

Corner Reflectors Revisited Again



Part 2: A Non-Systematic Look at Some Corner Variations

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In Part 1 of this return visit to the corner reflector, we examined a series of 72 reflectors, all modeled as wire grids using 0.1-m (wavelength) segments of 0.0159-m (wavelength) radius wire. In the discussion of planar reflectors, we had established that this method of forming a model of a closely spaced screen or a solid surface is quite accurate, at least, relative to assemblies using wires on a grid that is up to 4 times more dense.

The series of reflectors used vertical dimensions along the apex and the sides forming the aperture from 1.0 to 2.0 m (wavelengths). 1 m = 1 wavelength, because the test frequency is 299.7925 MHz. Each side length ranged from 0.5 m to 1.6 m long. Each successive model varied either the vertical dimension by 0.2 m or the horizontal side length by 0.1 m (for a total increase of 0.2 m in the overall sum of the two sides). For each of the 72 reflectors forming the matrix of sizes, the driver was a simple dipole using a 0.008-m diameter. Its length and position provides a very close 50-Ohm resonant match at the feedpoint.

On the basis of the detailed survey, we reached the following conclusions.

1. For the range of horizontal side lengths studied, a dipole-driven corner reflector reaches maximum gain with a vertical dimension between 1.4 wavelengths and 1.6 wavelengths, with the likely precise vertical size growing as the horizontal side length grows.
2. The maximum gain obtainable from a corner reflector shows continuous growth from horizontal side lengths of 0.5 wavelength through 1.6 wavelengths. However, there appear to be variations or undulations in the rate of growth with linear increases in the side length.
3. The worst case front-to-back ratio shows generally increasing values with the overall size of the reflector surfaces. The maximum value of 180-degree front-to-back ratio shows at least two distinct peaks across the span of side lengths used in the survey, although those peaks show differences in the peak value and in the side length of occurrence relative to the vertical dimension.
4. E-plane beamwidth shows only small and steady decreases with increases side length, with minimum values occurring at of near reflector size yielding maximum gain for a given side length. H-plane beamwidth is almost completely a function of the horizontal side length and shows a steady decrease with increasing side-length increases.
5. Operationally, a 50-Ohm 8-mm diameter dipole driver shows a 9.0% 2:1 SWR bandwidth. Reflector size makes virtually no difference to the SWR curve. Feedpoint behavior is operationally stable, but shows some interesting minor undulations.

There remain a number of outstanding questions, which we may divide into two groups. First are questions concerning performance using a dipole driver. Because the spacing of the driver from the sides of the reflector plays a role in the array performance, we are limited with the corner reflector in selecting drivers. We do not have the freedom that was possible with the simple flat planar reflector to choose any driver that might fit forward of the reflector surface. Nevertheless, we have a number of options, including fatter dipoles, folded dipoles, and fan dipoles that might either improve the forward gain or increase the SWR bandwidth of the array from its 9% value using the 8-mm dipole.

A second set of questions surround the reflector itself and rest on the fact that in our survey, even 1.6-m sides did not register the highest gain feasible from the corner reflector composed of tight screens or solid surfaces. So we are left with the question of whether there is in fact a corner reflector size beyond which the gain decreases.

It is not possible to perform a complete survey of all of the objects of study before us. Therefore, we shall be somewhat selective on the premise that, just as the driver showed regular progressions of values as we changed reflector sizes, any replacement drivers will show similar progressions. We shall shortly show the reason why we have adopted the premise. A reflector size that is 1.4-m vertical with 0.8-m side lengths will form our main test vehicle, although we shall employ other sizes from time to time. Using the same reflector will permit judicious comparisons among a number of the driver candidates without bogging us down in an excess of data that does not directly contribute to the comparison.

The following lines form the Green's file model for the main reflector in this part of the study.

CM Basic Corner Reflector: 299.7925 MHz; 1 m = 1 wl
CM T1 = center line, T2, T3 = verticals + GM
CM T4, T5 = horizontal centers + GM
CM Density = 0.1 m x 0.1 m
CM Size = 1.4 m x 1.6 m, File = C-Vn-Hn.WGF

```

CE
GW 1 14 0 0 -.7 0 0 .7 .0159
GW 2 14 0 -.1 -.7 0 -.1 .7 .0159
GM 0 7 0 0 0 0 -.1 0 2 1 2 14
GW 3 8 0 0 0 0 -.8 0 .0159
GM 0 7 0 0 0 0 0 -.1 3 1 3 8
GM 0 7 0 0 0 0 0 .1 3 1 3 8
GM 0 0 0 0 45 0 0 0 2 1 0 0
GW 4 14 0 .1 -.7 0 .1 .7 .0159
GM 0 7 0 0 0 0 .1 0 4 1 4 14
GW 5 8 0 0 0 0 .8 0 .0159
GM 0 7 0 0 0 0 0 -.1 5 1 5 8
GM 0 7 0 0 0 0 0 .1 5 1 5 8
GM 0 0 0 0 -45 0 0 0 4 1 0 0
GE 0 -1 0
FR 0 1 0 0 299.7925 1
GN -1
WG c-v14-h08.WGF
EN

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By appropriate number replacements, you may create any size reflector without lengthening the file itself. However, the stored WGF file will vary in size according to the total number of segments in the reflector wire grid.

Increasing the Bandwidth

A corner reflector does not change its gain and front-to-back characteristics very rapidly as one moves away from the design frequency. For a simple dipole driver, such as the 8-mm diameter dipole used in Part 1 of our work, the performance passband outstrips the SWR bandwidth by a wide margin. Therefore, we shall initially look at some suggested ways of expanding the SWR passband, keeping an eye out for performance changes along the way. I shall resonate each candidate driver at either 50 Ohms or at an impedance suited to the use of that driver. (There will be an exception to this rule along the way.)

1. Fatter Dipoles

The most immediate apparent solution to increasing the SWR bandwidth of a corner reflector is to employ fatter dipoles. To investigate this option, I selected our initial 8-mm dipole plus 12-mm and 16-mm dipoles as comparators. The 2:1 diameter ratio between the smallest and the largest in the group should provide an indication of using this route as a means to expanding the operating bandwidth while remaining well within the limitations of NEC-4 regarding the segment length vs. the wire radius.

The basic model for any dipole-driven corner reflector--using the Green's files generated by reflector models--has the following form.

```

CM Dipole 50-Ohm
CE
GF 0 c-v14-h08.WGF
GW 101 11 .324 0 -.212 .324 0 .212 .004
GE 0 -1 0
EX 0 101 6 0 1 0
RP 0 361 1 1000 -90 0 1.00000 1.00000
RP 0 1 361 1000 90 0 1.00000 1.00000
EN

```

The GW line will be the only difference among the dipoles. In fact, we may isolate the GW lines for the three drivers under comparison.

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GW 101 11 .324 0 -.212 .324 0 .212 .004   8-mm driver
GW 101 11 .326 0 -.2075 .326 0 .2075 .006   12-mm driver
GW 101 11 .328 0 -.2035 .328 0 .2035 .008   16-mm driver

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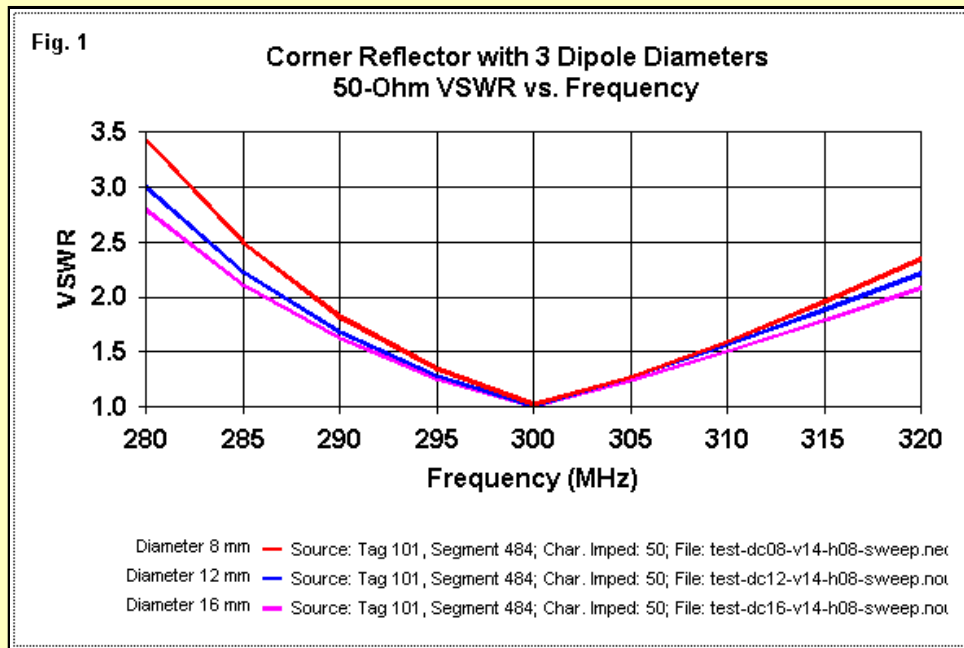
To obtain a resonant 50-Ohm feedpoint required a slightly different spacing from the reflector apex and a slightly different dipole length. The length, which shrinks from 0.424 m down to 0.407 m, is a function mostly of the increasing element diameter. However, since the element surface comes closer to the reflector surface as we increase the diameter, we have also to compensate for the change in mutual coupling. Increasing the spacing allows us to restore the 50-Ohm impedance, but that spacing change also affects the dipole length. In the end, a resonant driver requires a balance between the effects of coupling and of element length. The total spacing change was 4 mm for a radius change of 4 mm. The closest approach of the dipole surface to the reflector plane remains virtually unchanged.

To determine whether I needed to survey the alternative drivers over the entire set of reflectors, I initially chose two reflectors of very different sizes as test cases. One reflector is the version already noted, with a 1.4-m vertical dimension and 0.8-m side lengths. The second test reflector used a 1.6-m vertical dimension with 1.6-m side lengths--twice as long. The similarity in the vertical dimension stems from the fact that both reflector sizes represent the peak gain performance

for the selected side lengths, as derived from the survey in Part 1. For the three drivers, the two reflectors yielded the following performance figures. In the table, E-BW is the E-plane -3 dB beamwidth, and H-BW is the corresponding value for the H-plane. Gain values are for free space, and the front-to-back value is for 180-degrees.

Reflector Size	Dipole Dia. mm	Gain dBi	Front-to-Back Ratio dB	E-BW degrees	H-BW degrees	Impedance R +/- jX Ohms	50-Ohm SWR
V14-H08	8-mm	11.42	38.27	46	54	49.63 - j1.56	1.03
	12-mm	11.42	38.24	46	54	49.90 - j0.20	1.00
	16-mm	11.41	38.19	46	54	49.96 - j0.47	1.01
V16-H16	8-mm	13.38	37.35	40	34	48.82 - j1.69	1.04
	12-mm	13.37	37.51	40	34	50.08 + j0.37	1.01
	16-mm	13.37	37.47	40	34	50.14 + j0.09	1.00

Since there is no change in performance at the extremes of reflector sizes, we may let a single reflector size stand in for all sizes with respect to the SWR bandwidth. As shown in Part 1, reflector size makes virtually no difference to the SWR performance of the corner reflector design.

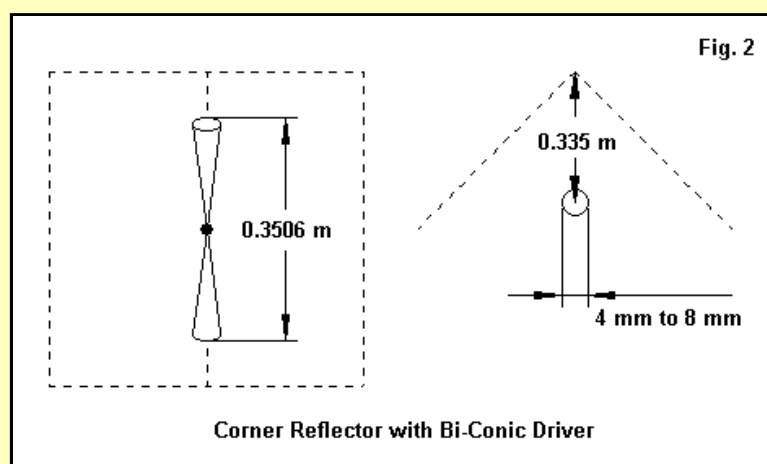


As Fig. 1 shows, we obtain the expected increase in SWR bandwidth as we increase the dipole diameter. However, the rate of increase is not very great. Whereas the 8-mm dipole has a 9.0% bandwidth between 2:1 SWR points, the 12-mm dipole shows an increase of only 1% and the 16-mm dipole has an increase of 1.7% over the initial size. Between the thinnest and fattest dipoles, we obtain only a 5-MHz increase in the passband.

The end result of the modeling experiment is simple: a fat dipole is beneficial, but does not achieve the desired goal of a significant widening of the SWR bandwidth.

2. The Bi-Conic Dipole

An alternative to the fat dipole is the bi-conic dipole. Fig. 2 suggests its shape and relationship to our primary reflector.



The bi-conic (or biconical) dipole is one that tapers from a thin center to a thicker pair of outer ends. For our test, segment-length vs. wire-radius limitations allowed only a relatively simple sample of this dipole type, with the center section at 8-

mm diameter and the outer ends at 16-mm diameter. The following lines show the model used, along with the GC entries used to effect the taper.

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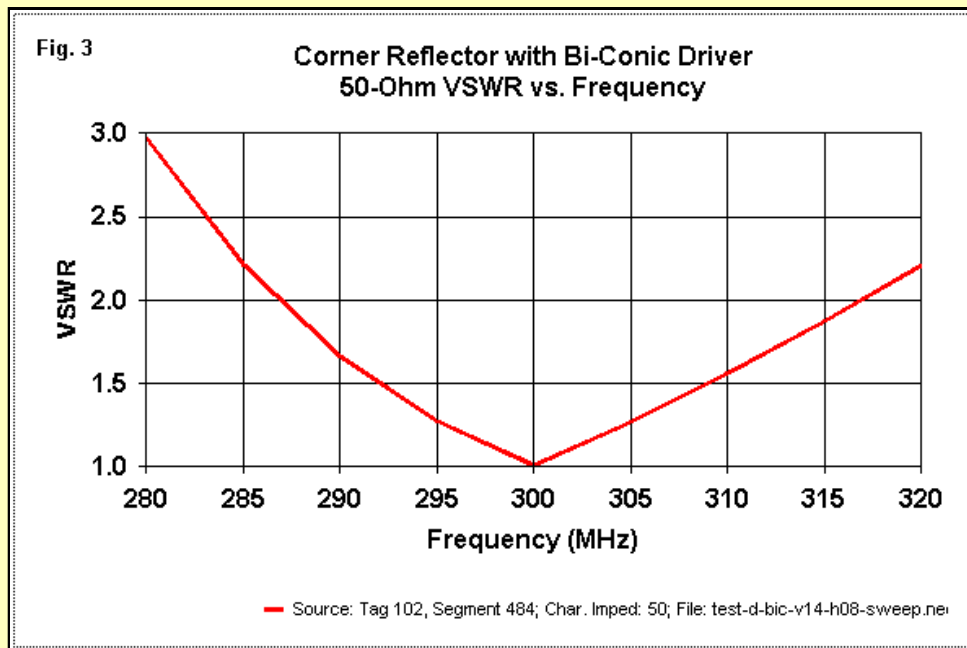
CM bi-conic dipole
CE
GF 0 c-v14-h08.WGF
GW 101 5 .335 0 -.1753 .335 0 -.02 0
GC 0 0 1 .016 .004
GW 102 1 .335 0 -.02 .335 0 .02 .004
GW 103 5 .335 0 .02 .335 0 .1753 0
GC 0 0 1 .004 .016
GE 0 -1 0
EX 0 102 1 0 1 0
RP 0 361 1 1000 -90 0 1.00000 1.00000
RP 0 1 361 1000 90 0 1.00000 1.00000
EN

```

The geometry continuation entries allow for a uniform increase in diameter as we move from one segment to the next working from the center outward. The result is a dipole that is 0.3056-m long, about 25% shorter than the uniform-diameter dipoles. A bi-conic dipole has a significantly lower feedpoint impedance than a uniform-diameter dipole and hence requires more spacing from the reflector apex to achieve a 50-Ohm feedpoint impedance. The following simple table compares the performance of our original model and the new driver.

Reflector Size	Dipole Dia.	Gain dBi	Front-to-Back Ratio dB	E-BW degrees	H-BW degrees	Impedance R +/- jX Ohms	50-Ohm SWR
V14-H08	8-mm uniform	11.42	38.27	46	54	49.63 - j1.56	1.03
	8-16-mm bi-conic	11.04	38.00	46	54	50.07 - j0.13	1.00

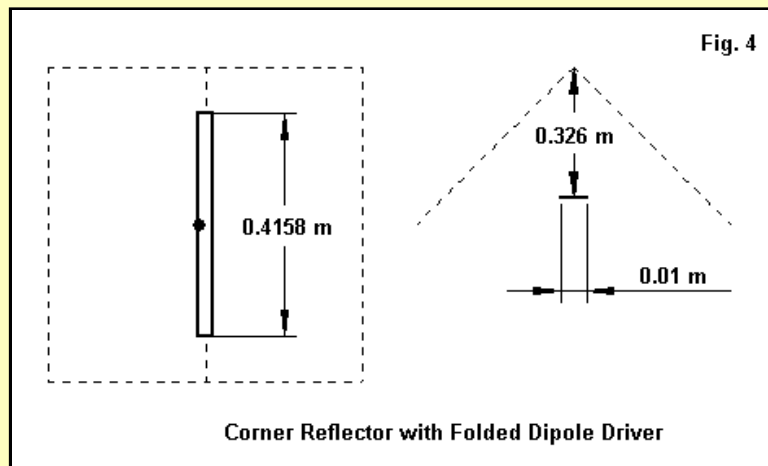
The very slightly reduced gain performance is a mutual function of the shorter overall length of the dipole and the increased spacing from the reflector apex. Otherwise, there is nothing to distinguish the two drivers.



Unfortunately, neither is there any significant difference between the SWR performances of the original dipole and the new bi-conic driver, as illustrated by the SWR curve in **Fig. 3**. The bi-conic driver has an SWR passband of 10.0%, about the same as for the 12-mm uniform-diameter driver. We must look elsewhere for a means to increase the corner reflector SWR bandwidth.

3. The Folded Dipole

A third candidate for increasing the SWR bandwidth is the folded dipole. Essentially, a folded dipole--in addition to its impedance transformation function--also acts like a piece of fat wire. **Fig. 4** shows our test set-up.



The dimensions of the folded dipole in the test are themselves interesting. The spacing between the two wires--each reduced to a 4-mm diameter--is 0.01 m, close to the value of the 12-mm uniform-diameter dipole. The spacing from the reflector apex--0.326 m--is the same value used with the 12-mm dipole. However, since the folded dipole effects a 4:1 impedance transformation, the reference standard will be 200 Ohms instead of 50 Ohms. The folded dipole length is 0.4158 m, only about 0.4 mm longer than the 12-mm dipole. The following lines show the model of the driver, ready for use with the standard reflector file.

CM Folded Dipole

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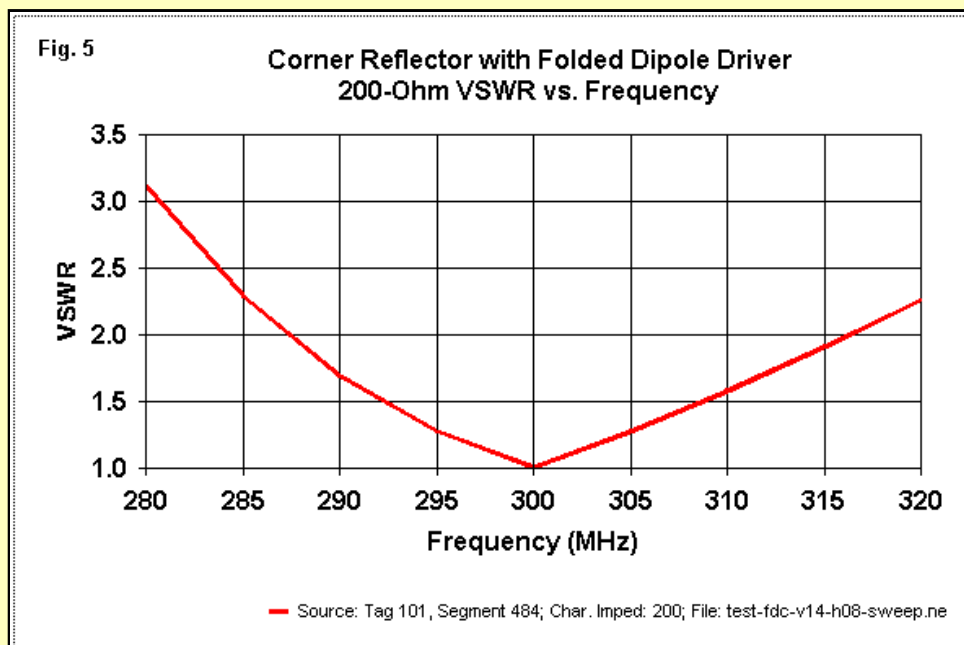
CE
GF 0 c-v14-h08.WGF
GW 101 11 .326 0 -.2079 .326 0 .2079 .002
GW 101 1 .326 0 .2079 .326 .01 .2079 .002
GW 101 11 .326 .01 .2079 .326 .01 -.2079 .002
GW 101 1 .326 .01 -.2079 .326 0 -.2079 .002
GE 0 -1 0
EX 0 101 6 0 1 0
RP 0 361 1 1000 -90 0 1.00000 1.00000
RP 0 1 361 1000 90 0 1.00000 1.00000
EN

```

The performance of the folded dipole does not vary the uniform-diameter dipole, as evidenced by the following simple table.

Reflector Size	Dipole Dia.	Gain dBi	Front-to-Back Ratio dB	E-BW degrees	H-BW degrees	Impedance R +/- jX Ohms	SWR
V14-H08	8-mm uniform	11.42	38.27	46	54	49.63 - j1.56	1.03 (50 Ohms)
	folded dipole	11.41	38.27	46	54	199.79 - j0.21	1.00 (200 Ohms)

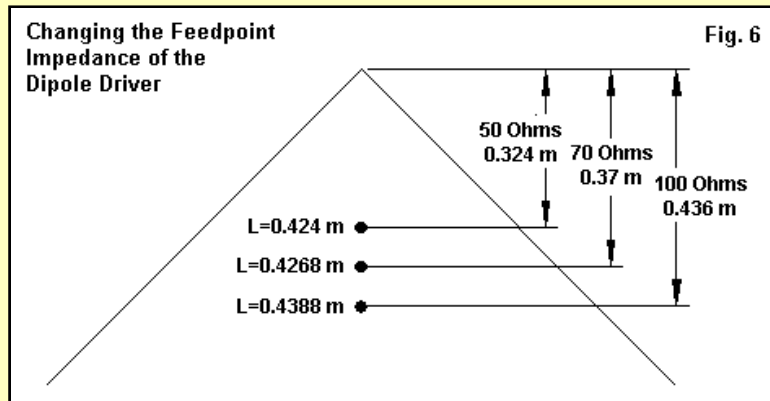
As a result of these comparisons, we should already suspect that the folded dipole will yield an SWR passband no smaller than for the 8-mm dipole and no larger than for the 12-mm dipole. In fact, as shown in Fig. 5, the SWR passband (at 200 Ohms) is exactly between the values for the two normal dipoles: 9.5%.



I chose the 200-Ohm impedance for its compatibility with the 50-Ohm drivers that we have so far surveyed, and because a simple 4:1 transformer would permit a match to standard coaxial cable. By increasing the spacing from the reflector apex and with minor adjustments to the overall folded-dipole length, one may adjust the impedance to 300 Ohms with little fall-off in performance. Since the increased impedance will be only about 1.5 times the impedance used for our test, the increase in the passband will be small. Nevertheless, the possibility does put us in touch with another strategy sometimes used to increase the SWR passband.

4. Changing the Dipole Feedpoint Impedance

Although we have been focusing on 50-Ohm drivers for our corner reflectors, we should not forget that we have considerable control over the feedpoint impedance of a corner reflector driver simply by changing its distance from the reflector apex and then adjusting the dipole length to resonance. As an experiment, I took our original 8-mm dipole and moved it to positions that yielded 70 Ohms and then 100 Ohms as the resonant feedpoint positions. **Fig. 6** sketches the relative positions of the dipole for the 3 cases, along with the values for spacing and length.



As we increase the distance from the reflector apex, we must lengthen the dipole to compensate for the reduced mutual coupling between the dipole and the reflector. The total increase in spacing for a 2:1 change in impedance is over 10 cm, which is informative in another direction. At the 300-MHz test frequency, the amount of movement of the dipole to arrive at the desired feedpoint impedance is well within the range of careful manual adjustment. In short, the corner reflector--while requiring careful handling--is not so finicky as to defy effective field adjustment.

The following lines simply present the individual GW lines of the models used for each test and replicate the data in **Fig. 6** within modeling form.

50-Ohm Dipole

GW 101 11 .324 0 -.212 .324 0 .212 .004

70-Ohm Dipole

GW 101 11 .37 0 -.2134 .37 0 .2134 .004

100-Ohm Dipole

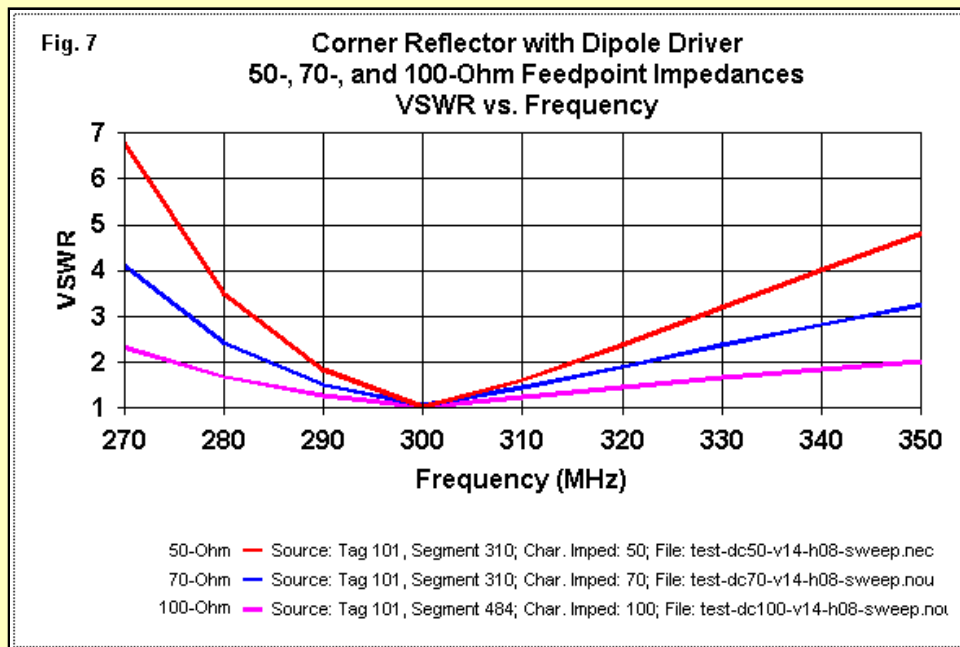
GW 101 11 .436 0 -.2194 .436 0 .2194 .004

The following table provides a performance comparison among the three drivers at the test frequency.

Reflector Size	Dipole Dia.	Gain dBi	Front-to-Back Ratio dB	E-BW degrees	H-BW degrees	Impedance R +/- jX Ohms	SWR
V14-H08	8-mm--50-Ohm	11.42	38.27	46	54	49.63 - j1.56	1.03 (50 Ohms)
	8-mm--70 Ohm	11.37	37.86	46	54	70.04 - j0.19	1.00 (70 Ohms)
	8-mm--100 Ohm	11.28	36.08	46	54	100.15 - j0.17	1.00 (100 Ohms)

As we move the driver away from the reflector apex, we see both a rise in the feedpoint impedance and a small drop in performance. However, within the boundaries of this test, the performance decrease would not be within the range of operational detection. Nonetheless, the decline does suggest that there is a limit to the progression before performance reaches the point of being unacceptable (as defined by design goals and alternative designs).

If we are willing to accept the small decrease in performance and the "trouble" of working with a 100-Ohm feedpoint impedance, we may be in for a pleasant surprise when it comes to the array's SWR passband. See **Fig. 7**.

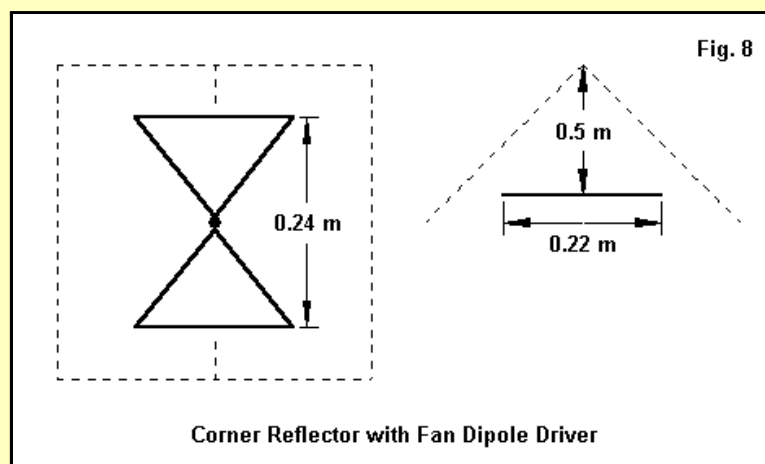


As we have noted in several places, the 8-mm dipole yields a 9% SWR passband when set for a 50-Ohm feedpoint impedance. If we are willing to work with 70-Ohm cables--such as surplus television cables and hardlines--we can increase the SWR passband by 40% to a total value of 12.7%. If a 100-Ohm impedance is not troublesome, the passband expands to 25%, that is, a 2:1 100-Ohm SWR that extends from about 275 to 350 MHz. Such a passband is sufficient to cover the entire FM broadcast band (about 20%, using the usual 88-108-MHz markers).

For many designers, 100 Ohms presents problems of losses within matching networks. Hence, there remains a quandary: can we obtain a similar SWR bandwidth and still have a 50-Ohm feedpoint impedance?

5. The Fan Dipole

In fact, there is a technique for obtaining both a 50-Ohm feedpoint impedance and a wide SWR bandwidth, and it has been around for perhaps a half-century. One may use a "bow-tie" or fan dipole in place of the dipoles that we have been exploring. A fan dipole can consist of a solid surface or a simple outline. In past commercial practice, planar fan dipoles have been widely used, some with part folded forward. For the purposes of modeling, a simple outline fan is the one to use, since we may construct it from 8-mm wire. The fat wire provides the closest approach to a solid surface, but does not completely simulate it. **Fig. 8** shows the general outlines and the dimensions.



The Fan is 0.24 m wide overall, with a maximum width of 0.22 m. Independent fan dipoles have their widest bandwidth when the main frame sections are at or near a 45-degree angle, and this fan approaches that goal. However, such a fan dipole has a low impedance (in the 20-25-Ohm range). As a consequence, it is necessary to space the fan considerably farther from the reflector apex than the uniform-diameter dipoles. A spacing of 0.5 m proved necessary to achieve a 50-Ohm impedance at the test frequency. The following lines show the model for this driver system. The center section (GW 102) is 0.03 m long so that its wire length is approximately equal to the length of the segments in the sloping wires.

CM Fan dipole

CE

GF 0 c-v14-h08.WGF

GW 101 5 .5 .11 -.12 .5 0 -.015 .004

GW 101 5 .5 -.11 -.12 .5 0 -.015 .004

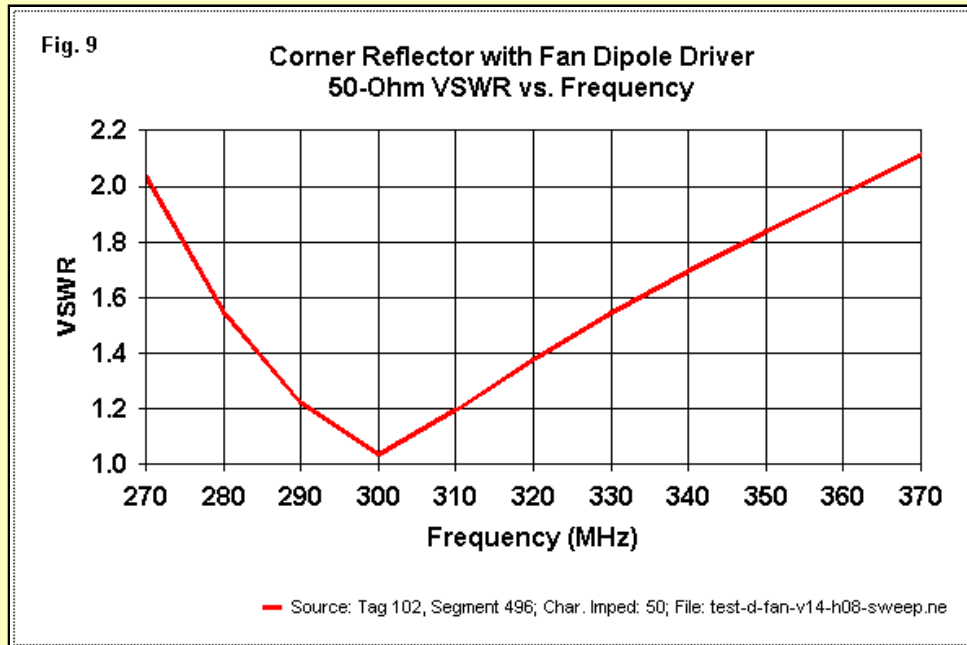
GW 101 7 .5 .11 -.12 .5 -.11 -.12 .004

GW 102 1 .5 0 -.015 .5 0 .015 .004
 GW 103 5 .5 0 .015 .5 .11 .12 .004
 GW 103 5 .5 0 .015 .5 -.11 .12 .004
 GW 103 7 .5 .11 .12 .5 -.11 .12 .004
 GE 0 -1 0
 EX 0 102 1 0 1 0
 RP 0 361 1 1000 -90 0 1.00000 1.00000
 RP 0 1 361 1000 90 0 1.00000 1.00000
 EN

The following table compares the performance of the fan dipole driver with the initial 8-mm driver at the test frequency.

Reflector Size	Dipole Dia.	Gain dBi	Front-to-Back Ratio dB	E-BW degrees	H-BW degrees	Impedance R +/- jX Ohms	50-Ohm SWR
V14-H08	8-mm uniform	11.42	38.27	46	54	49.63 - j1.56	1.03
	fan dipole	11.16	32.32	48	52	51.47 - j0.78	1.03

Performance is down a bit for two reasons. First, the dipole is only a little over half as long as the 8-mm dipole (0.24 m vs. 0.424 m). As well, the element actually terminates at the center of the horizontal end pieces. Hence, part of the current--although only a small part--is at 90 degrees to the general E-plane of the antenna. The second reason for a small decline in performance is the increased distance between the driver and the reflector apex. The fan dipole is even further from the reflector apex than the 100-Ohm dipole that we just surveyed. Although the decline is not especially significant from an operational perspective, it is great enough to show up in the beamwidth columns.



The reason for using a fan dipole becomes immediately clear from the 50-Ohm SWR curve in Fig. 9. The 2:1 or less SWR span goes from about 271 to 362 MHz, for a 30.3% passband. Solid fan dipoles may be able to cover even more territory, but the 91 MHz of coverage by the outline fan is a sufficient increase over all of the other driver systems. As is true for virtually any array based on a half-wavelength driver, the SWR climbs more slowly above the design frequency than below it. The fact that it occurs with a direct 50-Ohm feedpoint impedance is an added bonus. The question now is just the opposite from the one raised about uniform-diameter drivers: will the performance match the SWR passband. The following table of values for the standardized reflector used in all of these modeling tests gives us the data to evaluate. As in all tables in these notes, the gain is for free space, and the table uses the 180-degree front-to-back ratio. E-BW and H-BW are the E-plane and H-plane -3 dB beamwidths, respectively. Although the passband is between 271 and 363 MHz, the table counts in 10s starting at 270 MHz.

Frequency MHz	Gain dBi	Front-to-Back Ratio dB	E-BW degrees	H-BW degrees	Impedance R +/- jX Ohms	50-Ohm SWR
270	10.72	27.02	50	58	36.96 - j28.33	2.04
280	10.93	28.20	48	56	41.80 - j18.34	1.55
290	11.08	29.90	48	54	46.65 - j 9.10	1.22
300	11.16	32.39	48	52	51.57 - j 0.61	1.03
310	11.18	36.22	48	52	56.51 + j 7.04	1.20
320	11.16	43.28	50	50	61.26 + j13.77	1.38
330	11.13	57.08	50	48	65.57 + j19.66	1.54
340	11.09	41.04	52	48	69.21 + j24.92	1.70
350	11.06	36.07	54	46	72.05 + j29.81	1.84
360	11.01	33.16	58	44	74.07 + j34.64	1.97

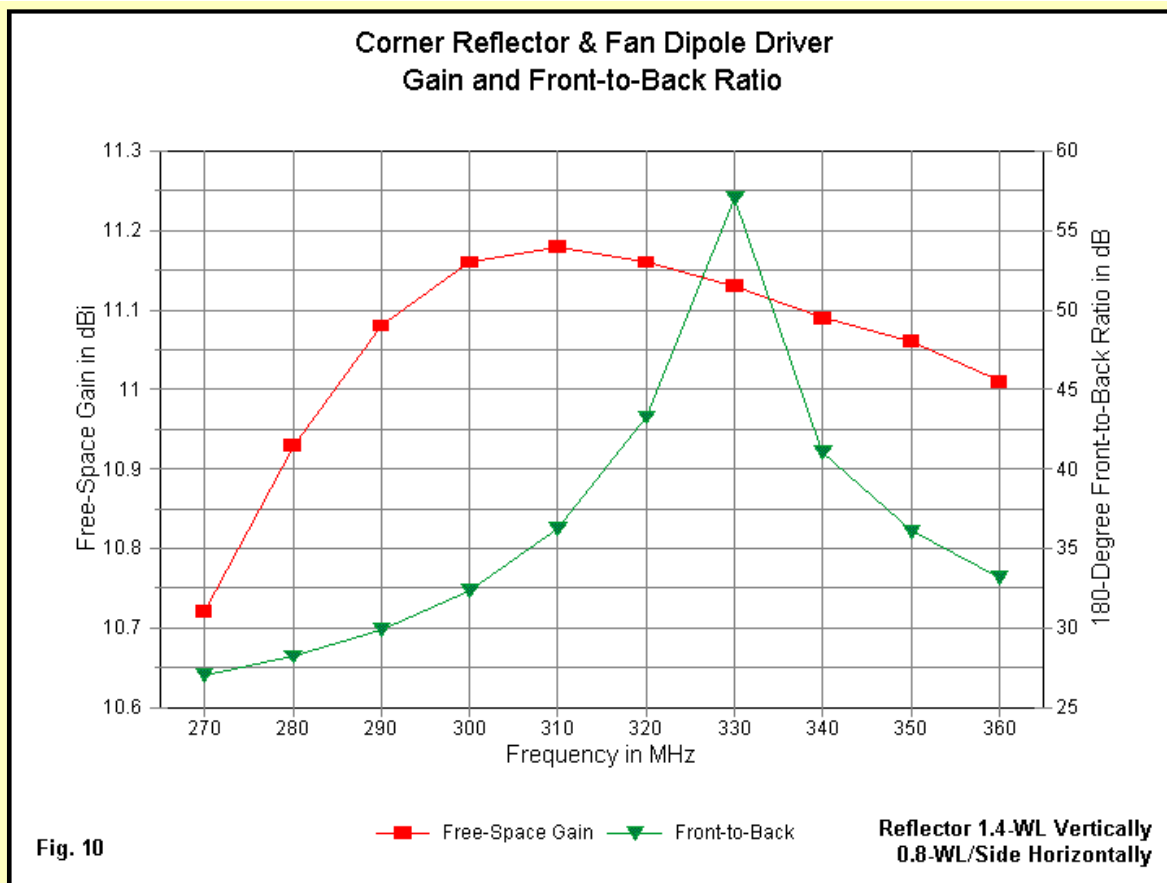
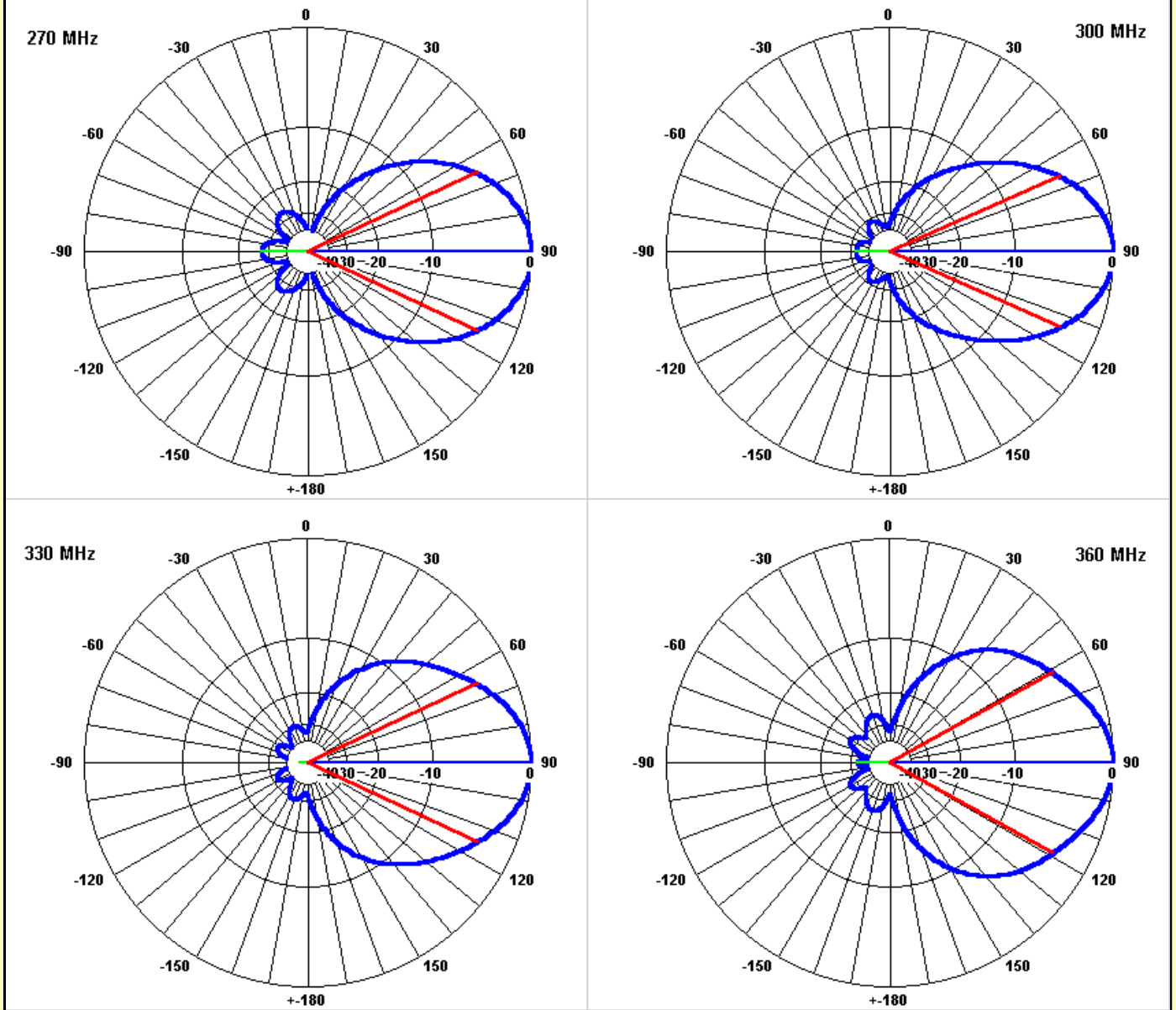


Fig. 10 summarizes the gain and front-to-back data in graphical form. Although the gain curve looks steep, the maximum gain variation across the passband is 0.46 dB, a very acceptable figure for many applications. Note that maximum gain occurs slightly above the design frequency. The 180-degree front-to-back figure shows an expected peak at a frequency still higher in the overall passband. The front-to-back values at the passband edges are more representative of the worst-case front-to-back values across the operating range.

The combination of front-to-back data and beamwidth data suggest that the E-plane and H-plane patterns show some variation as we change frequency. For example, the E-plane beamwidth varies by a total of 10 degrees across the band. To sample whether the E-plane patterns are uniformly acceptable, **Fig. 11** presents 4 sample patterns at 30-MHz intervals.

Selected E-Plane Free-Space Patterns
Corner Reflector with Fan Dipole Driver

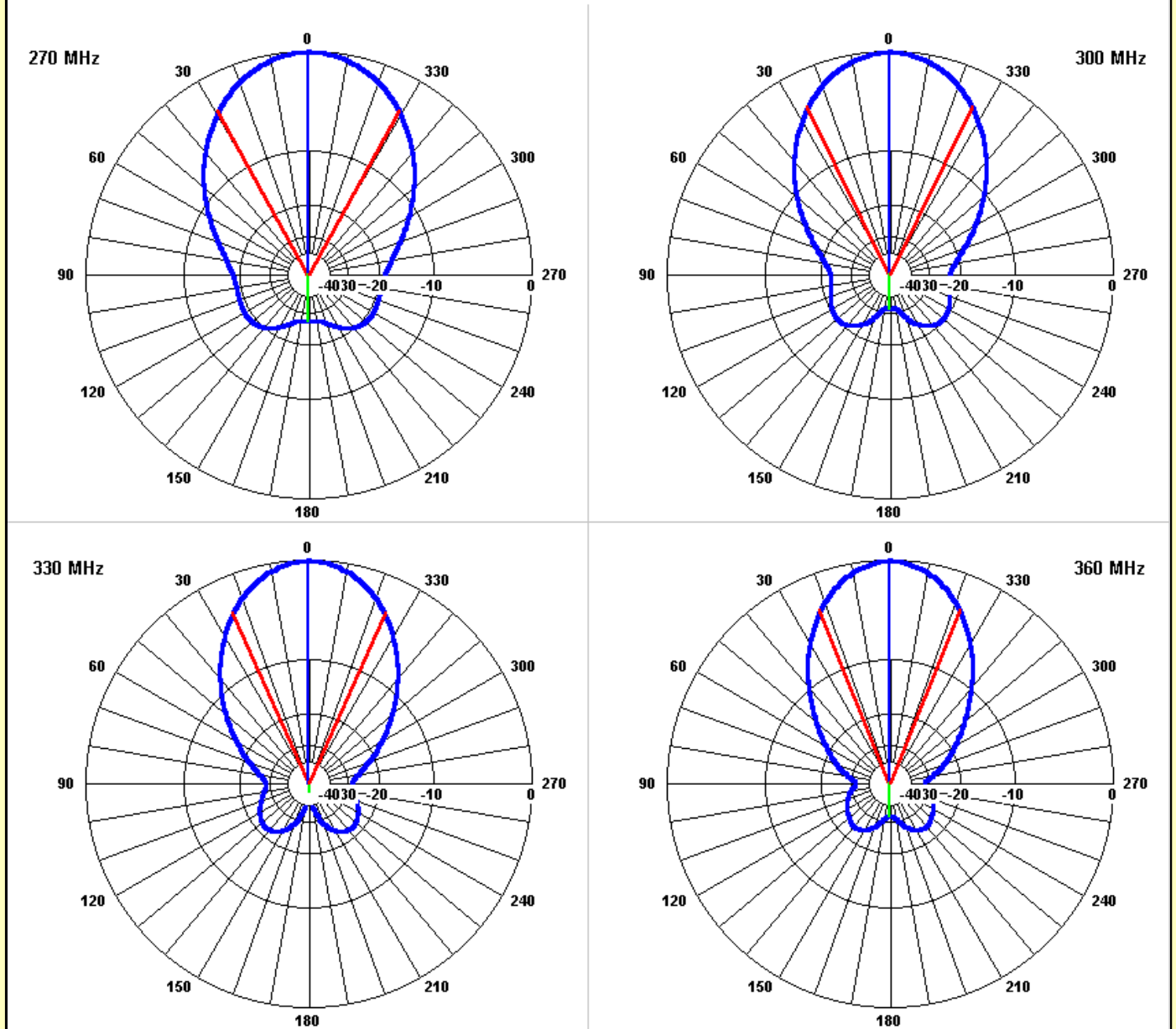
Fig. 11



The greatest rate of pattern shape change occurs in the upper 30 MHz of the passband. The E-plane beamwidth changes by 8 degrees in that span, and by the top end of the operating spectrum, the pattern has taken on a bit of a spade shape. In contrast, the H-plane beamwidth shows a steady decline from the lowest to the highest frequency. In large measure, this narrowing of the H-plane beamwidth--the side-to-side beamwidth if we use the array in a vertical orientation--results from the fact that the reflector side increases in length as a function of a wavelength as we increase the frequency. **Fig. 12** shows the resulting patterns at the same 30-MHz intervals.

Selected H-Plane Free-Space Patterns
Corner Reflector with Fan Dipole Driver

Fig. 12



The pattern evolution is in every way well-behaved. Indeed, the wide-band reflector array exhibits in these patterns one of its hallmarks: a clean forward lobe in both planes with no secondary forward lobes. In addition, the front-to-back ratio and the front-to-rear ratio are high enough to satisfy almost any application specification.

The fan dipole satisfies the need for a reflector array driver that provides an SWR passband that closely matches the performance passband of the antenna. The spacing of the driver and its short overall length do reduce maximum performance by about a quarter dB relative to the maximum gain provided by the best of the uniform diameter dipole drivers. As well, had we used a larger reflector, we would have obtained nearly 2 dB higher gain from any of our test cases. However, that fact only reminds us that we have some unfinished business with the reflector itself.

Is There a Maximum Reflector Size?

First, let's take stock of where we stand. We are exploring 90-degree corner reflectors composed of planar surfaces simulated in models by a wire-grid structure. The structure uses 0.1-wavelength cells, with a wire radius that is the cell length divided by 2 times PI or 0.0159 m. The basic driver for the array is a simple dipole, although we have seen that there are many ways to make a simple dipole into something more complex and still have a dipole. Driver structures other than dipoles, such as some of the phased dipole and monopole arrays used aptly with a flat or planar reflector, are not applicable to the corner reflector, because of their breadth. Maintaining a usable minimum spacing of closest approach by the outer elements to the reflector calls for a spacing from the reflector apex that severely reduces performance. In the end, some form of single dipole works best with the 90-degree reflector. For the following work, we shall return to our initial 8-mm dipole.

In the initial survey of reflectors, we used sizes that appeared to fall within the range that one might well build. The vertical dimension ranged from 1.0 to 2.0 m (wavelengths), and the maximum gain for the survey fell within this range. It occurred

for smaller side lengths at a vertical dimension of 1.4 m (wavelength) and for larger side lengths at 1.6 m (wavelength). At the longest side length within the survey, we noted two interesting features. First, the maximum gain from the array had not achieved a detectable maximum. Second, the vertical dimension for maximum gain was on the verge of appearing at the 1.8-m (wavelength) mark.

Therefore, it seemed appropriate to continue the survey for side lengths beyond 1.6 m. Since every increase in a reflector dimension increases the size of the Green's file, and Green's files are very large, computer time and storage space become active considerations. However, there is another issue to which the curves for vertical dimensions of 1.2 m and 1.4 m will become relevant. Therefore, I took the following tack. I created new reflectors for vertical heights of 1.2 through 2.0 m (wavelengths). As well, I increased the increment between side lengths to 0.4 m (wavelength). Combining the new results with older results gives us a portrayal of array performance from a side length of 1.2 m to 3.2 m, with vertical heights of 1.2 through 2.0 m.

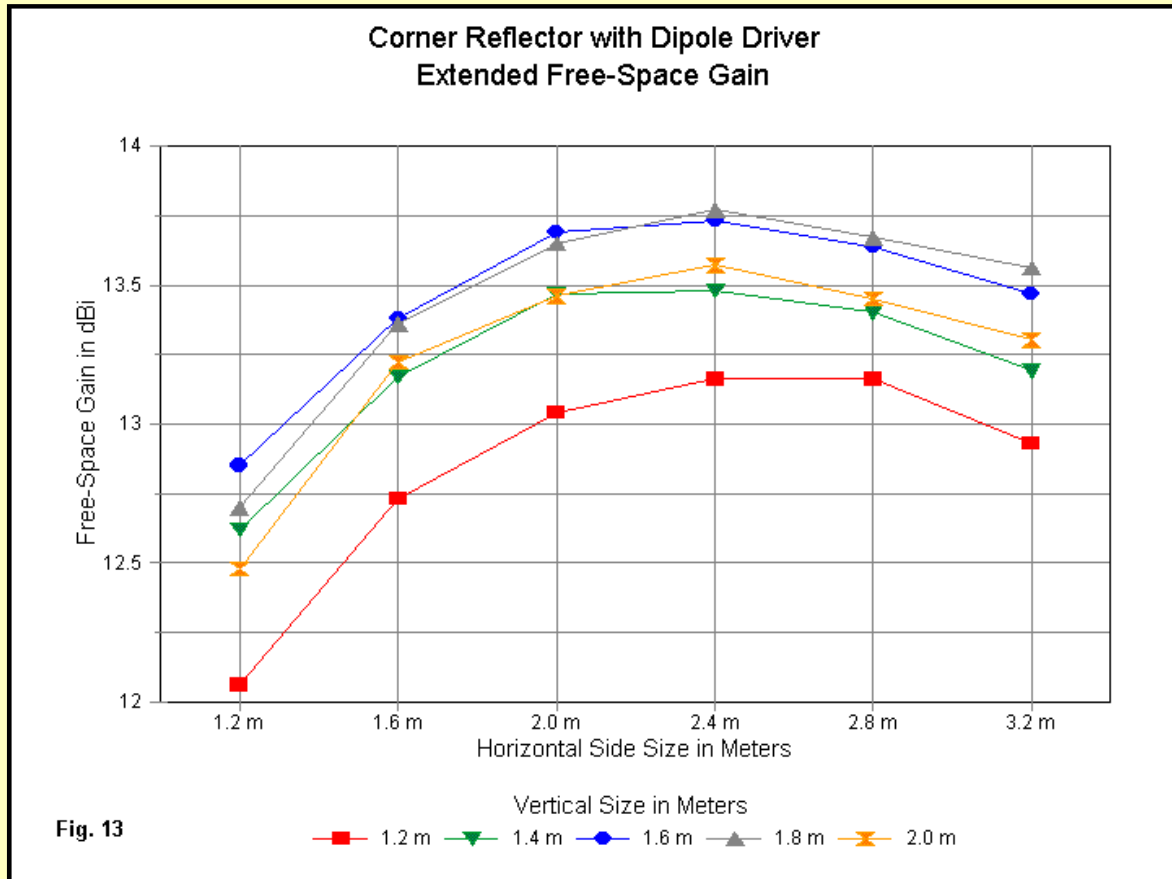
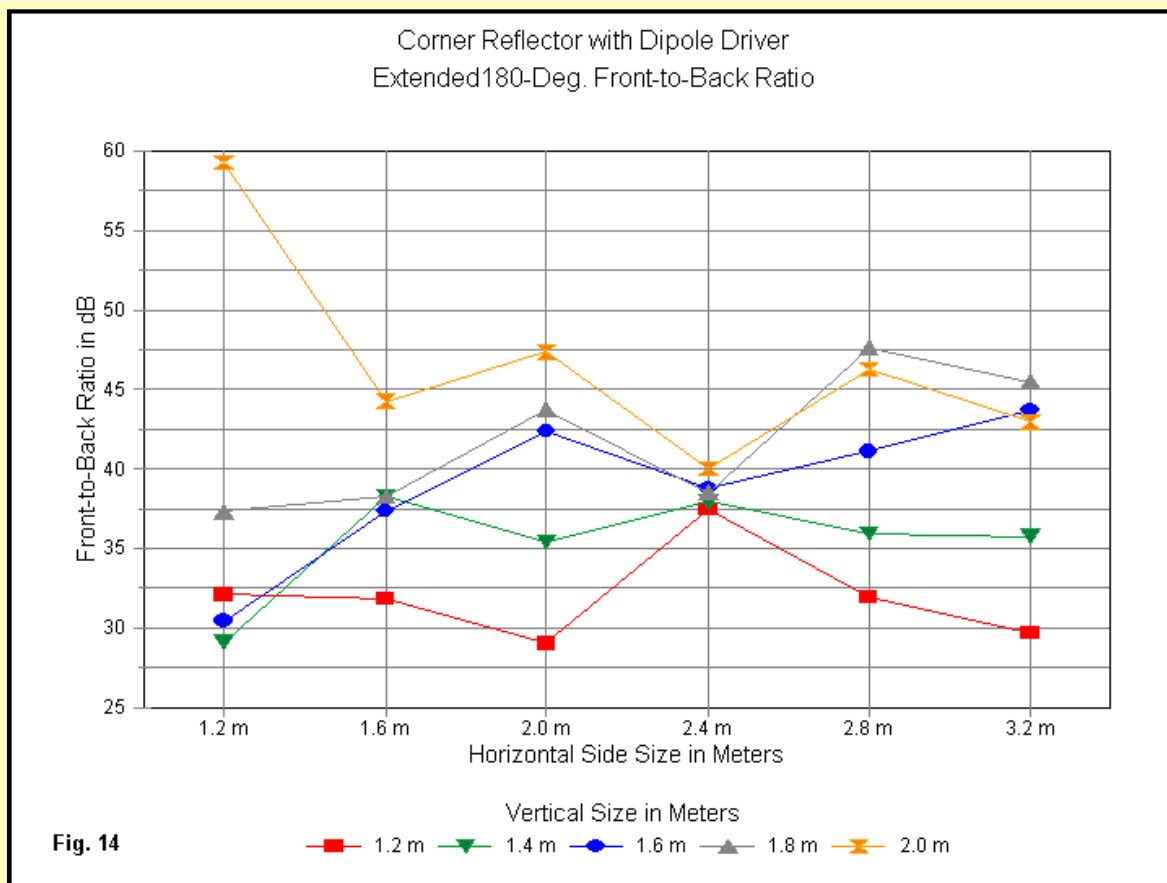


Fig. 13

As the curves show, the vertical height for maximum gain passes from the 1.6-m mark to 1.8 m somewhere between side lengths of 2.0 and 2.4 m. A vertical height of 2.0 m never shows the maximum gain derivable from a side length within the survey range. In fact, the curve for 2.0 m is almost coincident with the curve for a vertical dimension of 1.4 m. More significantly for our quest, maximum gain occurs with a side length of about 2.4 m (wavelengths). The fact that the values for side lengths of 2.0 m and 2.8 m are nearly equal suggests that a side length of 2.4 m is nearly optimal for maximum array gain. The highest gain value in the data set is 13.77 dBi.

The issue that makes the curves for 1.2-m and 1.4-m vertical dimensions especially interesting is the very smoothness of those two curves as they reach their respective peak gain levels and then decrease in gain with further increases in the vertical dimension. I checked some intermediate horizontal dimensions to ensure that I missed no aberrations. For example, with a horizontal dimension of 3.0 m, the 1.2-m vertical curve passes through 13.04 dBi, the free-space gain between the values for 2.8 m and 3.2 m. Likewise, the 1.4-m vertical curve registers 13.26 dBi, a figure intermediate between the 13.40 dBi at 2.8 m and 13.19 dBi at 3.2 m. When we examine rod-based corner reflectors in Part 3 of this series, we shall not find such smooth curves at the extremes of reflector side length.



The front-to-back curves in **Fig. 14** also tell an interesting tale, although the jagged lines may obscure it. If we trace the lowest values and ignore the high peaks, then we can see that the overall value--taken as the worst-case front-to-back ratio or the averaged front-to-rear ratio--continues to climb as we enlarge the reflector. Very interestingly, with a horizontal side length of 2.4 m, the 180-degree front-to-back ratios tend to come together into a tight cluster of values between 37 and 40 dB. What gives the cluster interest is the fact that all of the corresponding gain figures are at or very close to their peak values with a side length of 2.4 m.

Since the power is not increasing the forward gain above a side length of 2.4 m, but the rearward power continues to decrease, there are few other places for the power to go than in terms of increasing values of E-plane and H-plane beamwidth. Although the graph beyond the side length of maximum possible gain is too short to make this fact evident in patterns, the numbers tell the story. If we average the 3 E-plane beamwidth values for the surveyed vertical dimensions at each side length, a side length of 2.4 m shows the lowest average (39.3 degrees). By the time we reach the maximum side length of 3.2 m, the average has grown (to 40.0 degrees). The H-plane figures are more dramatic. At a side length of 2.4 m, the average H-plane beamwidth for the 3 vertical dimensions is 32.0 degrees. At a side length of 3.2 m, the value becomes 36.7 degrees.

The H-plane beamwidth values are indicators of performance to the sides of the reflector aperture. Up to the point of maximum gain, these values had steadily descended, inviting the idea that the extending sides of the reflector had a confining effect on the "side-to-side" radiation relative to the aperture. However, beyond a certain side length, the seeming confinement begins to weaken.

The corner array turns out to be perhaps more complex than its appearance may indicate. The reflector is--within the limitations of this study and the physical implementations anyone is ever likely to build--perhaps not simply a pair of plane surfaces. For example, we might wonder if the corner reflector, when composed of rods or bars instead of closely spaced screens or solid surface, has both the same performance and the same limitations as the wire-grid models suggest for solid surfaces. As well Kraus' early work suggested alternative reflector angles, and some antenna builders have suggested some alternative shapes. Perhaps, before we close the book on corner reflectors, we had better spend a little more time on the reflector and its corner.



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