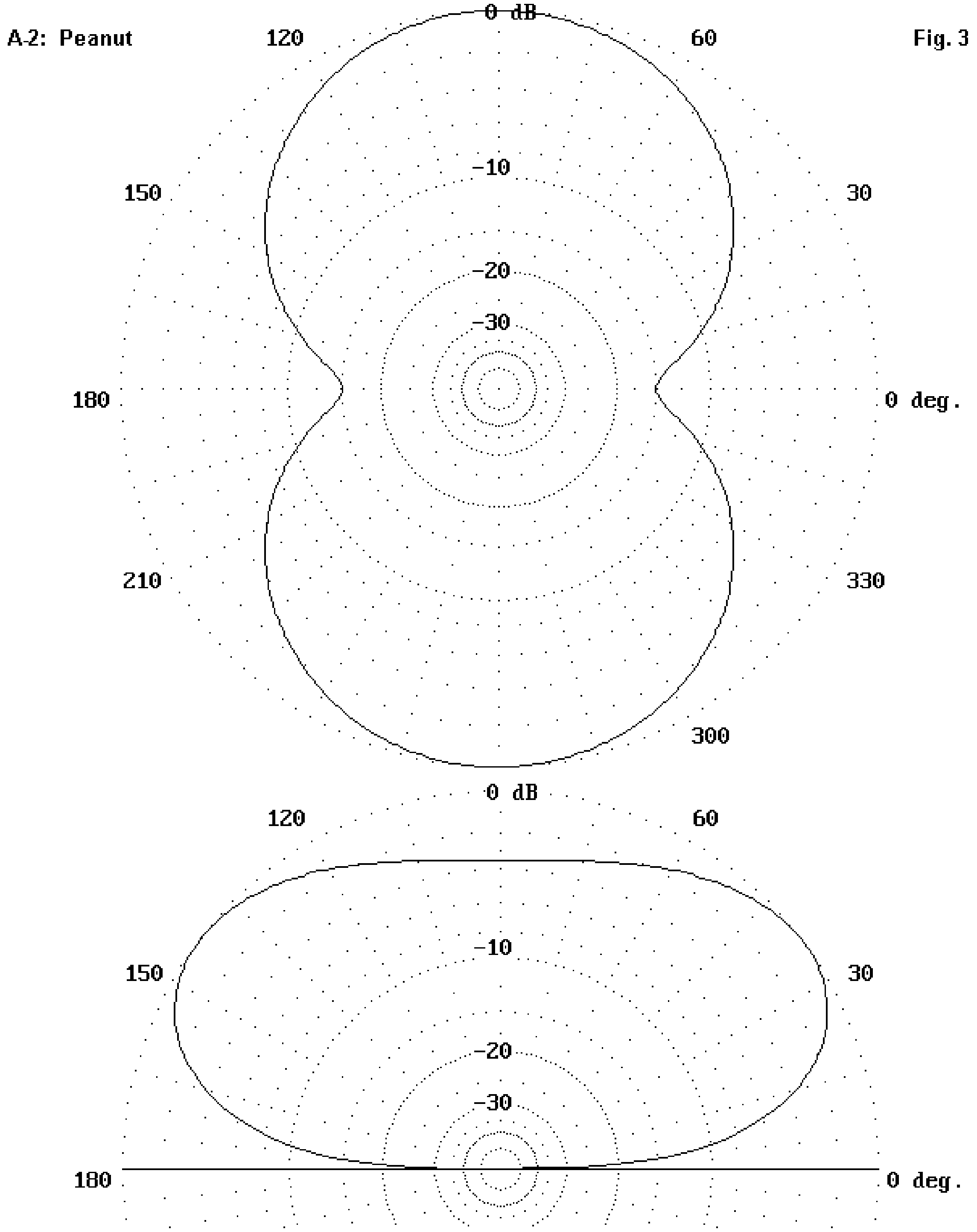
A1: The Rounded Oval



The oval azimuth pattern in **Fig. 2** is typical for horizontal wire antennas at heights under 1/2 wavelength (wl). The lower the height, the more circular the pattern. As we increase the height, the radiation off the ends or edges of the antenna decreases. Gradually, the pattern becomes dimpled and fades into the next pattern type (A2).

We should not neglect the elevation portion of **Fig. 2**. The egg-shaped pattern just touches the out ring at a high angle. Maximum signal strength for this example is around 60 degrees above the horizon, the "take-off" (TO) angle. For distant signals, we are much more interested in radiation at much lower levels. The 40-meter range of most- desired elevation angles might be from 15 to 30 degrees, while the 10 meter range might be 5 to 15 degrees. You can interpolate values for the bands between. These rules of thumb (which often have exceptions) apply not only to this pattern, but as well to every other pattern in this group.

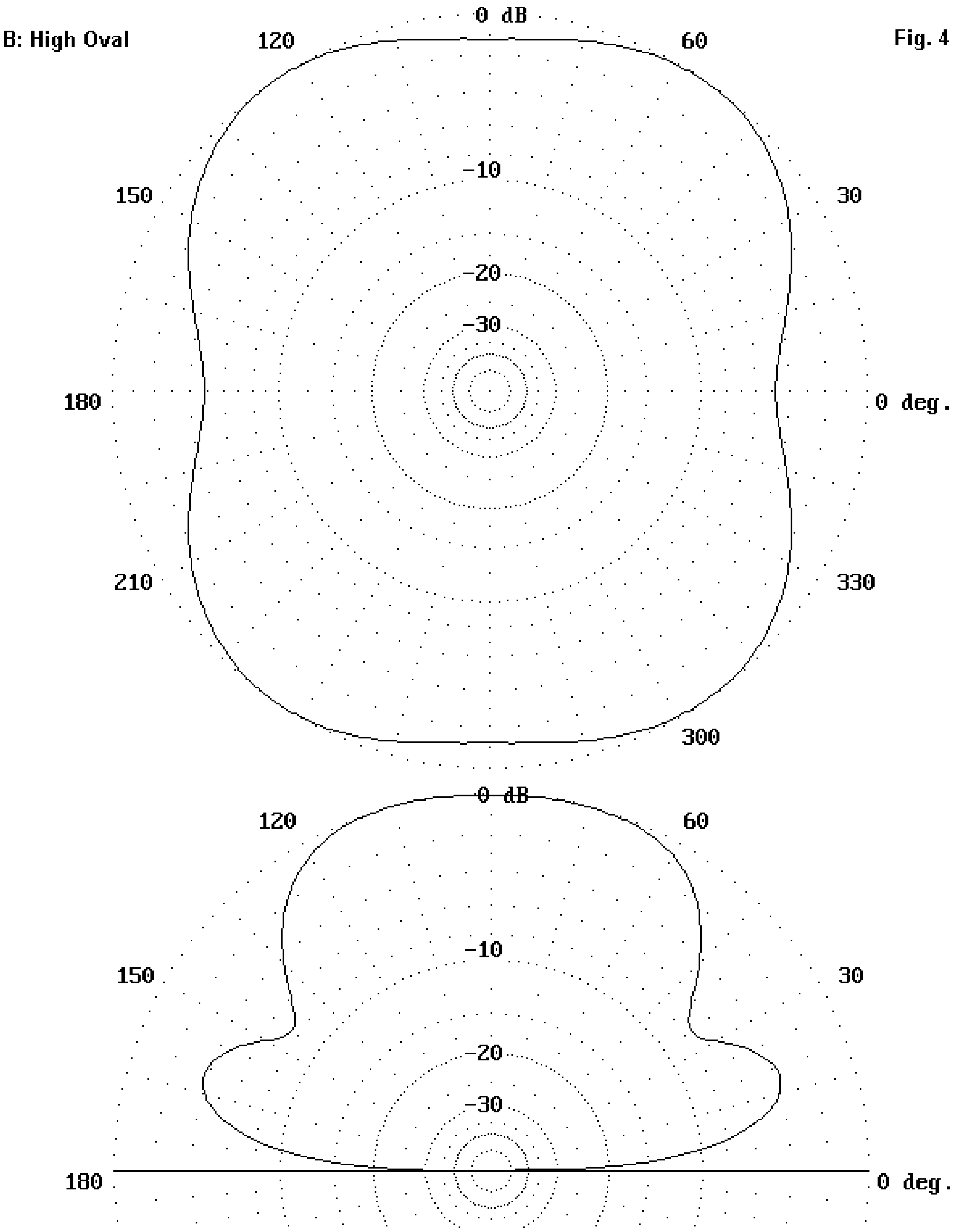
A2: The Peanut



The peanut, shown in **Fig. 3**, is a natural evolution from the oval. With doublets, this pattern is what happens when you elevate the antenna.

Notice not only the deeper side nulls, but also the lower TO angle of the elevation pattern.

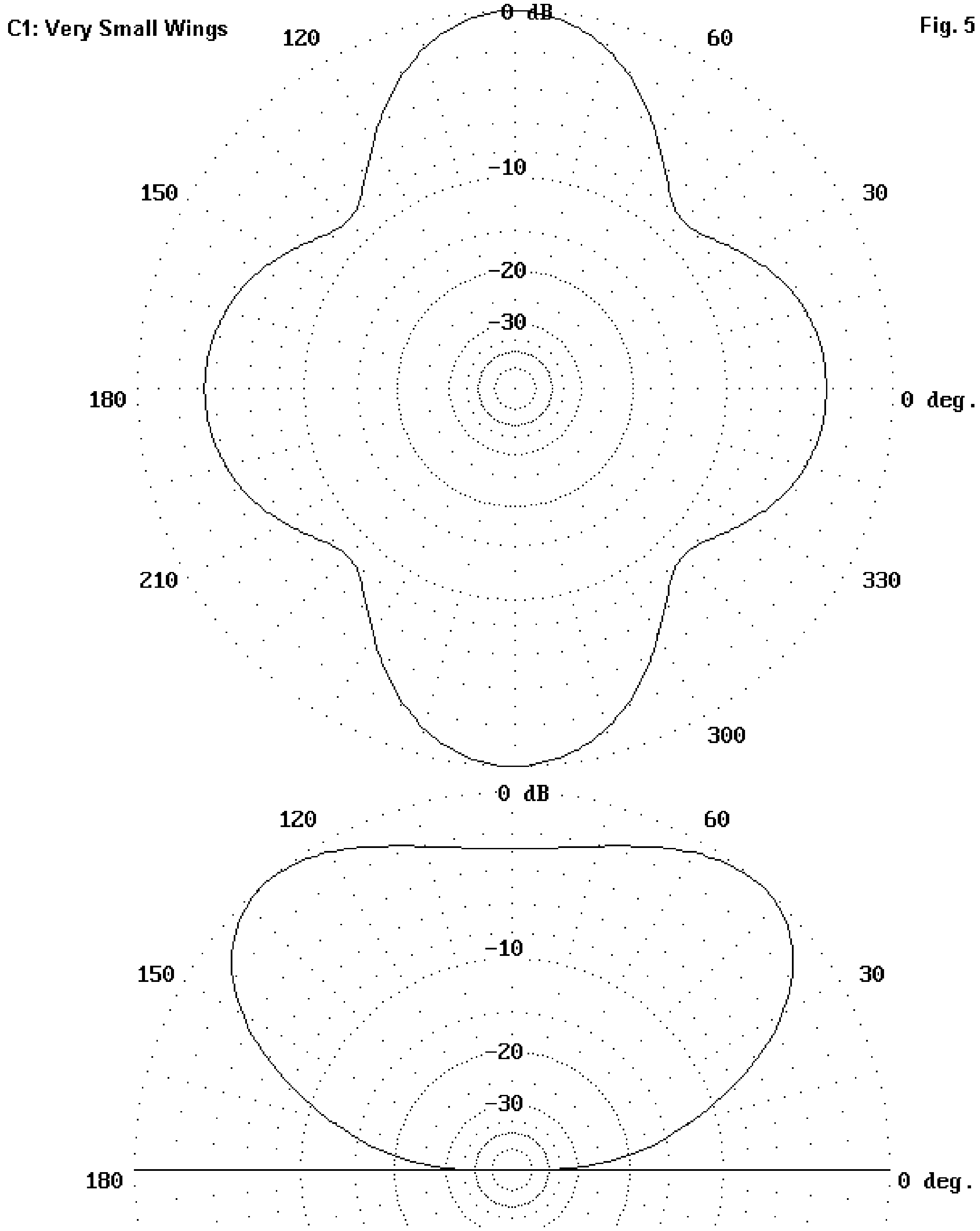
B. The High Oval



The high oval in pattern B (**Fig. 4**) is distinct, but not because of the shape of the azimuth pattern. This portion of the pattern can range from a near circle to an indented square. It occurs usually at frequencies above the baseline frequency for which a VOHPL is designed.

The key to the high oval is the elevation pattern. Note that the strongest radiation is straight up--or nearly so. What emerges at lower angles is relatively weak. In general, this is not a desirable pattern for an antenna on any of our favorite bands.

C1: Very Small Wings

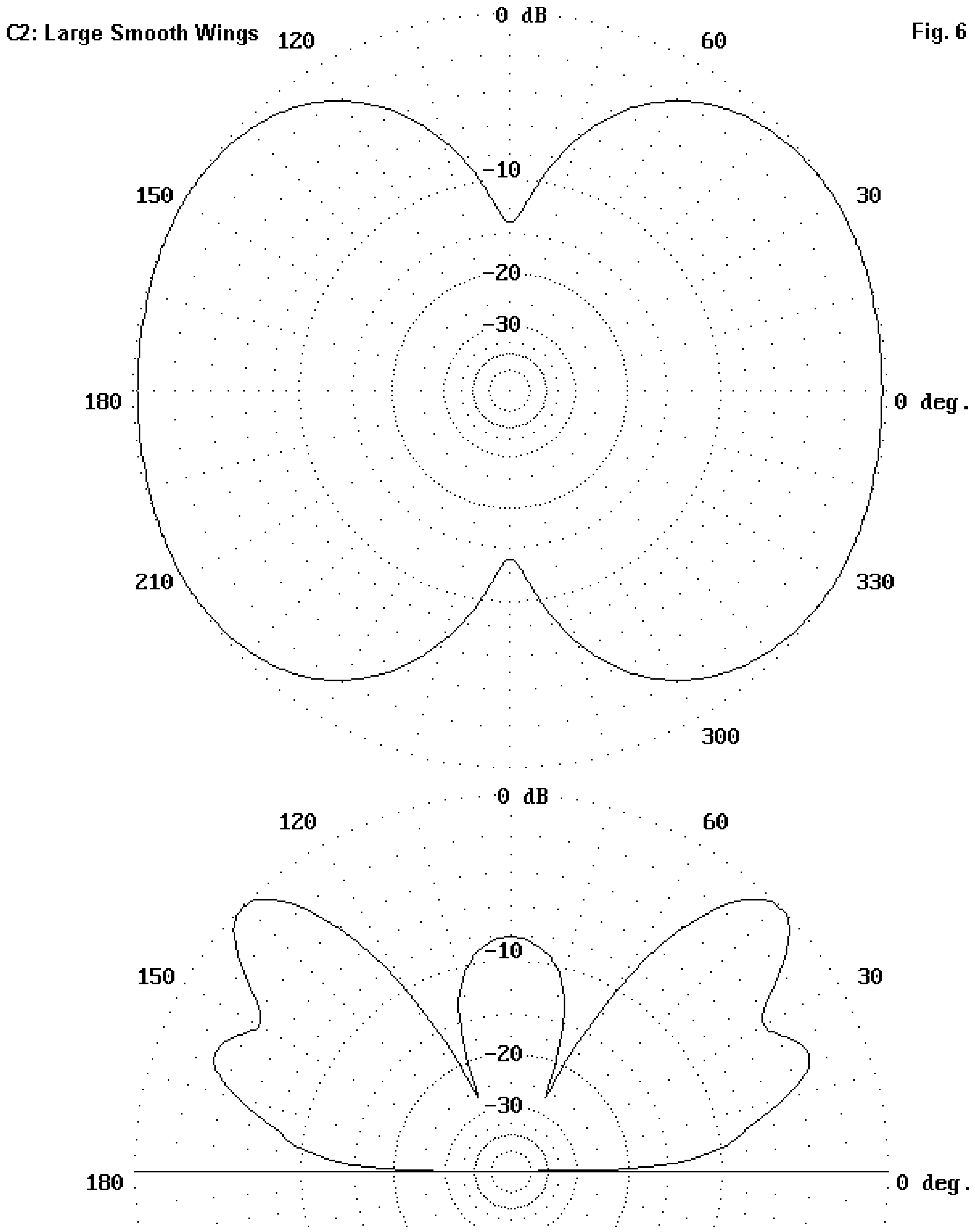


C1: Very Small Wings

Fig. 5

With VOHPL loops operated above their fundamental frequency, patterns do not always break up in the ways typical of doublets. We do not obtain cloverleaf or daisy-petal azimuth patterns. One of the variations for lobe formation (shown in **Fig. 5**) is the development of side "wings" off the edges of the antenna. In most cases, when these wings are small, antenna performance tends to be good. If you examine the elevation pattern for C1, you will see that its TO angle is in the vicinity of the elevation pattern we called the peanut (A2). This is a pattern with which we can easily live in a multi-band antenna.

C2: Large Smooth Wings



Large smooth wings, shown in **Fig. 6**, develop as we change the loop shape or increase the frequency somewhat further. Notice that now the radiation is off the edges of the loop and is no longer broadside to it. In addition, the elevation pattern is marked by multiple lobes. For any given case, either the lower or the upper lobe may be stronger--or they may both be at about the same strength.

If we note on which bands this type of pattern occurs, it may be quite usable. We simple have to remember that signals will be stronger off the edges of our loop.

C3: High-Angle Wings

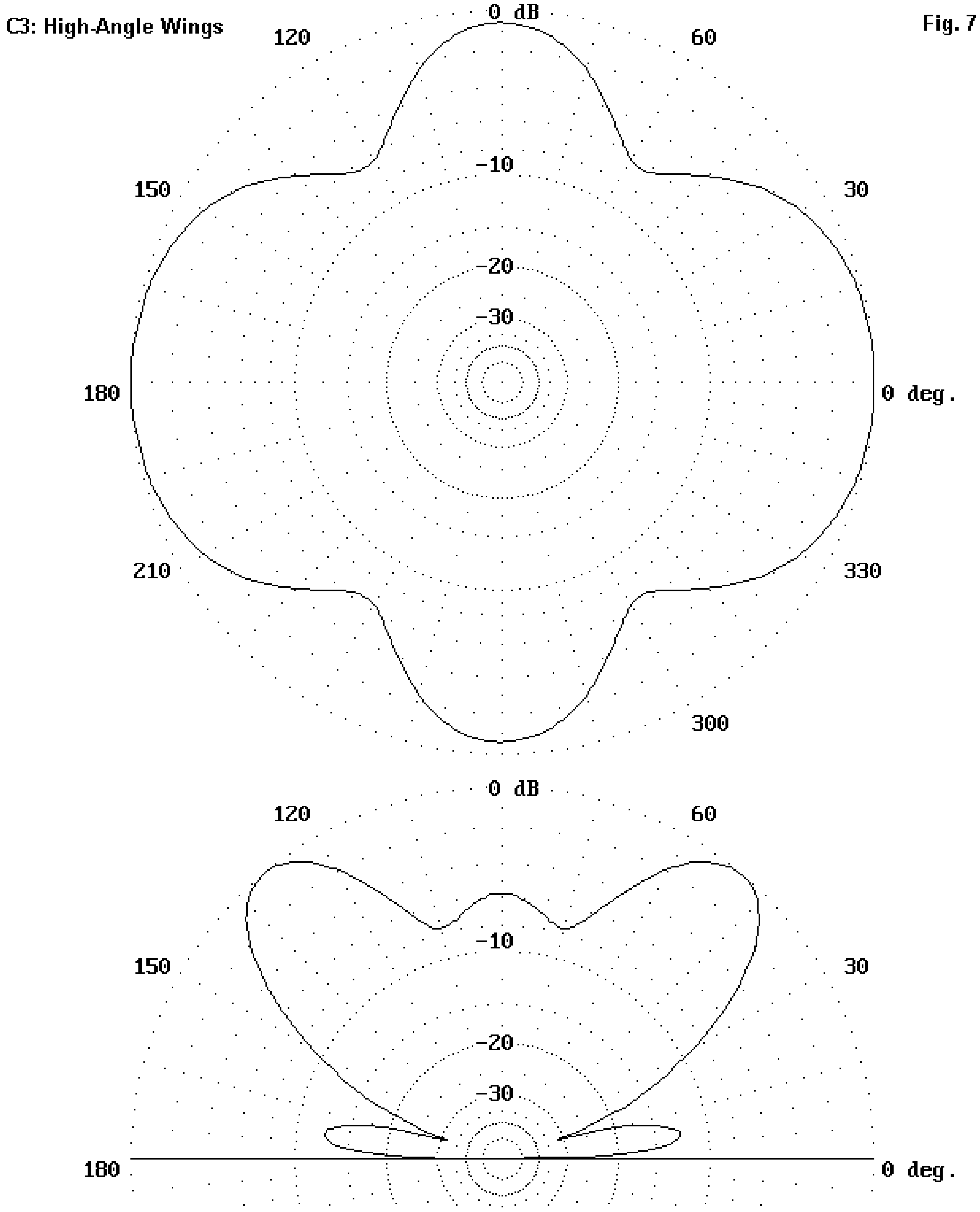

C3: High-Angle Wings

Fig. 7

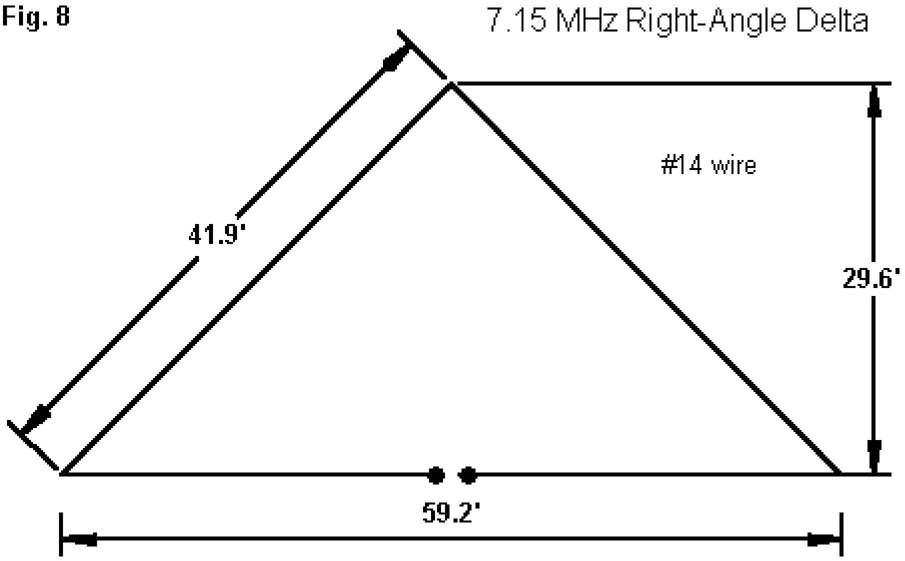
Sometimes, the development of side-wings in the azimuth pattern is accompanied by an almost complete loss of low-angle radiation. **Fig. 7** shows the patterns for such a case, which is common on the upper HF bands for some 40-meter loops. Although the azimuth pattern may show a high gain figure, the gain is often at angles too high in the upper HF region to do more than bring in an occasional E-layer signal. For general operation, C3 is not at all a desirable pattern.

Virtually all of the radiation patterns of 1 wl VOHPLs will fit one of these general patterns, although the gain and precise elevation angle of maximum radiation will vary widely. However, with this catalog in hand, we can efficiently characterize the radiation pattern of a VOHPL on every band of operation.

Now we are ready to look at the individual possible vertical loop antennas of the VOHPL collection. The following tables--for two kinds of deltas and for two kinds of rectangles--provide data on take-off angle, maximum gain, approximate feedpoint impedance, and pattern type.

1. The Right-Angle Delta

Fig. 8



The right-angle delta appears in **Fig. 8**. With a top height of 66', it has a lower horizontal wire at about 36.6' up. In the table following the sketch of the right-angle delta, the lowest angle data are shown if the lowest lobe is either dominant or if it is close to equalling a higher more dominant lobe.

In addition to the data shown, it is useful also to examine modeled data on the -3 dB beamwidth both horizontal and vertical. This information gives clues to the shape of the lobes.

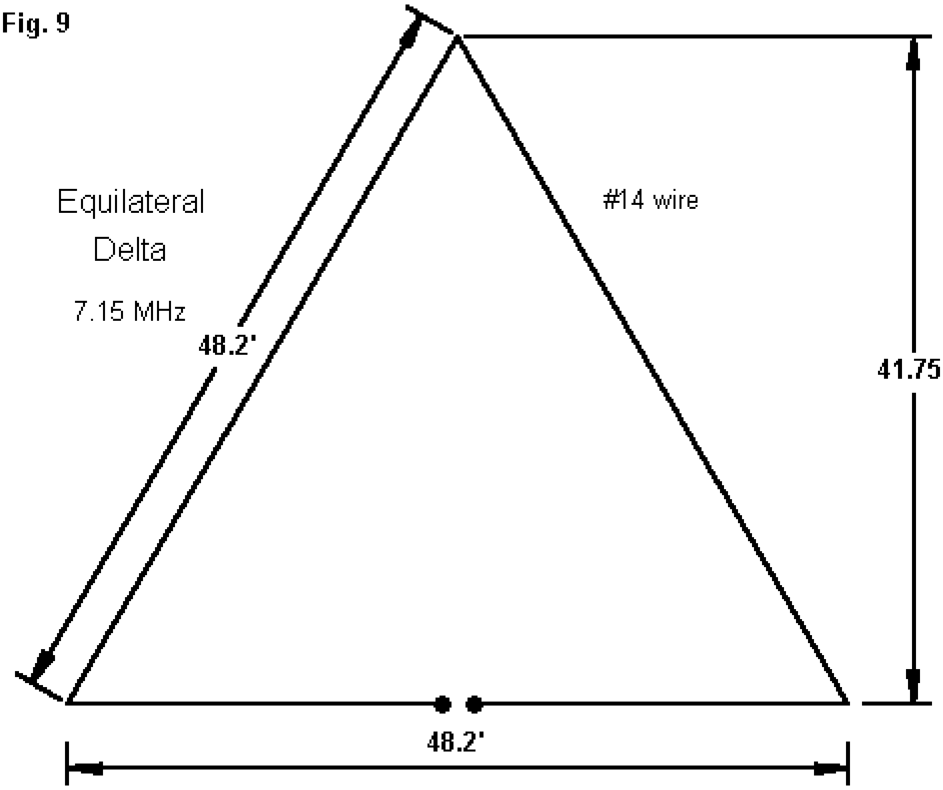
Freq. MHz	TO Ang	Gain dBi	Impedance R ± jX	Ptn
7.15	40	5.9	240 -j 5	A1
10.1	28	7.6	2150 +j2055	A2
14.15	36	7.1	120 -j 20	A2
18.1	22	8.5	1055 -j 910	C1
21.15	13	7.5	215 +j 130	C2*
24.95	65	8.1	1515 -j1700	B
28.5	15	8.0	405 +j 195	C3

*** 15 meter patterns vary depending on elevation angle.**

The B and the C2-C3 patterns on the upper bands on a 40-meter right-angle delta limit the effectiveness of this loop above about 30 meters.

2. The Equilateral Delta

Fig. 9



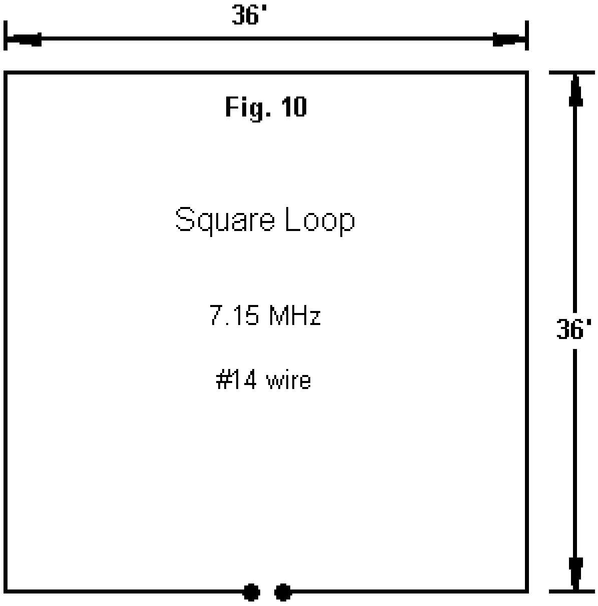
An equilateral delta (**Fig. 9**) is taller but narrower than its right-angle cousin. With a 66' top, the equilateral delta is about 12' closer to the ground at the bottom. This makes a difference in the performance, especially above 40 meters.

Freq. MHz	TO Ang	Gain dBi	Impedance R ± jX	Ptn
7.15	46	5.3	135 -j 5	A1
10.1	33	5.7	2380 +j1160	A1/2
14.15	43	6.1	265 +j 70	A2-B
18.1	43	6.4	1255 -j2135	B
21.15	30	4.3	110 +j 160	C2/3
24.95	14	5.4	2055 -j1655	C2
28.5	20	6.6	315 +j 305	C3

For the same top height as a right angle delta, the equilateral delta has a lower gain on every band, accompanied by generally higher TO angles. The exceptions to this trend appear on the upper bands, where the length of the sides exceeds 1/2 wl and thus changes the patterns more radically relative to the slightly shorter sides of the right-angle delta.

The presence of B through C3 patterns from 20 meters upward limits the effectiveness of the equilateral delta as a multi-band antenna.

3. The Square Quad Loop



A square quad loop (**Fid. 10**) cut for approximate resonance on 40 meters at about 66' high places its lower wire at about the 30' level. The square shape makes this VOMBA among the most compact of those we have so far examined. Again, the change in length and orientation of the sides will give this version some distinct performance trends, compared to the deltas.

Freq. MHz	TO Ang	Gain dBi	Impedance R ± jX	Ptn
7.15	35	6.3	145 -j 5	A1/2
10.1	24	7.6	2900 +j2760	A2
14.15	48	6.7	290 +j 65	B
18.1	35	7.2	1215 -j1640	B
21.15	14	5.0	255 +j 50	A*
24.95	16	6.8	1520 -j1400	A**
28.5	45	7.9	295 +j 185	C3

*** Very "square" oval**
**** Very narrow beamwidth**

For the lower HF bands, the quad loop offers generally lower TO angles and higher gain than the deltas. However, its utility on 20 meters and up is very limited by B and C3 patterns, as well as a very narrow beamwidth on 12 meters.

4. The Rectangular Quad Loop

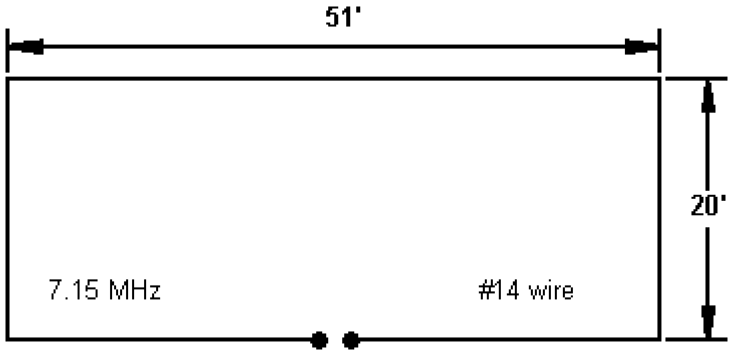


Fig. 11 Rectangular Loop

A horizontally fed quad loop increases in gain at its fundamental frequency when stretched vertically. However, the more common ham configuration is to stretch the loop horizontally. For multi-band operation, this stretch-mode is not necessarily a disadvantage, since it places the bottom wire higher, promising at least a lower elevation angle for signals. If the top wire of the model in **Fig. 11** is at 66', the lower wire will be 46' up for this particular rectangle. (Since we can make rectangles with any ratio of height to length, this model is just a random sample.)

A second feature of stretching the loop horizontally is to raise the feedpoint impedance on the fundamental frequency. If we had the room to stretch the quad up and down, we would have seen a drop in the feedpoint impedance. In either case, the impedances for bands above the fundamental are not greatly affected by any of our reshapings.

Freq. MHz	TO Ang	Gain dBi	Impedance R ± jX	Ptn
7.15	37	6.2	285 +j 10	A1
10.1	26	7.6	2655 +j1135	A2
14.15	40	3.3	135 -j 30	B
18.1	19	8.4	1930 -j2365	A1
21.15	12	9.4	155 -j 75	C2
24.95	11	7.6	2505 -j 555	C2
28.5	43	7.9	385 +j 60	C3

On the lower bands, the performance of the rectangle is generally comparable to the square quad loop. On the upper HF bands, there is a trend toward higher gain and lower TO angles, but, it does not extend to all of the bands. 20 and 10 meters remain under the weight of B and C3 patterns, which limits the effectiveness of the antenna on these bands.

Overall, the VOHPL group does not show outstanding characteristics in multi-band service. On at least two bands per antenna, we encounter either B or C3 patterns. The high TO angles of these patterns limit long-range skip performance on just the bands where we want it. Moreover, lower angle radiation tends to be weaker than for other pattern types.

These problems are not fatal to enjoying one of the loops as the multi-band antenna for a station. Effectiveness depends also on other factors. 1. Is this the only antenna my yard can support? If so, then we can tailor our operation to use the antenna on the bands where it is most effective. 2. What are my favorite bands? If the list coincides with the bands on which one of the loops is quite effective, then we have a match that will be hard to beat. On the other hand, if our favorite bands fall where the loops are least effective, it is time to think of other antenna possibilities.

Before we leave the VOHPL group altogether, let's pose one more question: What is an appropriate standard of comparison to use in trying to decide if a vertically oriented loop has enough performance to justify its existence in my yard? There is not single answer to this question. However, we can provide a reasonably fair comparison with a rather basic antenna.

Our top height is 66' for this exercise. Suppose that we also have 67' for the length of a wire antenna. Why not try a simple 40-meter doublet as our multi-band antenna?

The 66' Doublet

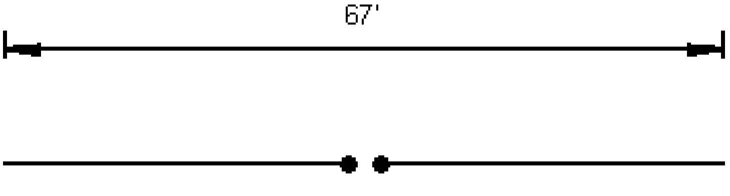


Fig. 12 7.15 MHz Dipole, #14 wire

A 67' doublet is approximately resonant on 40 meters (**Fig. 12**). At a height of 66', it is also about a half wavelength up, which is a reasonably good height for dipole performance. Above 40 meters, the antenna become a doublet for open wire transmission line and ATU use. As the table shows, it acquits itself quite well.

Freq. MHz	TO Ang	Gain dBi	Impedance R ± jX	Ptn
7.15	28	7.3	70 -j 10	A2
10.1	20	8.1	275 +j 800	A2
14.15	15	9.0	4670 -j 345	A2
18.1	11	10.5	175 -j 860	D
21.15	10	8.4	100 -j 115	E
24.95	8	9.3	375 +j 730	E-F
28.5	7	9.5	3265 +j 375	F

Overall, the doublet displays a lower TO angle on every HF band compared to the entire collection of loops having the same top height. This fact is not hard to explain. Even with a favorable pattern, the loop elevation angle of maximum radiation is a composite function of the low angle off the top wire and the higher angle off of the bottom wire. The doublet, with only a top wire, does not have its TO angle lowered by the presence of a lower wire.

The doublet also exhibits a very different pattern of feedpoint impedances across the bands relative to the entire collection of loops. Since the doublet starts out only 1/2 wl long, rather than 1 wl for the loops, the feedpoint impedances will reflect its total length on any given band. On 20 and 10 meters, it is an even number of wavelengths and hence shows very high feedpoint impedances. These impedances need not defeat use of the antenna, since the exact values of R and X will vary along the open-wire feedline. Careful length selection can present the antenna tuner with easily handled values.

The gain of the doublet also tends to exceed that of the loops on all bands. For the lower three bands, the A2 peanut patterns assure a signal direction perpendicular to the wire length. However, on the upper four bands, the patterns will differ from anything we have so far examined.

D. The EDZ Pattern

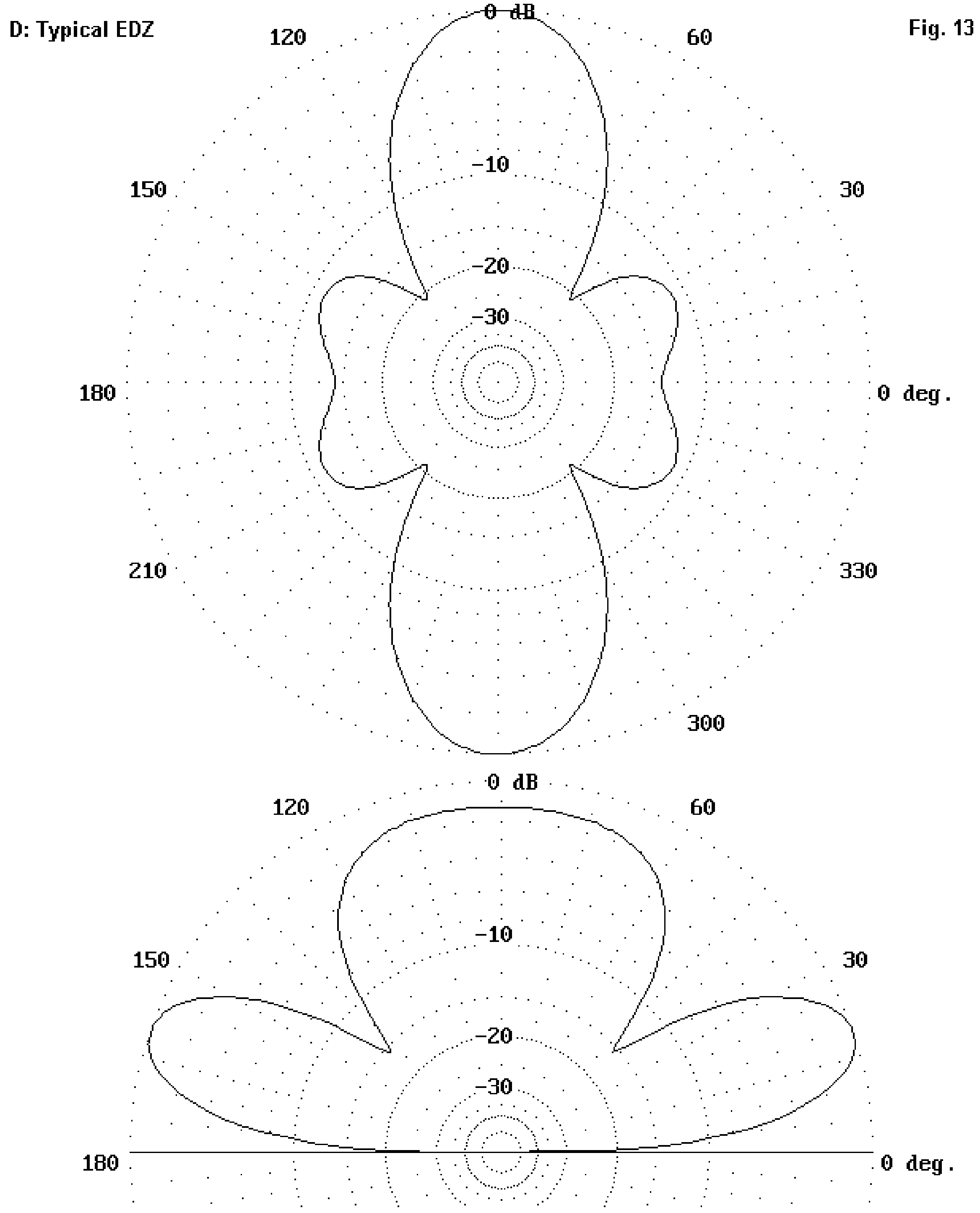
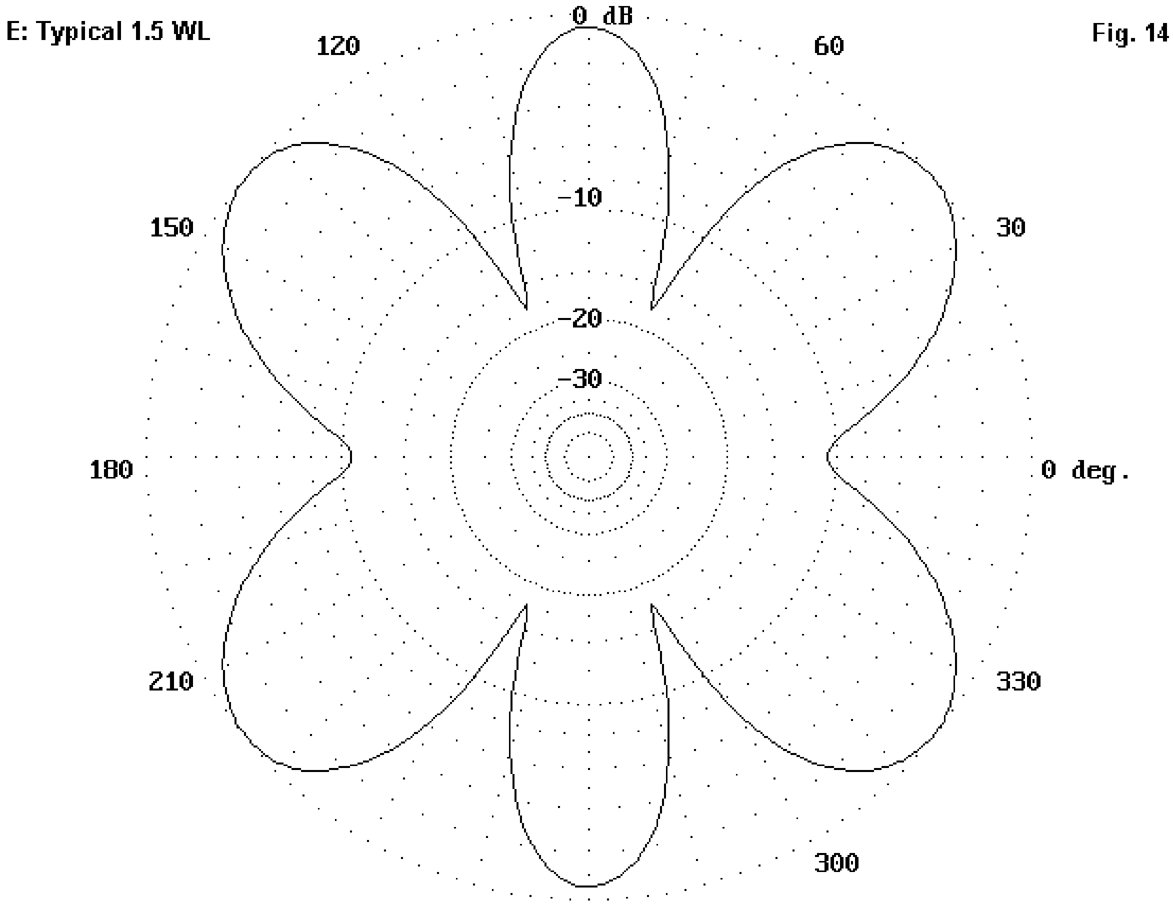


Fig. 13 shows a typical set of azimuth and elevation patterns for an extended double Zepp--or EDZ. On 17 meters, the 40-meter doublet is about 1.25 wl long and hence exhibits these patterns. The azimuth pattern main lobe is considerably narrowed relative to our typical peanuts (A2), and new lobes are beginning to show up as a set of "ears" on the azimuth pattern. However, the elevation pattern remains very well behaved, with much of the energy concentrated at low elevation angles.

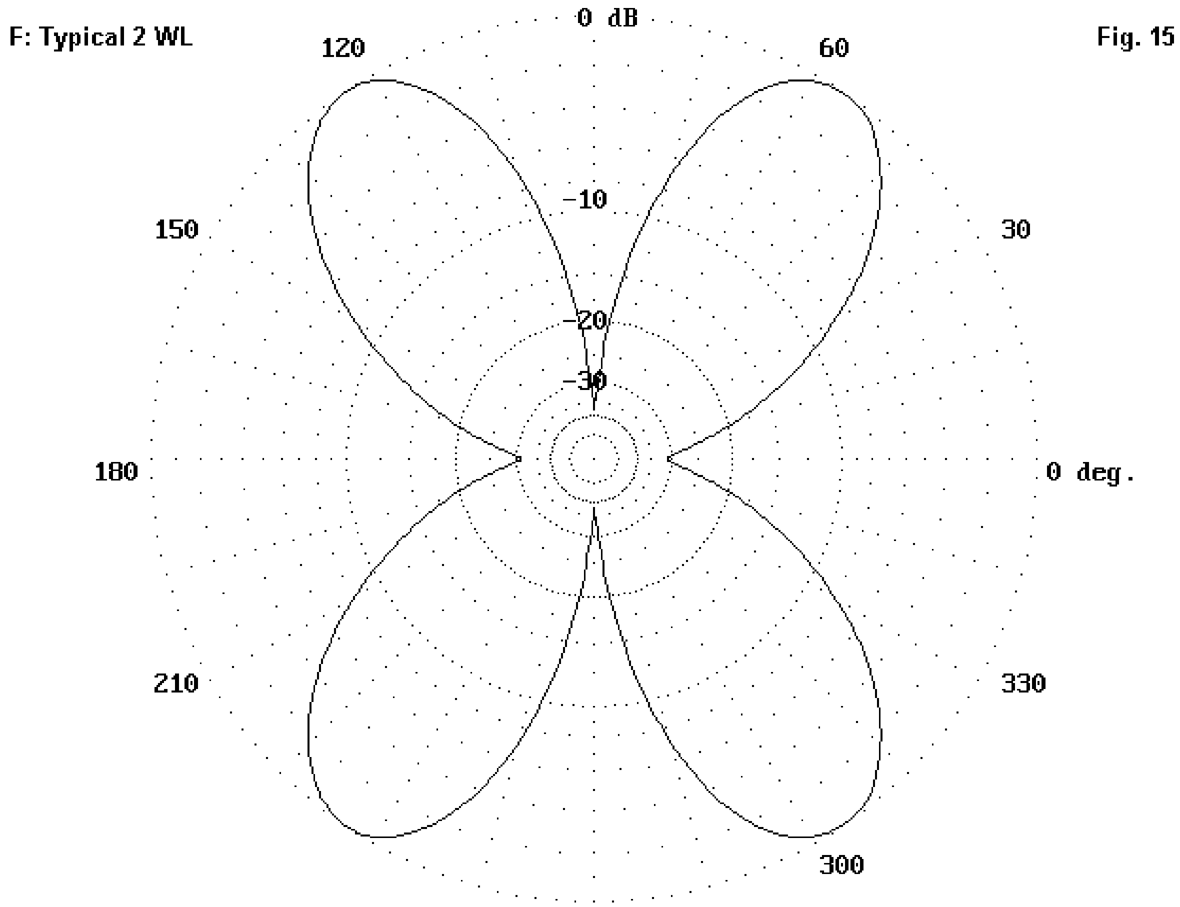
As we increase the frequency still further, we can expect the new lobes to increase in size. An equivalent move would be to keep the frequency at 17 meters and to increase the length of the antenna wire. In either case, we would be setting the antenna at something approaching 1.5 wl. At this length, that antenna pattern shows us something new.

E. The 6-Petal Pattern



When the antenna is about 1.5 wl long, the 6-petal pattern of **Fig. 14** emerges. Here, we have radiation lobes of roughly equal strength in 6 different direction. This is the 40-meter doublet pattern on 15 meters. Since the elevation patterns of the doublet are so well-behaved, I have omitted them in these figures.

F. The 4-Petal Pattern



On 10 meters, the 40-meter doublet is 2 wl long. Its azimuth pattern, as shown in **Fig. 15**, becomes as 4-petal affair.

Someone may ask how we lost 2 petals when "everyone" knows that making doublets longer tends to increase the number of lobes. Perhaps a useful way to look at the situation is with a simple bit of arithmetic.

If the doublet is an integral number of wavelengths long (that is, 1, 2, 3, . . .), then the number of lobes will be exactly twice the length in wavelengths. However, lobes do not simply appear and disappear as we change the antenna length. Rather, they grow and shrink. As we grew from 1 wl to 2 wl, the 1-wl broadside lobes shrunk, while the 2-wl lobes emerged and grew. At about 1.5 wl, both sets were the same size. Hence, 6 lobes. The general rule is something like this: at any half-wavelength point between integral numbers of wavelengths, the doublet will show a number of lobes that is the sum of those for the lower integer and those for the upper integer. Hence, the 1.5 wl doublet had 2 lobes for a 1-wl antenna and 4 lobes for a 2-wl antenna, for its total of 6.

With these easy formulas in mind, you can readily imagine the 40-meter doublet on 12 meters, where the pattern is listed as E-F. We would expect to find the 2 wl lobes dominating the overall azimuth pattern, with traces of the broadside 1 wl lobes still visible, but not too strong. This situation is just the opposite case from the EDZ pattern, which is closer to 1 wl long. With the EDZ, the 1-wl broadside lobes were dominant, with traces of the emerging 2-wl lobes visible as "ears."

Our small safari into the jungle of lobe formation for doublets has a point. We have noted that, in general, the performance of the doublet is superior to that of the loops in terms of gain and elevation angles of maximum radiation. However, that improvement comes at a price. On the upper HF bands (15 through 10 meters), the main lobes of the pattern are no longer broadside to the antenna wire.

Therefore, as we change bands in this high frequency region, our radiated energy tends to go in different directions. What we gain in gain, we lose in terms of controlling where our signals go. The question of control is a potential problem (but not for everyone) to which we shall return before ending the exercise.

However, at this point in our journey, I must reach a conclusion that no VOHPL fan wishes to hear. Given the choice of a 1 wl vertically oriented horizontally polarized loop and a doublet at the height of the loop's top wire, I would choose the doublet. Of course, that decision assumes two high support points. Deltas remain the choice of hams with only one high support point.

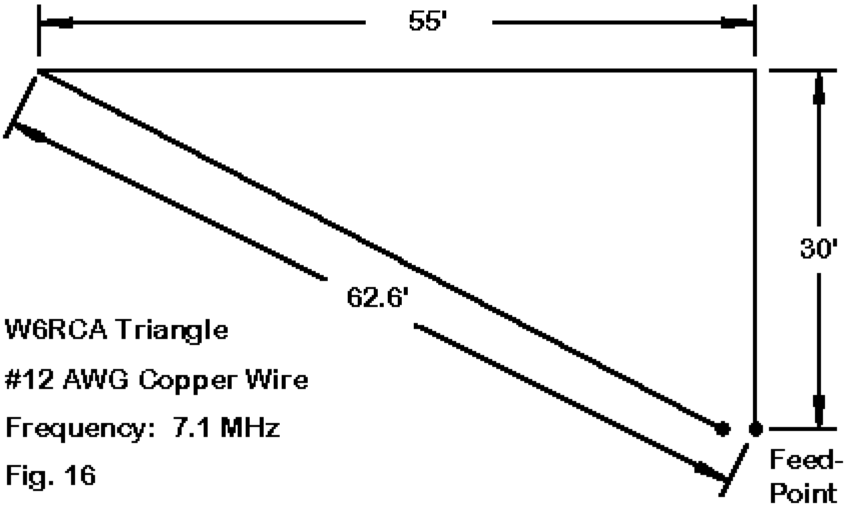
The Hybrid Triangle

Let us not, however, give up wholly on 1-wl loops. The results we have examined so far characterize loops that are fed at a center point along one of the loop's horizontal wires. The centered feedpoint ensures that the loop will maximize its horizontally polarized radiation.

In other places, I have extensively discussed a class of antennas called SCVs, the self-contained, vertically polarized 1-wl loops. Although this group includes the half-square and the bobtail curtain, let's confine ourselves to loop versions. Any of the four loops we have examined can be converted to an SCV. For the rectangle and the square quad loop, we simply move the feedpoint to the middle of the vertical leg. For the two deltas, we move the feedpoint to a position 1/4 wl down from the apex of the triangle. In the process, we shall likely have to alter the delta dimensions a bit to restore resonance.

SCVs show patterns in which the vertically polarized radiation field dominates. The horizontal field tends to cancel itself. Gain is not high, but the radiation angle is very low--a boon to low HF band DXing. However, as a group, SCVs tend to be poor performers as multi-band antennas. Once more, I would prefer a simple doublet to an SCV on the upper HF bands.

What we have not so far considered is a hybrid loop: a 1 wl antenna that is not fed for either horizontal or vertical polarization. Instead, it is fed somewhere between those two extremes. If we do not go too far toward the purely horizontal feedpoint, we might retain some of the low elevation angle of the SCV. At the same time, if we go far enough, we might obtain some gain from the growing horizontal radiation pattern that no longer cancels itself out.



W6RCA Triangle
#12 AWG Copper Wire
Frequency: 7.1 MHz
Fig. 16

To test this idea, let's look at one interesting example of an antenna designed to achieve just these goals. The sample is the corner-fed triangle developed by W6RCA and shown in the sketch in **Fig. 16**. With #12 AWG copper wire, the antenna is 55' long at the top, which is set at a 60' height. The vertical dimension is 30', which places the feedpoint (the "dots" in the lower right corner) 30' above ground. Dimensions are not critical, but every variation will alter the performance a little bit.

One of the conveniences Cecil Moore designed into his wire creation is an accessible feedpoint. At the corner, the feedpoint is easier to support than when we place it at the center of a wire. As well, the feedpoint is at the lowest point of the antenna.

Now we have only two questions to ask. How well is it likely to perform? How does it achieve the performance? We can answer the first question with another model data table.

Freq. MHz	TO Ang	Gain dBi	Impedance R ± jX	Ptn
7.15	18	2.2	41 +j 5	A1
10.1	26	6.2	8000 +j 525	Fig. 17
14.15	17	7.6	150 +j 145	Fig. 18
18.1	14	8.6	695 -j1125	Fig. 18
21.15	12	8.5	295 +j 310	Fig. 18
24.95	10	9.2	625 -j 955	Fig. 19
28.5	25	8.0	445 +j 525	Fig. 20

On 40 meters, the behavior of the W6RCA triangle is similar to that of an SCV. The gain is limited, but the TO angle of 18 degrees promises quiet reception for hearing DX signals. Note that the feedpoint impedance for this band is also similar to what we expect from SCVs.

On the other bands, the triangle exhibits a somewhat unique pattern of feedpoint impedances, including the very high value on 30 meters. These values for the vertical and horizontal components of the total far field patterns result from side lengths and their mutual coupling on each of the bands above 40 meters. As we change bands, the horizontal field comes to play an increasingly dominant role in the total pattern--hence, the improved gain values above 40 meters.

To understand the remainder of the modeled performance predictions, we must look at some more azimuth patterns. In this case, we shall show both the vertical and horizontal far fields along with the total field. How the two "sub-fields" combine to produce the overall field is interesting in its own right.

As an side note, let's look briefly at the relationship among the vertical, horizontal, and total field components of the far field patterns that have become so familiar to us from articles based on antenna modeling. For any given heading from the antenna, the total field is a function of the vertical and horizontal fields. How they relate involves logarithms to the base 10. Using antilogs (the reverse of logs), we extract the power ratios from each subfield and add them together. Finally, we take 10 times the log of the sum. The result is summarized in an equation that looks like this.

$$T_{dB} = 10 \log \left(\log^{-1} \frac{V_{dB}}{10} + \log^{-1} \frac{H_{dB}}{10} \right)$$

This is not an equation to be memorized or put on a 3x5 card by the computer--such as we do with SWR formulas. Instead, I have noted it in passing to remind you that there is a very clear relationship among the components of the far field patterns we use to indicate the potential performance of antennas. With this in mind, we can better understand the composite azimuth patterns of the W6RCA triangle as we move to frequencies above 40 meters.

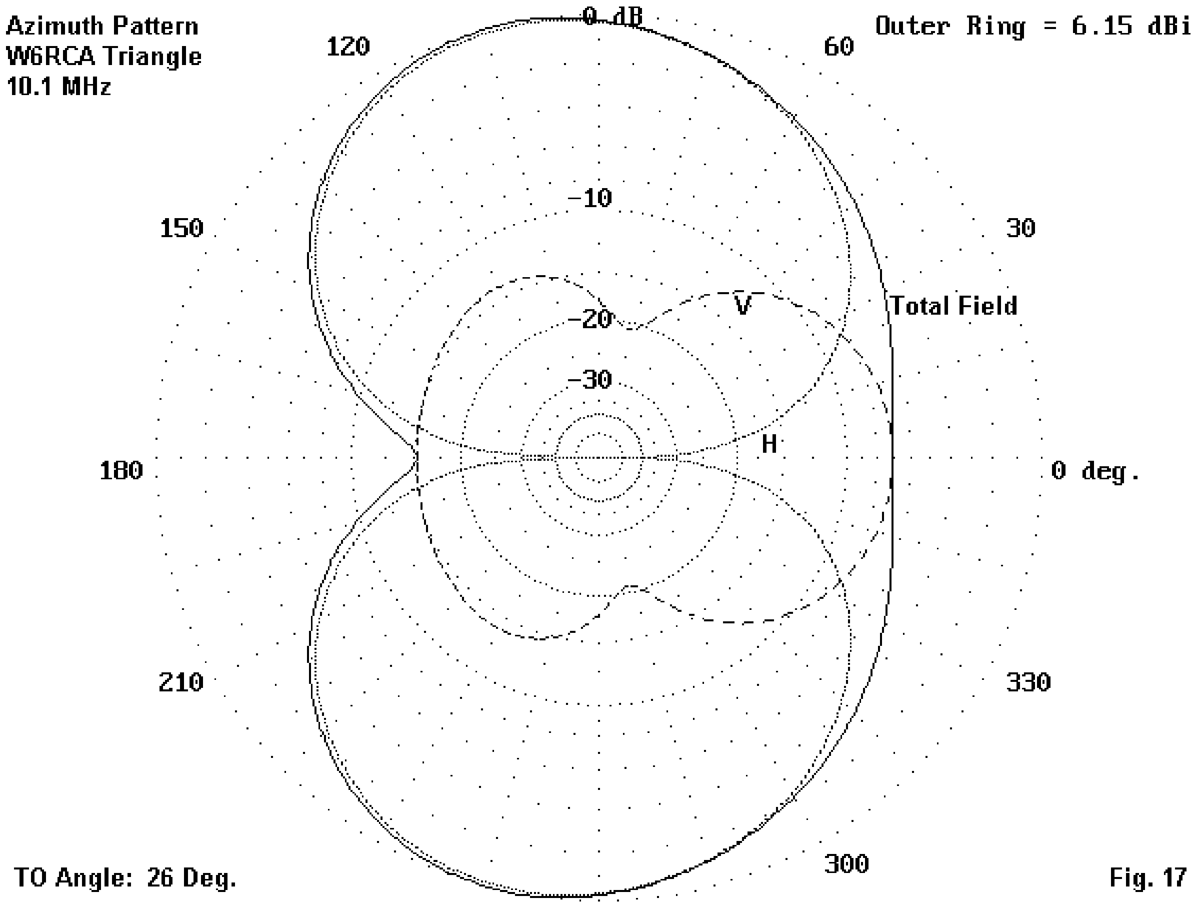


Fig. 17 shows the azimuth pattern of the triangle on 10.1 MHz, where the TO angle is 26 degrees. In general, the pattern qualifies as an A pattern, but with a difference. The left side is a peanut, while the right side is an oval, giving us a kidney bean. The feedpoint and the vertical leg of the triangle are at the right, as shown in the sketch in **Fig. 16**. The antenna is 30' above ground, for a top-wire height of 60'.

Although the horizontal field is relatively well formed, the vertical field is stronger in the direction away from the wires extending from the vertical leg. The resulting composite total pattern shows a null to the left and almost a bulge to the right. But, the main strength of the field is broadside to the triangle.

Fig. 18 shows the pattern at a 14-degree TO angle for 18.12 MHz.

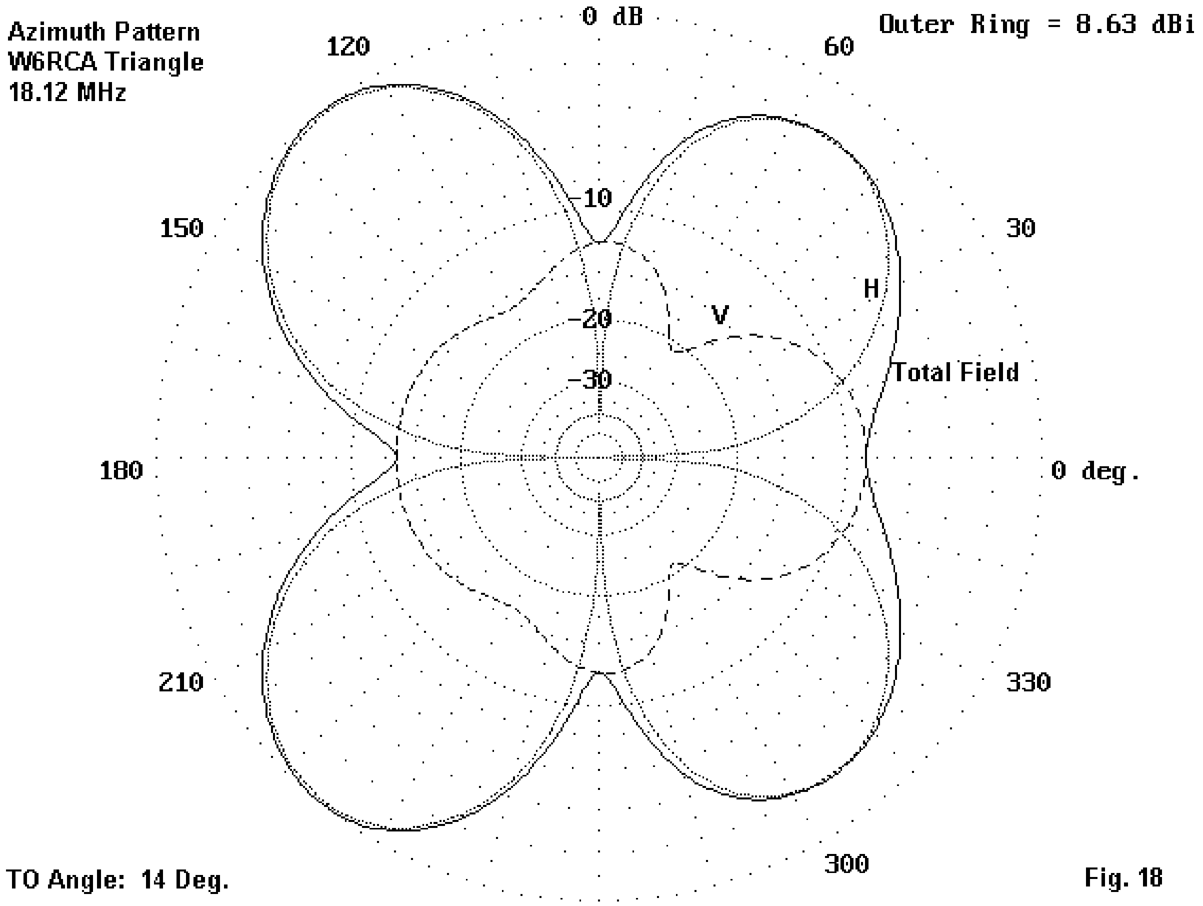


Fig. 18

This pattern is a stage in the evolution of the pattern as we move further upward in frequency. The 4-lobe 2-wl pattern is evident in the horizontal component. The vertical component is once more stronger away from the more horizontal legs of the triangle, making the null to the right much more shallow. Note, however, that the vertical component also has 4 lobes, even if not well-formed. (In some patterns, especially for antennas having complex geometric shapes, identifying lobes can be difficult, since the null between lobes may not be evident.) Moreover, the vertical pattern lobes are roughly where the horizontal component has nulls.

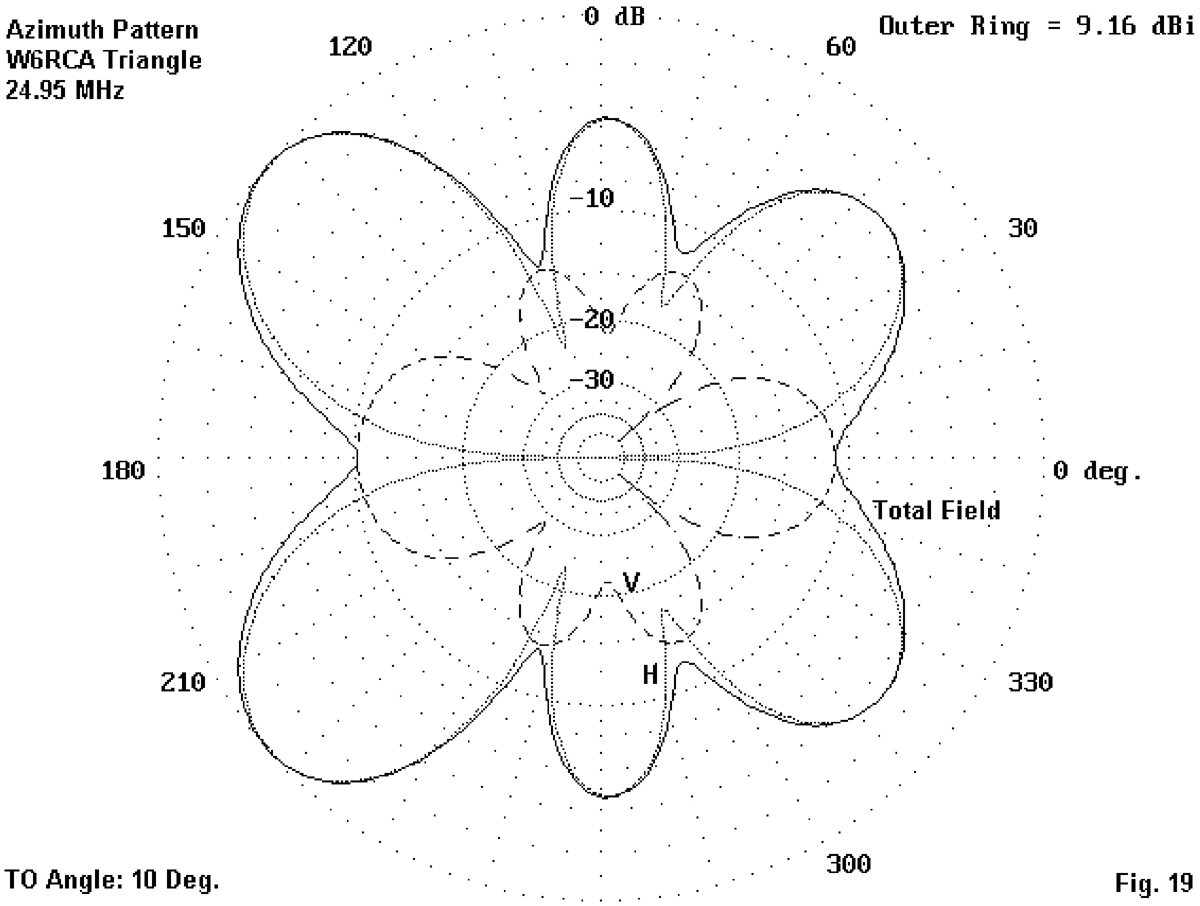
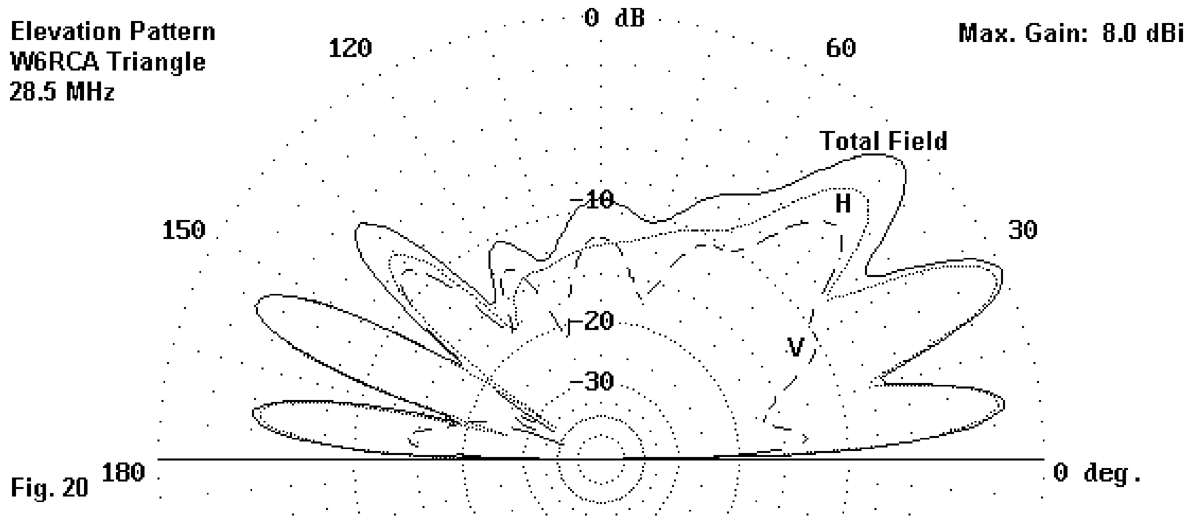


Fig. 19 makes the relationship of the vertical and horizontal components even more graphic. The pattern is for 12 meters with a TO angle of 10 degrees. In this 6-petal pattern, the locations of lobes and nulls of the component patterns are very clear. Note that, except for the new lobes that are emerging with the rise in frequency, the trend in pattern development follows that of the preceding two figures. The notable difference is in the vertical component field: at 12 meters, the field is slightly stronger in the direction of the horizontal wires, not away from them.

On 10 meters, the pattern grows even more complex. From the table, we can note the higher than expected TO angle. Once more, the mutual coupling and lengths of the three wires of this antenna form a complex set of relationships as we move to a frequency that is now 4 times the original 1 wl resonant frequency of the antenna on 40 meters. **Fig. 20** illustrates the results of these relationships with the 10-meter elevation pattern, where the right side of the pattern represents the direction from the vertical side of the triangle.



Had the field in **Fig. 20** not been a complex composite of both vertical and horizontal components, we might have classified it as a type B or C3 pattern, with only high-angle radiation. The third lobe from the horizon on the right side might have been the strongest. The composite field, however, yields an intermediate TO angle at about 25 degrees above the horizon, with a weaker lobe at about 7 degrees. Since this lobe is only about 2 dB down from the strongest lobe, we may still find some long distance skip signals.

Looking at the component fields of a total far field can help us understand just how the total field emerges. The vertical and horizontal components are also indicators of likely signal strength for clear path point-to-point communications with either vertical or horizontal antennas. However, these clear paths occur only for local communications--and even then, the clutter and terrain may modify them. Hence, locally, we often achieve better signal strength than cross-polarization might predict.

For distant or skip communications, we are most interested in the total far field pattern of radiation (or receiving sensitivity) with respect to any antenna design. Refraction of signals within the layers of the ionosphere tends to skew polarization, so that for most communications purposes, we may concern ourselves only with the total field.

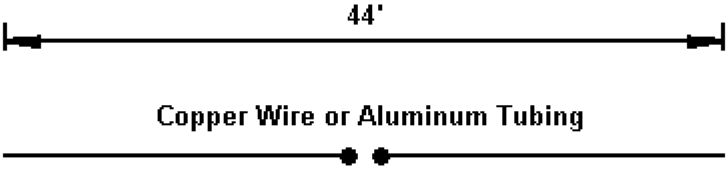
Despite the limitations of the W6RCA triangle, it represents a perfectly usable general-purpose wire antenna for 40 through 10 meters. As we increase frequency, the total pattern comes more and more to resemble that of the 67' doublet at about the same top height. In some ways, the performance figures for the doublet are marginally superior. However, the triangle offers two mechanical advantages. First, it requires a span of only 55' or so (for support ropes). Second, the feedpoint connection is only 30' above ground rather than 60' plus. The cost is this: the triangle requires twice as much wire.

If you alter the dimensions of the triangle--for example, making it taller and shorter, then the patterns we have shown will vary somewhat. Local ground clutter may also create some differences. The patterns are for general guidance, and do not predict performance perfectly.

The EDZ and the Lazy-H

Gain is not everything in wire antennas. One of the shortcomings that we encountered with the VOMBAs we have so far explored is that the radiation patterns do not maximize in the same direction on all bands. Hence, if we align the wires north and south, hoping for east-west communications, we do not achieve our goal on all bands. This situation is not a problem for everyone, but let us suppose for a short while that consistent pattern direction from 40 through 10 meters is a major goal. Is there an antenna that will let us reach this goal--and still have reasonably good gain on all of the bands?

The answer is yes, although it may come as a bit of a surprise. Let's make a doublet that is only 44' long. Since we have been putting our VOHPL top wires at 66' up, let's use that height for our new short doublet. **Fig. 21** shows the super simple arrangement.



10 Meter Extended Double Zepp
(44' Doublet)

Fig. 21

Notice that the sketch bears a second name for the antenna: the 10-meter extended double Zepp or EDZ. On 10 meters, the antenna is about 1.25 wl long, the standard EDZ length. On 15 meters, the antenna is just about 1 wl long. On 30 meters, it is just a bit short of a 1/2 wl dipole. On 40 meters, the antenna is in the vicinity of 3/8 wl long.

A doublet length of between 1/3 and 3/8 wl is about as short as we would wish to go. As we shorten the doublet further, the feedpoint impedance shows a very low resistance and a very high reactance--a combination that may challenge our antenna tuners. At the 3/8-wl mark, we still have most of the gain of a 1/2 wl dipole, with feedpoint resistance and reactance values that most tuners can handle. We might have to adjust the feedline length to put a favorable combination of resistance and reactance at the tuner terminals, but this is standard practice.

As a little exercise, lets' tabulate the modeled performance from the 44' doublet and compare the numbers to those from the 67' doublet at the same height.

a. The 44' Doublet

Freq. MHz	**TO** Ang	**Gain** dBi	**Impedance** R ± jX	**Ptn**
7.15	29	7.0	25 -j 580	A1/2
10.1	20	7.6	55 -j 100	A2
14.15	15	7.7	195 +j 385	A2
18.1	12	8.6	920 +j1565	A2
21.15	10	9.0	4160 +j 155	A2
24.95	8	10.4	520 -j1545	A2-D
28.5	7	10.5	140 -j 650	D

b. The 67' Doublet

Freq. MHz	**TO** Ang	**Gain** dBi	**Impedance** R ± jX	**Ptn**
7.15	28	7.3	70 -j 10	A2
10.1	20	8.1	275 +j 800	A2
14.15	15	9.0	4670 -j 345	A2
18.1	11	10.5	175 -j 860	D
21.15	10	8.4	100 -j 115	E
24.95	8	9.3	375 +j 730	E-F
28.5	7	9.5	3265 +j 375	F

Overall, the gain picture favors neither antenna. Gain on the lower HF bands favors the 67' doublet, but on the upper bands, the 44' doublet shows its advantage. Part of the reason for the higher gain in the upper HF region appears in the tables, where the 67' doublet patterns are labeled E and F. Compare those patterns with **Fig. 22**.

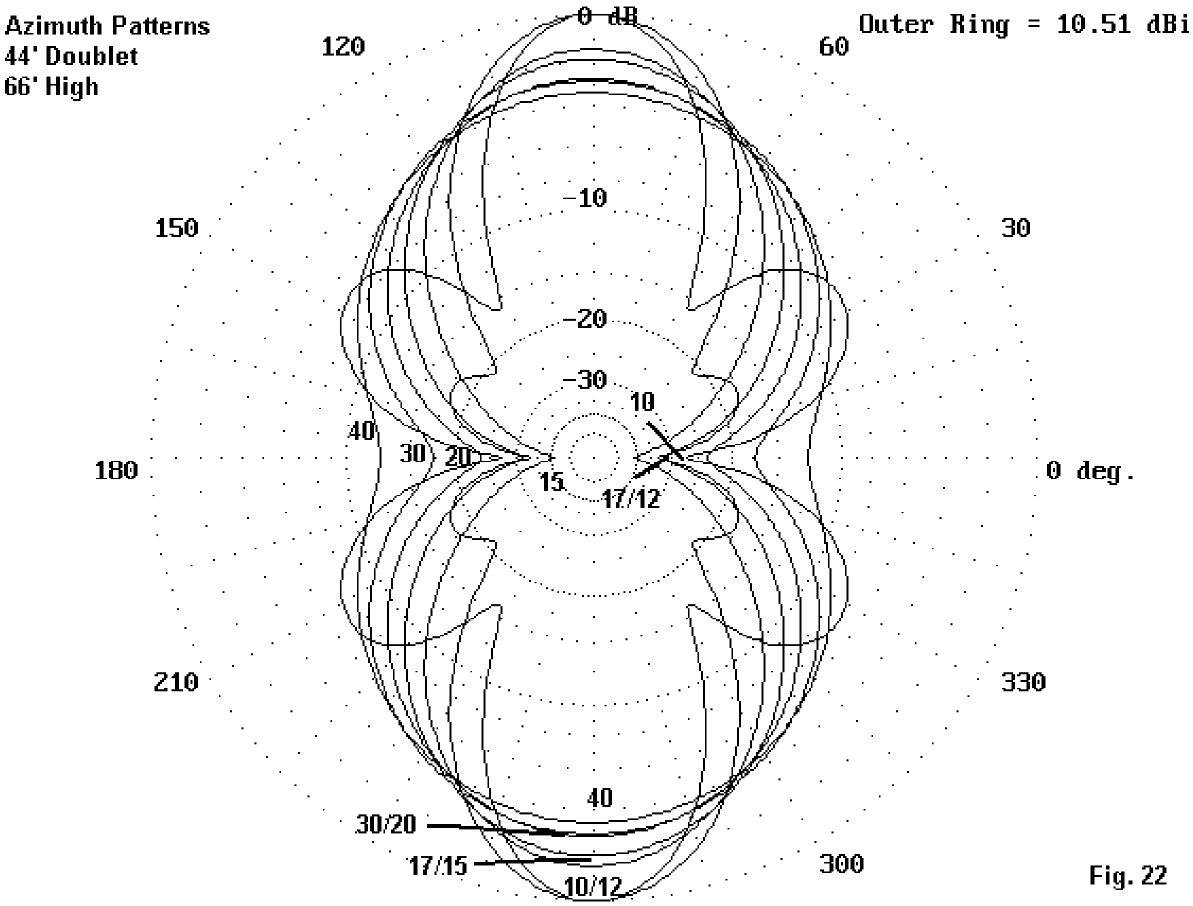


Fig. 22

By setting the maximum length of the doublet at the 1.25-wl mark on the highest frequency we plan to use, we obtain bi-directional patterns for all of the bands (40 through 10 meters). The same principle can be applied for any 4:1 frequency ratio: for example, an 88' EDZ/doublet to cover 80 through 20 meters with bi-directional patterns.

For every antenna advantage, there is a potential disadvantage to consider. As we increase the operating frequency with our 44' doublet, we encounter a narrowing beamwidth. We also acquire deeper nulls off the ends of the antenna. For some operators, these are desirable properties; for others, they limit the sphere of communications. Let's catalog the evolution of the beamwidth and front-to-side ratios.

Freq. MHz	TO Ang	Beamwidth degrees	Front-to-Side Ratio--degrees
7.15	29	94	9
10.1	20	83	15
14.15	15	72	20+
18.1	12	60	30
21.15	10	51	40
24.95	8	40	35
28.5	7	31	20

Beamwidth generally means the distance in degrees between points on the pattern that are 3 dB lower in gain than the maximum gain. Although a 31-degree beamwidth (on 10 meters) is perfectly adequate for covering all of Europe from points within the US, a 44' doublet broadside to Europe would have some difficulty on paths to Africa on 10 meters.

The chart also answers the question of from where the 44' doublet gets its upper HF gain advantage over the 67' doublet. The narrower beam width and the 2-lobe pattern place more power in the primary direction for the antenna pattern. This answer covers most of the gain, but remember that it represents

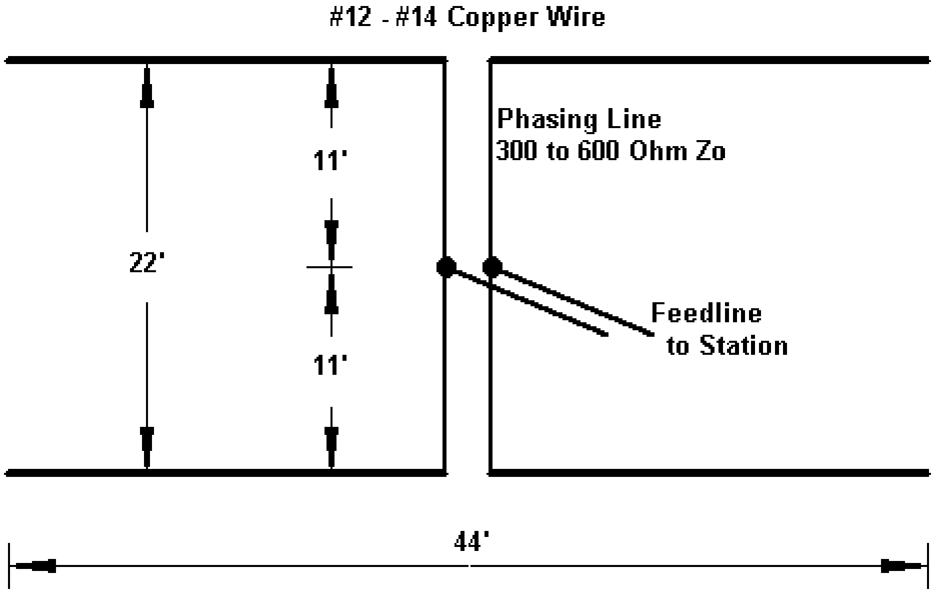
2-dimensional thinking. Antenna patterns have a third dimension. Although not too important in the present case, that third dimension will become very important shortly.

For the person whose objectives include knowing just where his or her signal is going, the 44' doublet is an elegantly simple solution to having a single element that covers 40 through 10 meters. There are no rules that demand that we make the antenna from wire. If we are up to the mechanical task, we might make the element out of aluminum tubing and mount it atop a tower. We would need a mast extension to hold some truss ropes. We would also have to use great care in routing the parallel feedline around the rotator to the element and then away from the tower leg on the way toward the shack. However, if you can put a 66' tower in place and construct a 44' aluminum element, these extra tasks will seem minor.

Before we get carried away in grand plans for a rotatable 44' doublet, let's remind ourselves that our subject is VOMBAs, vertically oriented multi-band antennas. The 44' doublet, like the 67' doublet, is not a true VOMBA, since it lacks a vertical dimension. However, the 44' doublet forms the basis for a true VOMBA, the extended Lazy-H.

The classical Lazy-H consists of two wires, each 1 wl long and separated vertically by a 1/2 wl distance. Both wires are center fed by equal-length phasing lines to a center point, from which we bring the main feedline back to the shack and its ATU. Various schemes have been developed to allow for feeding the array from the bottom with 50-Ohm coax, some of which can be found in the Editors and Engineers *Radio Handbook*.

The earliest reference I have found to the expanded version of the Lazy-H is in a November, 1968 article in *CQ* by John Schultz, W2EEY. Bill Orr resurrected the antenna in the 1980s in one of his regular *Ham Radio* columns. The key to the array lies in increasing the element length to 1.25 wl and the spacing to 5/8 wl, as shown for a 10-meter version in **Fig. 23**.



Expanded Lazy-H

Fig. 23

We have some options in how we think about the expanded Lazy-H for 10 meters. Actually, the antenna is a standard 1-wl by 1/2-wl Lazy-H for 15 meters. Alternatively, it is an array of 2 10-meter EDZs, each 44' long. However, we think about the antenna, the spacing is 22', so if we place the top wire at 66' up, the bottom wire is at the 44' mark. If we have the ability to put up a 44' wire doublet, the odds are that we can also construct an expanded Lazy-H.

How well will the expanded Lazy-H perform across the 40 through 10 meter range?

Freq. MHz	TO Ang	Gain dBi	Impedance R ± jX	Ptn
7.15	33	6.4	10 +j 95	A1/2
10.1	24	8.1	50 +j 105	A2
14.15	17	9.0	385 -j 395	A2
18.1	13	10.9	45 -j 125	A2
21.15	11	12.5	20 -j 15	A2
24.95	10	14.6	15 +j 115	A2-D
28.5	8	15.1	65 +j 425	D

Let's notice a few special features of the table of modeled performance values. First, we do not need to add a table of the horizontal beamwidths, since they would be almost exactly the same as those for the 44' doublet. Second, the TO angles for the Lazy-H are very slightly higher than those for the single EDZ. The Lazy-H has a second wire at a lower height, and its overall TO angle will be a composite of the TO angles for each wire alone. The differences, however, are not operationally significant.

Third, the gain is higher on all bands except for 40 meters. The gain also exceeds the gain of the 66' doublet on all bands except 40. The lower wire on 40, where the two wires are too close to derive any gain, tends to reduce gain on that band. However, the final figure is only about a dB less than that of the 67' doublet on the same band. The higher gains on all other bands give this array an advantage worth considering--especially since the patterns are bi-directional on every band of operation.

The feedpoint impedances call for some comment. The models for this antenna were constructed with 450-Ohm parallel line with a velocity factor of 0.95, similar to what would be obtained from common vinyl-covered windowed 450-Ohm line. In addition, the lines are exactly 11' long each, meeting at the midpoint between the elements. (For wire versions of this antenna, I would recommend that you use a rope between elements to support the line and provide strengthening where the two phasing lines meet the main feedline to the shack.)

If you change the length of the phasing lines or change the characteristic impedance (for example, by using open-wire 600-Ohm lines), you will not change the antenna performance. However, you will change the impedance at the junction where the main feedline joins the phasing lines. Some combinations will yield lower impedances at the junction; others will yield higher impedances. Since there are almost innumerable combinations we might use, be prepared to experiment with main feedline lengths that provide values at the ATU terminals which fall within the component range of the tuner.

As a sample of the range over which feedpoint values might run, here are comparative feedpoint values for three types of line, each of which is arranged as a pair of 11' phasing lines to the midpoint between elements.

	Feedpoint Impedance (R ± jX Ohms)		
Freq MHz	450-Ohm 0.95 VF	300-Ohm 0.8 VF	600-Ohm 1.0 VF
28.5	65 + j425	115 + j570	105 + j610
24.9	17 + j115*	11 + j140*	30 + j140
21.2	22 - j 15*	10 + j 38*	40 - j 50
18.1	45 - j125	16 - j 26*	90 - j230
14.15	385 - j395	75 - j150	1050 - j350
10.1	50 + j105	40 + j 65	50 + j155
7.15	10 - j 95*	6 - j 80*	13 - j 90*

Starred entries represent very low resistive components to the feedpoint impedance which might present larger excursions along whatever line is chosen as the main feedline to the shack. Note that the starred entries are fewest with the 600-Ohm phasing line. Once more, it is worth noting that these numbers are derived for general guidance from models. Variations will emerge from the actual construction of the antenna and from conditions and clutter at the antenna site.

To get a sense of how the expanded Lazy-H performs, let's look at a few selected azimuth patterns on various bands. For all patterns, the top wire is 66' up, as always, above average ground.

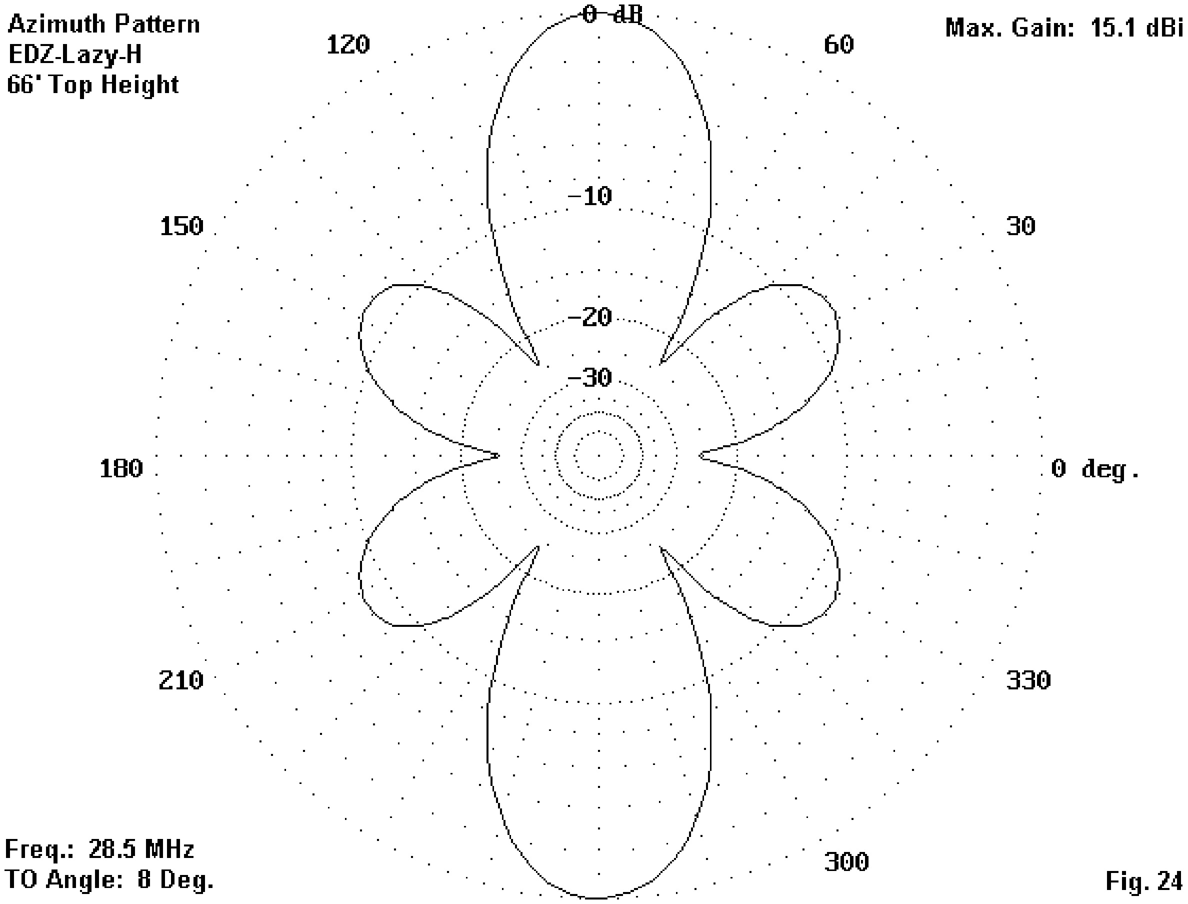


Fig. 24 gives us the basic EDZ pattern for 10 meters--with one modification. The gain is considerably higher than for a single EDZ at 66'. On 10 meters, the 5/8-wl spacing of the wires provides the highest possible increase in gain for a broadside array. As a rough comparison, the gain is equal to that of a 5-element 24' boom Yagi on 10 meters, although the Yagi, of course, will use considerably shorter elements. The Yagi will also have a wider beamwidth, but its pattern will be in only one direction.

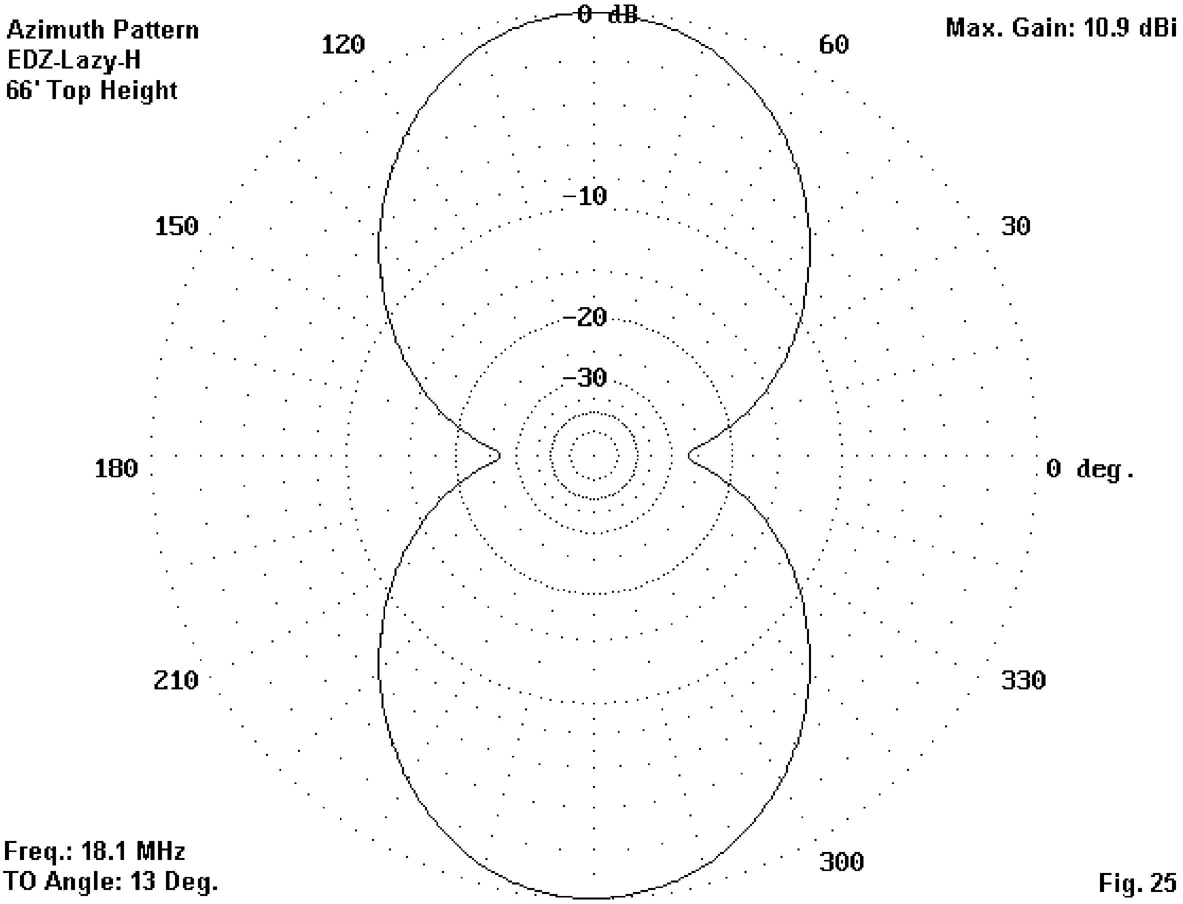


Fig. 25

As we decrease frequency, the beamwidth will become wider and the EDZ "ears" will diminish. Below 12 meters, we obtain only a 2-lobe pattern. **Fig. 25** shows the pattern for 17 meters, where it is now wide enough to provide broad coverage. However, the nulls of the ends of the wires are greater than 25 dB down from the main lobe, making the antenna highly directional.

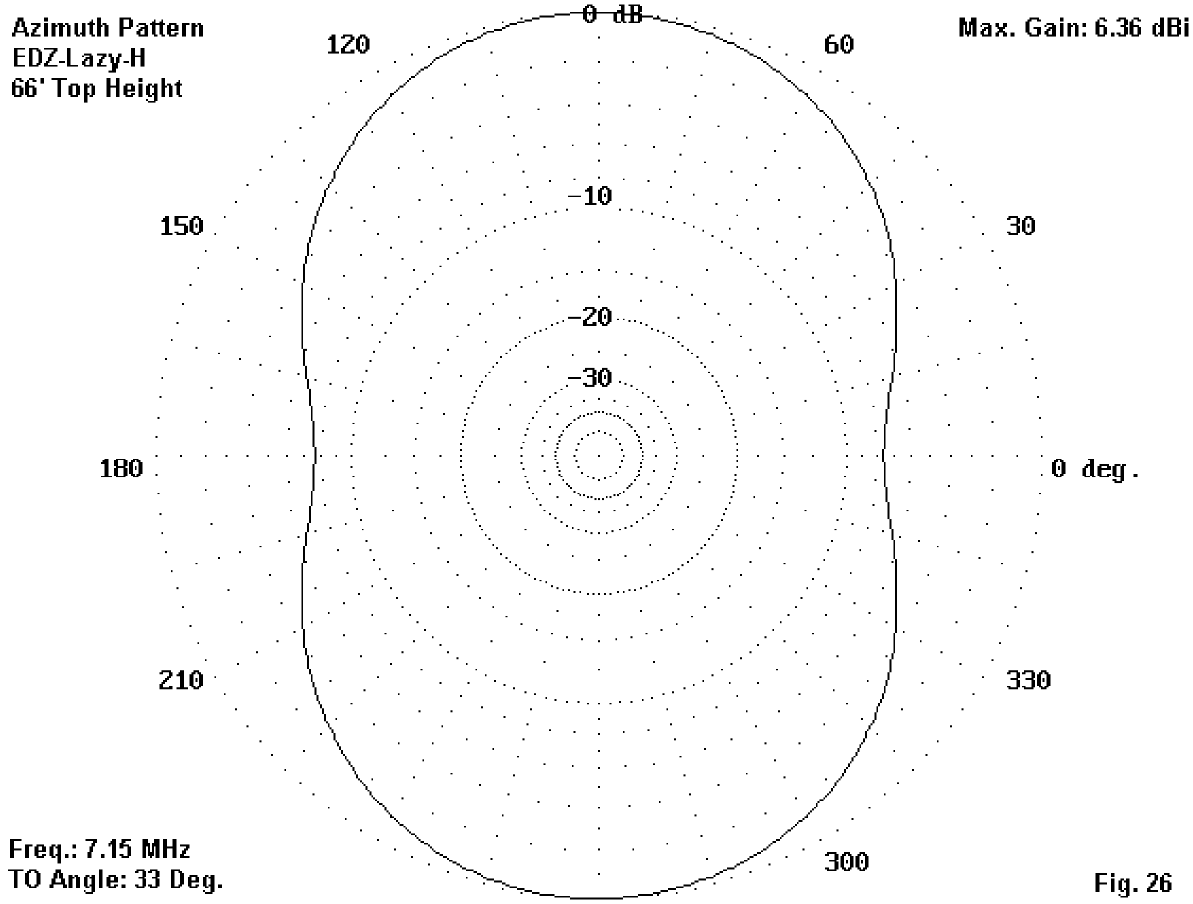


Fig. 26

On the lowest band of operation, 40 meters (**Fig. 26**), the pattern has become an oval, with just a trace of the peanut shape. As we earlier noted, the gain is less than that of the single 10-meter EDZ or the 67' doublet, but it is still high enough to provide excellent coverage.

One question that almost always emerges with respect to comparing the single wire and the array gain figures for 10 meters is this: how can the array have 4.5 dB gain over the single wire with just about the same horizontal beamwidth? The answer is straightforward if we think in 3 dimensions. Since we know that the horizontal patterns are very similar, we can compare elevation patterns for the EDZ and the expanded Lazy-H. **Fig. 27** tells the tale.

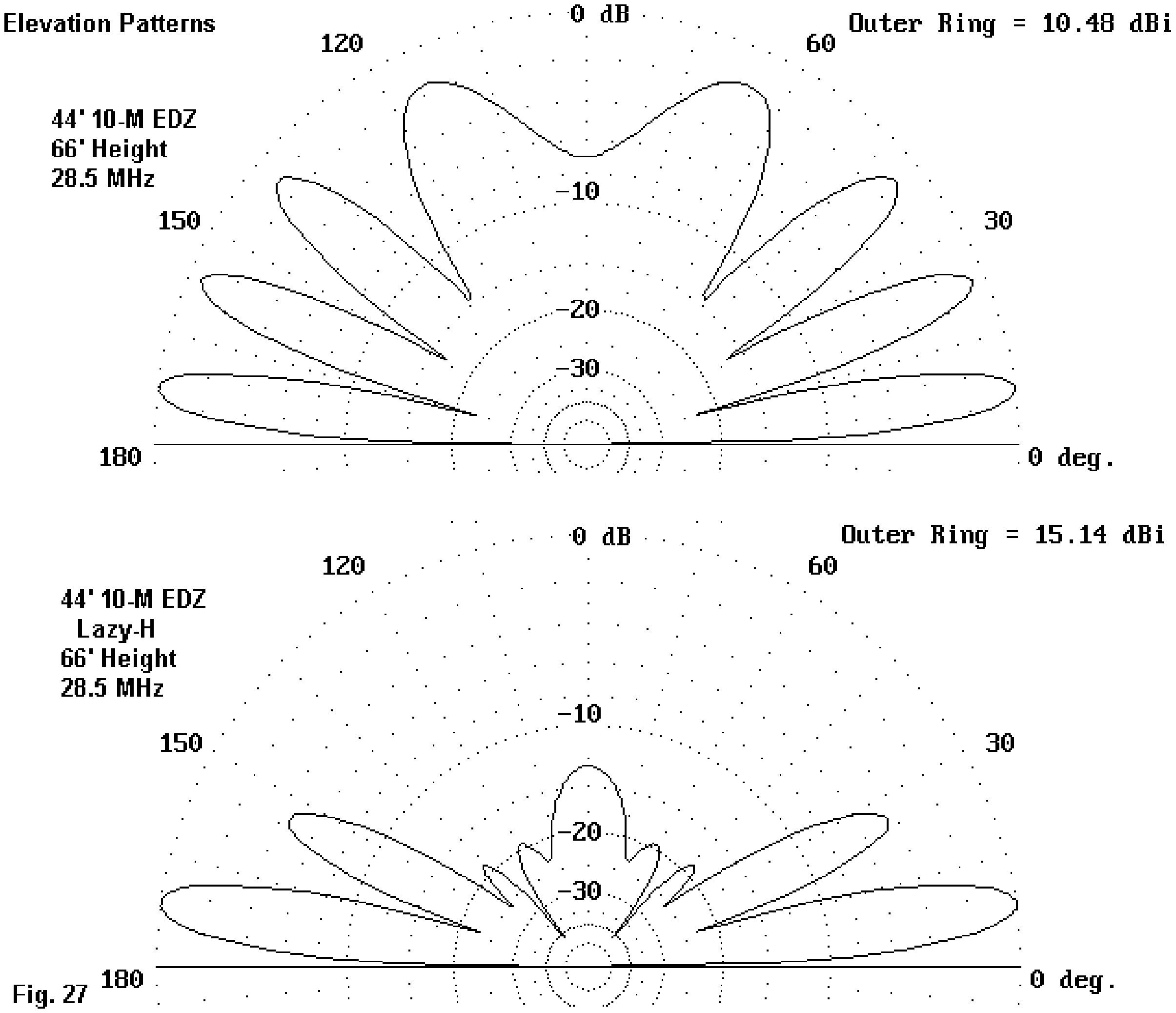


Fig. 27

Like any single-wire antenna, the EDZ at 66' on 10 meters shows a set of nearly equal-strength vertical lobes: 4 to be exact. In contrast, the upper lobes of the Expanded Lazy-H are suppressed, leaving a single dominant lobe and a secondary lobe well over 4 dB weaker. All other lobes are down by 12 dB or more. The array tends to waste far less power at very high angles of radiation compared to the single wire. This comparative pattern, with variations, tends to hold true down through 20 meters.

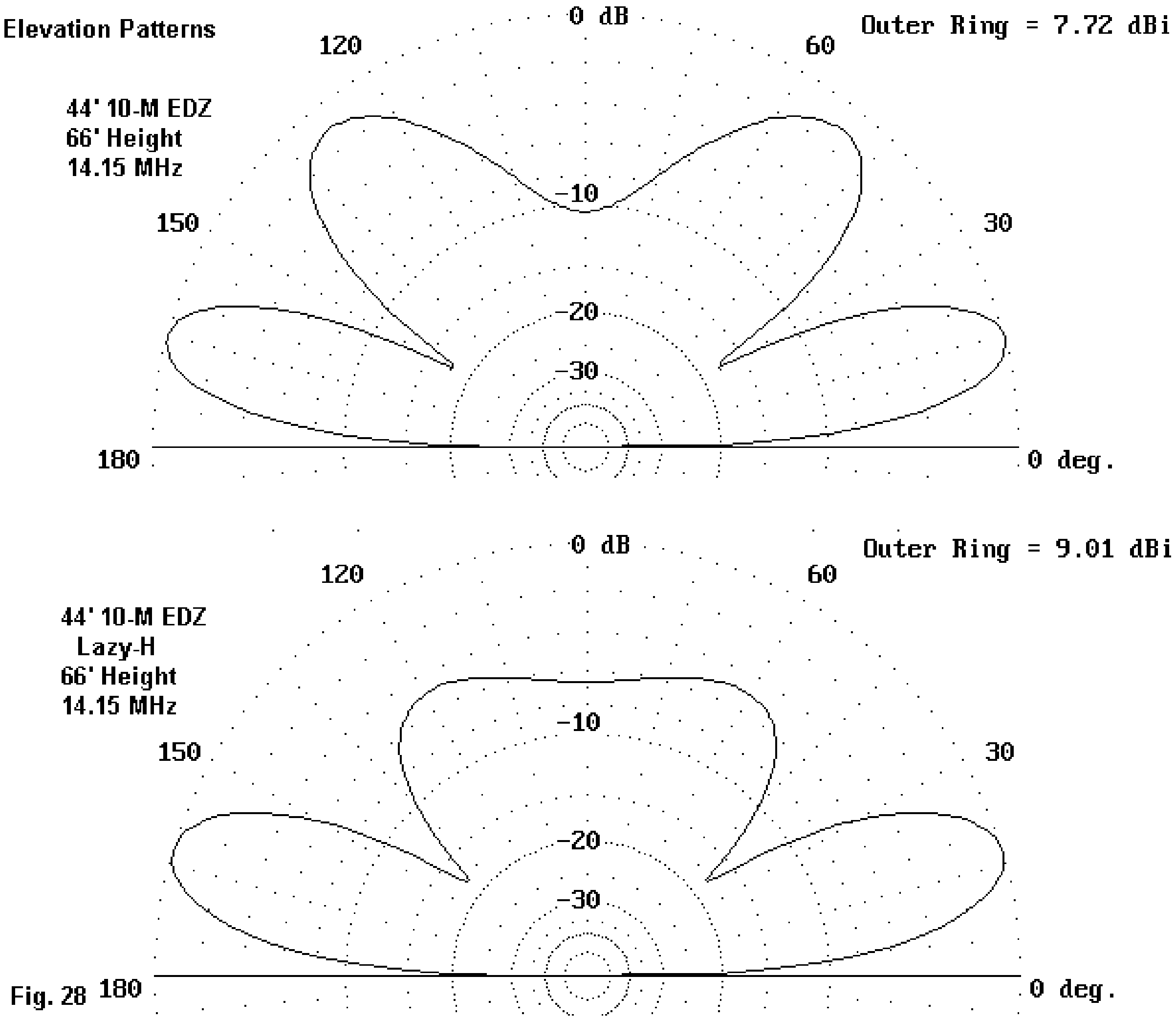
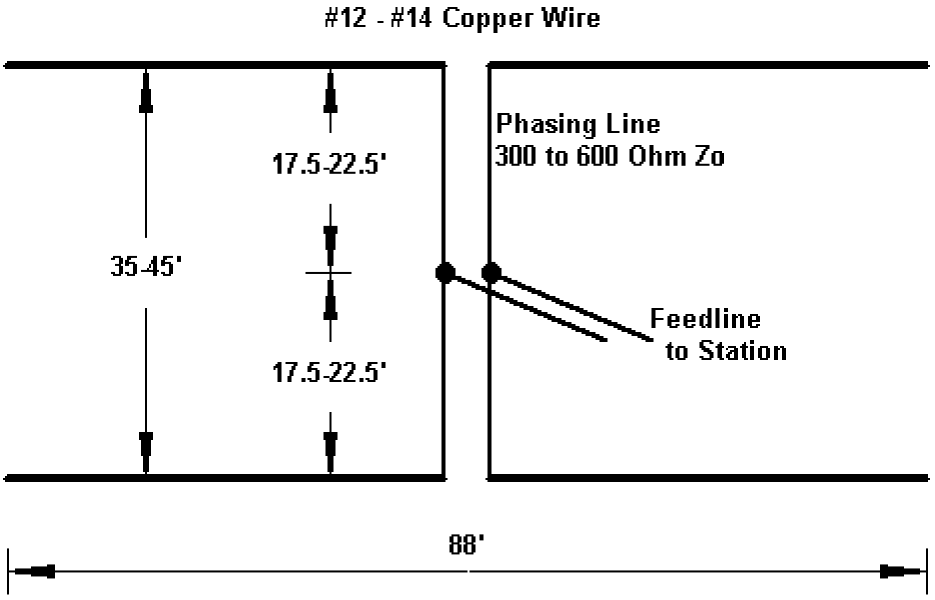


Fig. 28

On 20, the effect is less pronounced but still easily measured, as shown in **Fig. 28**. The area enclosed by the upper lobes of the single wire at the top of the figure is distinctly greater by a considerable margin than the area enclosed by the upper lobe (barely discernable as a double lobe) of the Lazy-H array. The difference in area (assuming that the azimuth patterns are comparable, as they happen to be in this case) is a rough measure of the added power appearing in the lower lobes. In this case, that additional power shows up not only in the maximum gain, but as well in the vertical beamwidth. The phased feeding of vertically stacked horizontal wires has benefits hard to match in a typical flat-top wire array.

Along side the benefits come some limitations. The Lazy-H requires a pair of tall supports and is suited to the antenna farm with more tall trees than money. The expanded Lazy-H is an outstanding bi-directional array for 10 meters in the design given here. Its performance holds up well down through 20 meters, and we can press it into service on lower bands. It takes up very little room horizontally in the yard, although a couple of optimally spaced tall trees certainly can aid the installation process. The wires for the elements and the phasing lines, as well as the feedline to the shack and the UV-resistant support ropes, are certainly inexpensive compared to the cost of a tower, rotator, coax, and commercial aluminum antenna.

Before we leave the Lazy-H, let's consider a few of its further potentials. For example, we might consider a pair of 88' doublets in a configuration for 80 through 20 meters.



Expanded 20-M Lazy-H

Fig. 29

Such an array as shown in **Fig. 29** deserves as much height as we can obtain. Let's look at performance figures for only 2 versions. The first will have a top wire at 80 feet, with the bottom wire at 35', for full 5/8-wl element spacing on 20 meters. The second version lowers the top wire to 70', which is near the top height we have been using. The lower wire remains at 35' for 1/2-wl on 20 meters. The comparison is instructive. In each case, direct 450-Ohm, 0.95 velocity-factor lines have been used for phase feeding the elements from a central point.

a. 35-80' (5/8-wl Spacing)

Freq. MHz	TO Ang	Gain dBi	Beamwidth degrees	Impedance R ± jX
3.6	66	5.8	130	9 -j 90
3.9	56	5.8	129	13 -j 55
7.15	28	7.9	78	310 -j 380
10.1	20	11.1	57	22 -j 35
14.15	15	13.7	32	61 +j 430

b. 35-70' (1/2-wl Spacing)

Freq. MHz	TO Ang	Gain dBi	Beamwidth degrees	Impedance R ± jX
3.6	80	6.0	135	10 -j 125
3.9	69	6.0	131	15 -j 85
7.15	32	7.2	81	585 -j 290
10.1	23	10.1	58	36 -j 120
14.15	16	13.6	33	23 +j 150

Even the smaller and lower of the two arrays has good potential on all of the bands covered. From 7 MHz upward, there is little to choose between the two versions of the larger expanded Lazy-H. On 80 and 75 meters (3.6 and 3.9 MHz), the lower version seemingly has a very high TO angle. However, if we choose an arbitrary elevation angle, such as 45 degrees, both arrays have gain in the 5.2 to 5.3 dBi region. This gain level is not bad, considering that the height of the upper wire is in the 1/4-wl region.

Whether we work with the single 44' or 88' doublet or with the expanded Lazy-H, we have obtained directional control of our antenna patterns. We also obtained gain on most bands and acceptable performance on all. If we cannot somehow manage a rotatable 88' Lazy-H array, we are faced with the question of directing our main lobes in all--or at least many--desired directions.

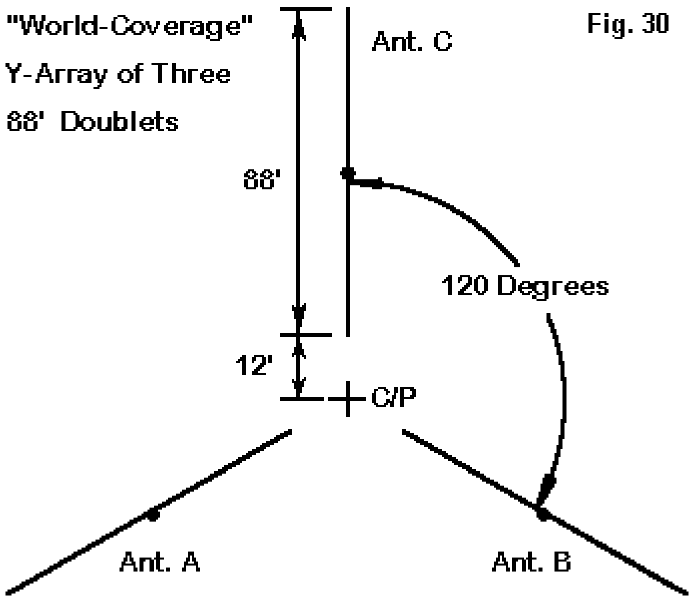


Fig. 30 shows one way to accomplish the desired goal. If we have the room and the supports--in short, if we live in a forest--we can set three Lazy-H arrays in a Y pattern. The sketch shows the larger version, but you can always directly scale the dimensions for the smaller 40-10 meter version.

With a 12' gap from the antenna wire ends to the array center-point, there is virtually no interaction among the wires. A 6' gap would do for the version using 44' doublets. Within plus or minus 10-15 degrees, any of the individual Lazy-Hs can be moved from perfect symmetry in order to better align it with desired communications targets.

Besides the space required for 3 Lazy-H arrays, the one drawback to the Y-array is the need for 4 supports. One might get away with only 3 supports if one is knowledgeable about rope-based trussing systems. However, there is an alternative to the Y.

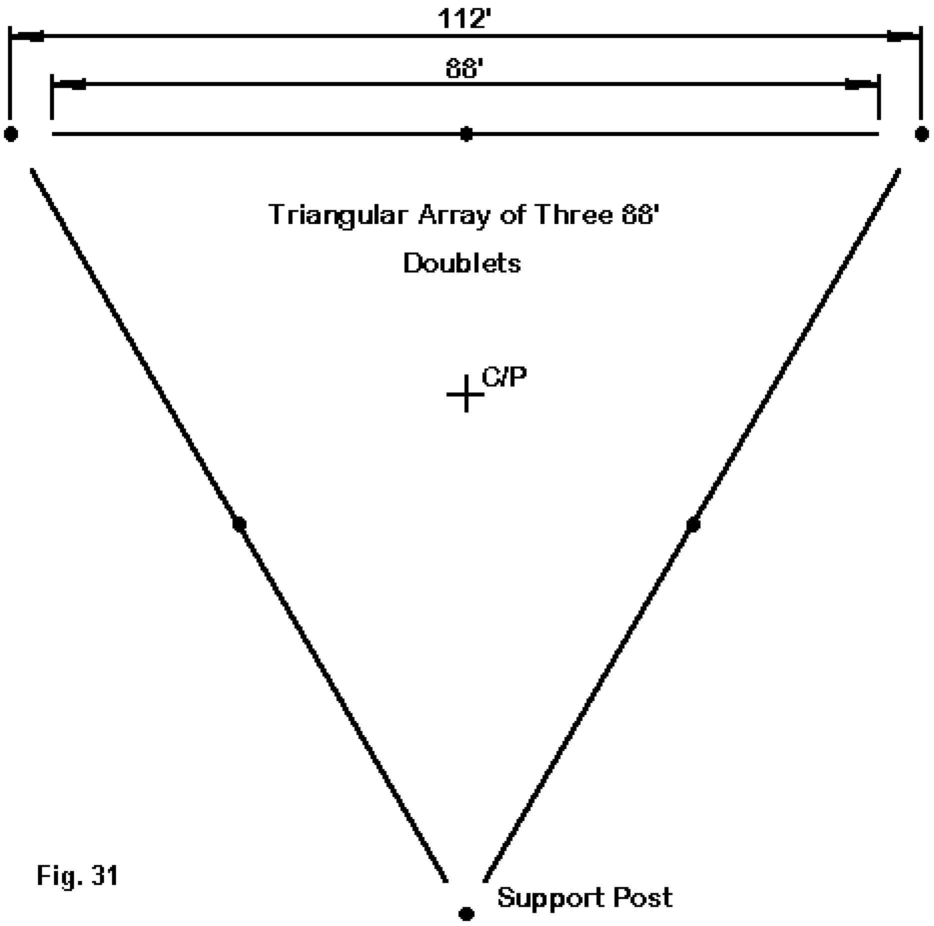


Fig. 31

A standard triangle (**Fig. 31**) offers a more compact arrangement of the antennas and needs only three supports--just one more than a single Lazy-H would require. Once more, scale the space down for the smaller array. As with the Y, variations in the exact angles of each array will not be noticed except in the better aim we obtain for each Lazy-H relative to our communications targets.

The two arrays of arrays are often the cheapest ways to obtain world-wide coverage with minimal gaps. The lower the frequency within each range, the fewer the gaps in coverage for the 6 possible main lobes.

The triangular arrangement does not offer the nearly perfect absence of interaction among the arrays. The worst case pattern distortion amounts to under 5 degrees along the horizon, whether the unused antennas are open or shorted at their feedpoints. Hence, for all practical purposes, interaction among the arrays can be ignored.

Controlling the arrays requires a remote switching box unless we wish to bring three sets of feedlines into the shack. A weatherproof box with a series of relays capable of handling high voltages and currents in their contacts can be placed in the center of the arrangement, with a single feedline back to the shack.

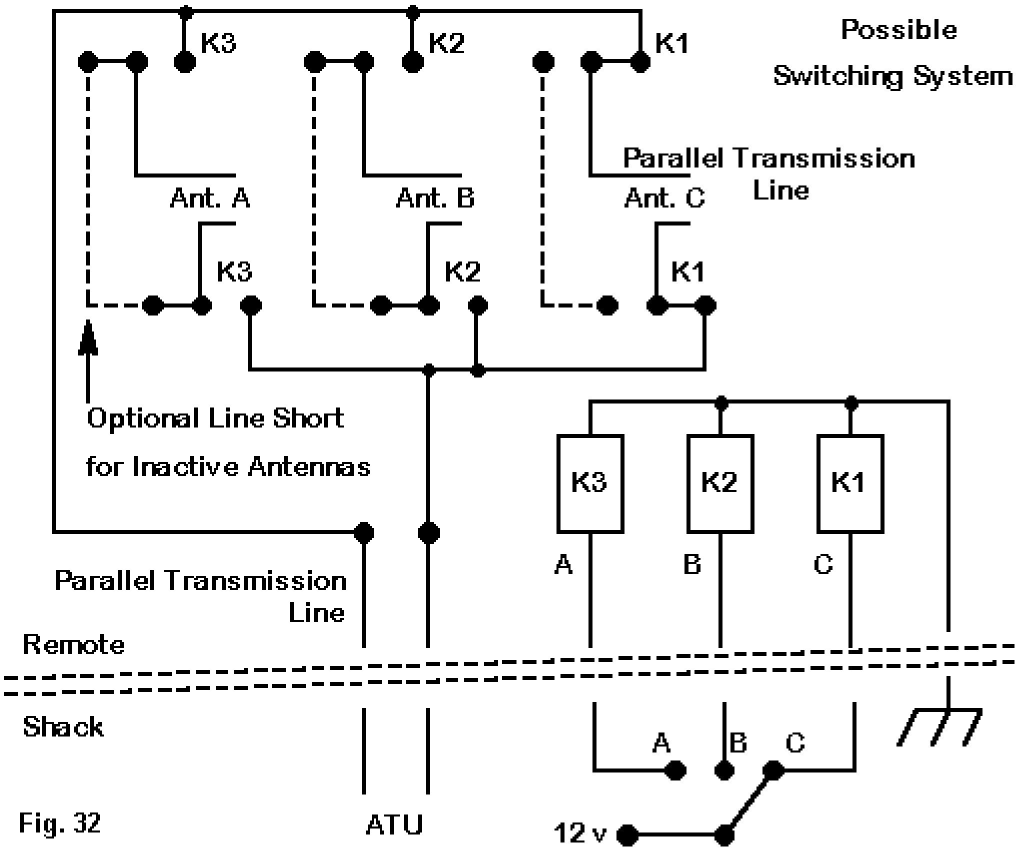


Fig. 32

Fig. 32 shows one possible switching system for remotely controlling which antenna is active. The in-shack controller can use almost any indicator system the user might imagine. Therefore, I shall leave further refinements to the reader's sketch pad.

Conclusion

In our quest for the perfect VOMBA, we have covered a large territory, ranging from simple doublets to arrays of arrays. We began with the popular 1-wl loops, vertically oriented. These turned out to be far from the best we might do for a vertically oriented multi-band antenna. We looked at simple 67' doublets and hybrid triangles. When we added pattern direction control to our list of desires, we ended up with the 10-meter EDZ and the derivative expanded Lazy-H. Then we dared to dream much bigger dreams.

If my goals were 40 to 10 meters with all patterns broadside to my antenna wire, and if I could have but one wire, I would likely choose the 44' doublet and get it as high as I could manage. If I could manage 60 to 70 feet of height, I would add the second wire and make an expanded Lazy-H. If I could use a square that was 50 by 50 feet or so, I would erect 3 expanded Lazy-H arrays in a triangle. If I has another square that was a little over 100 by 100 feet, I might erect a second low-band set of Lazy-H arrays. All this planning, of course, assumes that I already have the supports or that I have the patience to watch my newly planted Douglas firs grow.

If I have only one tall support, then I would likely opt for some form of delta. However, I would not stop planning for a second tall support and the day I could replace the delta with a Lazy-H.

Every antenna decision, however, is a compromise between the antenna types that perform best and the kind and size of space we have to erect them. Consequently, my concluding statement of my own "druthers" is likely to be highly modified by whatever places I may live in the future. And your evaluation of the potentials of the VOMBAs we have examined must be moderated and modified by the realities of your own unique circumstances.

However, in your quest for a vertically oriented multi-band antenna, it pays to look beyond whatever may be a current fad in wire antennas. Some of the "older models," like the Lazy-H, may have more to offer than first meets the eye. In addition, do not be put off by that fact that we call antennas like the Lazy-H a "phased" array. If you can cut two pieces of parallel transmission line to the same length--and long enough to meet in the middle of the array--then you can successfully build something like a Lazy-H.

In addition, while you resign yourself to present circumstances that force you to build small, continue to dream big. You never know when you might be transferred to a big forest where you can support an array of Lazy-Hs for 160 meters.