Corner Arrays for Personal Communications

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Corner arrays are much neglected antennas with wide-spread applications. They are inherently broad-banded: a simple dipole driver with a properly sized reflector is capable of about 100 MHz of consistent pattern properties and under 2:1 SWR in the 500 MHz region. As well, gain can be excellent for the antenna simplicity, ranging from over 10 dBi to about 14 dBi free space gain, depending upon the reflector size.

An added advantage of the corner reflector is that it lends itself to somewhat casual building practices in the home shop--as long as one seeks only good or adequate performance rather than absolute peak performance. With the casual building and adjusting technique that we shall suggest, look for 10-11 dBi gain rather than the 14 dBi figure. In addition, many hardware, craft, and kitchen supply store materials can be pressed into service.

In this design exercise, we shall explore corner reflectors for two frequency ranges: 800-900 MHz and 1800-2000 MHz. Both bands are used for personal communications. A common problem is home use of low power transmitting and receiving devices: from many suburban or country locations, they do not quite provide reliable communications with the nearest local relay tower. A few dB of gain over the built-in stub antenna can make a big difference in reliability. Of course, there will be a cable between the indoor antenna and the transceiver, so a few more dB are useful to overcome line losses.

The corner reflector can be set for either horizontal or vertical polarization simply by turning the assembly 90 degrees. We can then use a 2-step procedure that I call "aim and adjust" to set up a corner reflector. Of course, having commercial test and measurement equipment on hand can peak the system, but the simple procedure often suffices for reliable communication.

Corner Reflector Basic Ingredients

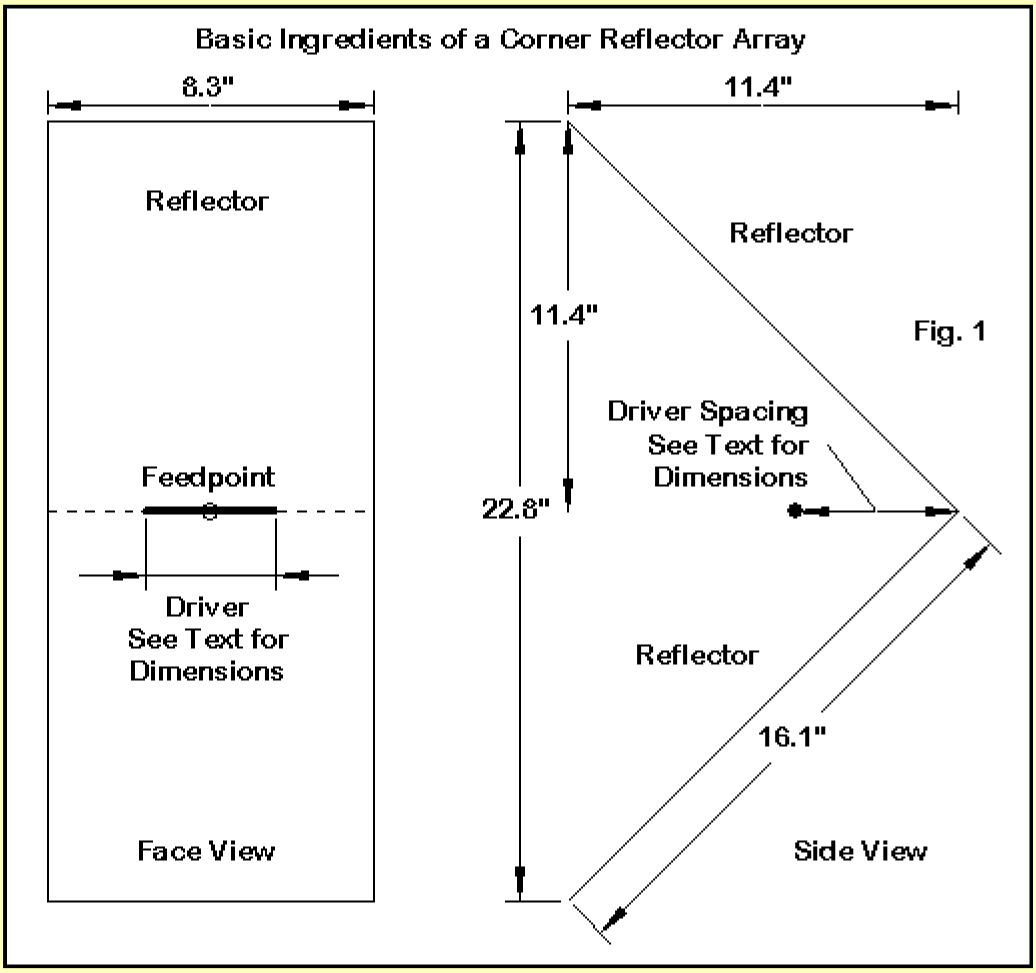

Fig. 1 shows the basic ingredients of a monoband corner reflector. It consists of the pair of panels that form a 90-degree angle behind a simple dipole driver. The reflector can be sets of rods that parallel the driver, a screen, or a solid panel. For outdoor use, rods and screens that pass the wind are favored. However, for indoor use, solid panels will do well and are easier to obtain. Raiding the kitchen supply counter for cookie sheets is one easy route to reflector material.

The size of the panels for this design exercise is about 8.3" across with an individual length of about 16.1". Such panels will yield a reflector that is 22.8" top-to-bottom and 11.4" front-to-back. We shall later discuss some home construction methods, but feel free to innovate. All dimensions will be given in inches. However, you can translate these into millimeters by multiplying all of them by 25.4.

The exact size of the reflector is not critical, although the given dimensions are about the smallest that I would recommend. Rounding the dimension upward will do no harm. In fact, 9" by 12" sheets for the upper and lower sections would be very good indeed. We shall use the present reflector for both bands of interest--and one might use it for any band in between them.

The dipole is cut for resonance near the middle of desired passband. My practice is to choose a frequency between 1/3 and 1/2 the way up the passband, since the SWR curve may not be completely symmetrical, rising slightly faster below the design frequency than above it. Of course, one needs a way to support the dipole. For the frequencies in question, a polycarbonate tube is likely best, but simple wood will work. There is no rule that the tube must be round: square and rectangular cross sections will work as well. For reasons that we shall spell out near the end, you might consider using brass or copper tubing for the driver element.

Pass the tube and the feedline through the rear of the reflector. Add some mounting brackets. Then aim and adjust.

A 800-900 MHz Version

Modeling corner reflectors can typically use two techniques that reflect construction practices. One is to create a reflector from individual rods. A second is to create wire-grid assemblies for the two plates. I have modeled the present antennas on NEC-4 using both methods, along with wire grids with various size grid squares and grid-wire diameters. In general, the results coincide quite closely--closely enough to require no adjustments to the dimensions to achieve acceptable results. The calculated result presented here to illustrate corner reflector properties for the bands in question emerge from wire-grid models of the reflector.

The only semi-critical element is the driver. For broadest bandwidth, fatter is better. The design frequency impedance will be in large measure a function of the distance of the driver from the reflector apex. I have somewhat arbitrarily set the mid-band SWR standard (resonant impedance) at 88 Ohms. Lower impedances result from moving the driver closer to the reflector apex; higher impedances require a larger spacing.

For the 800-900 MHz range at the 88-Ohm impedance level, the distance of about 5.7" is fine. For most purposes, a 0.5" diameter dipole will require a 5.7" length. Reducing the dipole to 0.25" requires a length of 5.85". The broad-banded nature of the antenna allows rough interpolation and extrapolation for other driver diameters.

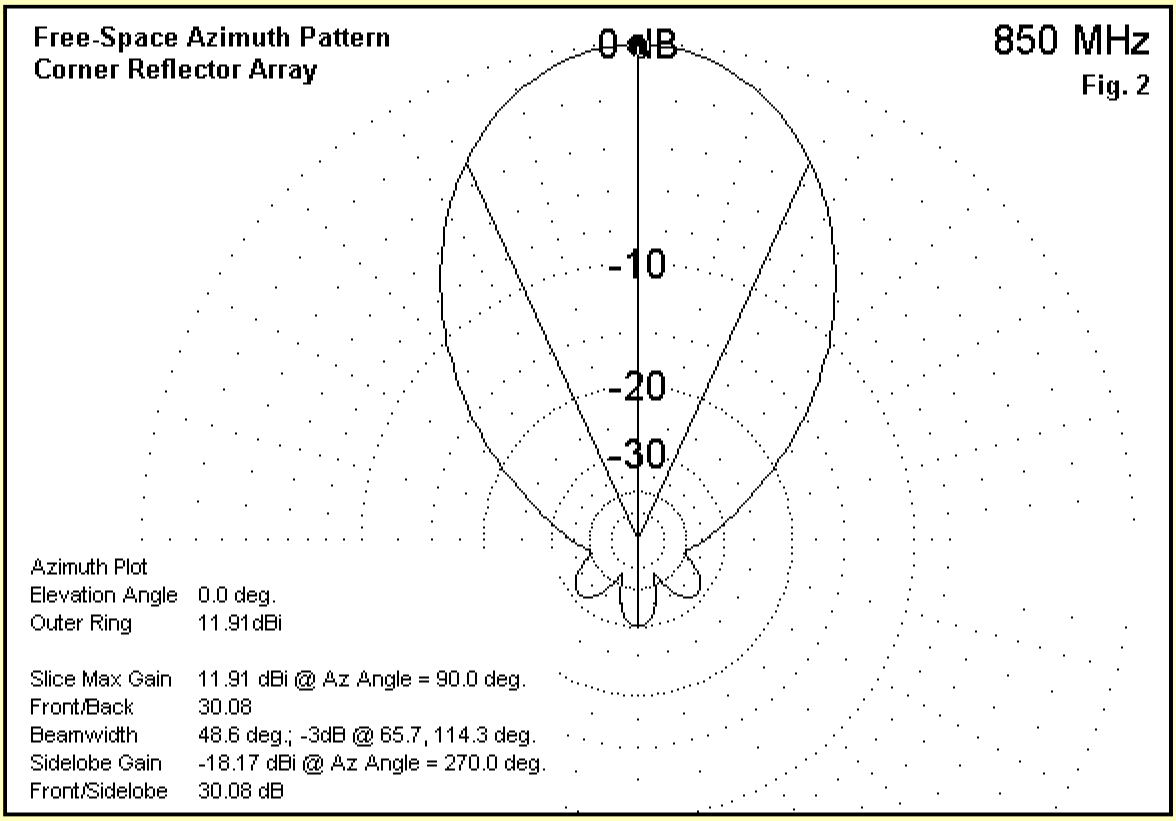

Fig. 2

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Azimuth Plot
Elevation Angle   0.0 deg.
Outer Ring        11.91dBi

Slice Max Gain    11.91 dBi @ Az Angle = 90.0 deg.
Front/Back        30.08
Beamwidth         48.6 deg.; -3dB @ 65.7, 114.3 deg.
Sidelobe Gain     -18.17 dBi @ Az Angle = 270.0 deg.
Front/Sidelobe    30.08 dB
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Fig. 2 provides a mid-band azimuth pattern for the corner reflector. For the intended application, the pattern, gain, and beamwidth are quite good, allowing for precision aiming using signal strength alone as a guide. Showing further patterns would be an exercise in sameness, so the following table lists the performance reports of the model from 800-900 MHz. The driver is 0.25" in diameter.

Frequency MHz	**Gain dBi**	**F-B Ratio dB**	**Feed Impedance (R +/- jX Ohms)**	**88-Ohm VSWR**
800	**11.53**	**30.39**	**67.3 - j 18.7**	**1.434**
810	**11.61**	**30.51**	**71.9 - j 13.2**	**1.299**
820	**11.68**	**30.52**	**76.7 - j 8.0**	**1.184**
830	**11.76**	**30.42**	**81.6 - j 2.9**	**1.086**
840	**11.83**	**30.28**	**86.8 + j 1.9**	**1.026**
850	**11.91**	**30.08**	**92.1 + j 6.4**	**1.088**
860	**11.98**	**29.89**	**97.6 + j 10.7**	**1.167**
870	**12.06**	**29.68**	**103.2 + j 14.6**	**1.247**

880	**12.13**	**29.52**	**109.0 + j 18.2**	**1.327**
890	**12.21**	**29.37**	**114.9 + j 21.5**	**1.406**
900	**12.28**	**29.27**	**120.8 + j 24.4**	**1.483**

The total change of gain across the passband is about 0.75 dB, with a change of front-to-back ratio of 1.25 dB. The SWR curve appears in **Fig. 3**. Its smoothness results from the fact that the feedpoint resistance shows a total change of only about 53 Ohms, while the reactance range is about 43 Ohms.

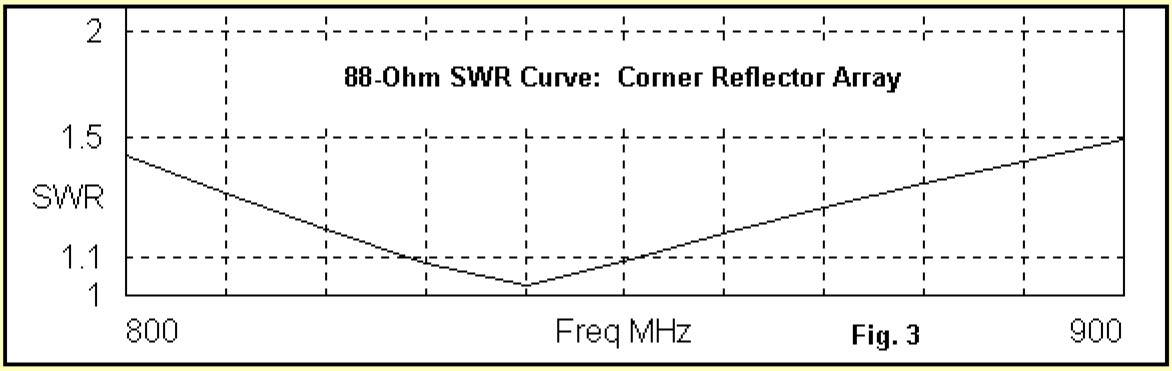


Fig. 3

It is possible to design Yagis with similar gain values for the same range, but their front-to-back ratio values will generally be inferior by considerable amounts. Although such Yagis (generally about 12 elements) will show a flatter vertical dimension, they will be considerably longer: close to 48" long compared to the 1' front-to-back dimension of the corner reflector. Moreover, a Yagi requires careful replication of the design length and spacing of each element down to about a millimeter, which is often beyond casual home workshop capabilities.

A 1800-2000 MHz Version

The most standard practice to follow in designing a high-band version of the corner reflector would be to scale every dimension and obtain similar performance to the 800-900 MHz model just examined. However, to make the 1800-2000 MHz design worth noting, let's follow a different procedure. We shall retain the same corner reflector assembly and simply position a different driver to see what we get.

Since the reflector is nearly twice as large as it needs to be as a recommended minimum, we should expect some changes in the upper-band pattern relative to what we saw for the lower band. **Fig. 4** shows the mid-band pattern, which is typical of the patterns for all frequencies in the passband.

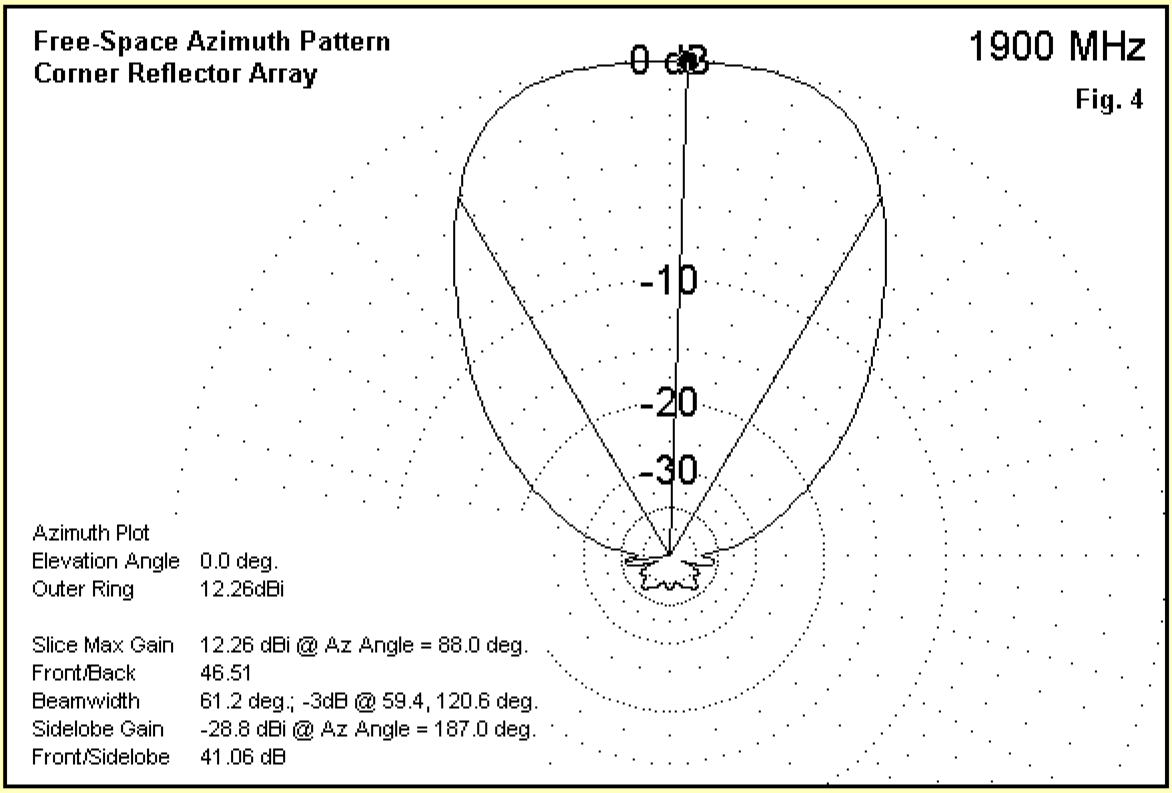


Fig. 4

Note that the pattern is not only a bit stronger, it also maintains that strength across a wider beamwidth--thus easing the aiming problem somewhat. The front to back ratio is above 40 dB across the passband, which makes differences from one frequency to another largely irrelevant.

The driver for the assembly is spaced 2.5" from the reflector apex. A 0.25" diameter driver requires a 2.5" length, while a 0.125" driver needs to be about 2.55" long. Again, the arbitrary SWR standard will be 88 Ohms, although changing the driver spacing from the reflector apex can raise or lower this value to suit user needs.

The following table provides passband data from the NEC-4 model to give some idea of the performance stability across the 200 MHz passband, using a 0.25" diameter driver.

Frequency MHz	**Gain dBi**	**F-B Ratio dB**	**Feed Impedance (R +/- jX Ohms)**	**88-Ohm VSWR**
1800	**12.58**	**42.35**	**65.5 - j 10.2**	**1.382**
1820	**12.52**	**43.02**	**70.0 - j 7.7**	**1.282**
1840	**12.46**	**44.22**	**74.7 - j 5.4**	**1.193**
1860	**12.40**	**45.34**	**79.6 - j 3.4**	**1.115**
1880	**12.33**	**46.53**	**84.6 - j 1.7**	**1.045**
1900	**12.26**	**46.52**	**89.7 - j 0.3**	**1.020**
1920	**12.22**	**49.20**	**95.0 + j 0.6**	**1.080**
1940	**12.22**	**48.53**	**100.3 + j 1.2**	**1.140**
1960	**12.22**	**48.64**	**105.6 + j 1.4**	**1.201**
1980	**12.23**	**48.44**	**111.0 + j 1.1**	**1.261**
2000	**12.24**	**49.28**	**116.3 + j 0.4**	**1.321**

The total gain change is only 0.36 dB, with a front-to-back range of 7.2 dB. The resistance range is 51 Ohms, while the reactance range is only 12 Ohms. The small reactance range results from using the out-sized reflector. The progression shows a reversal in the expected direction of reactance change at the high end of the band. The resulting SWR curve appears in **Fig. 5**.

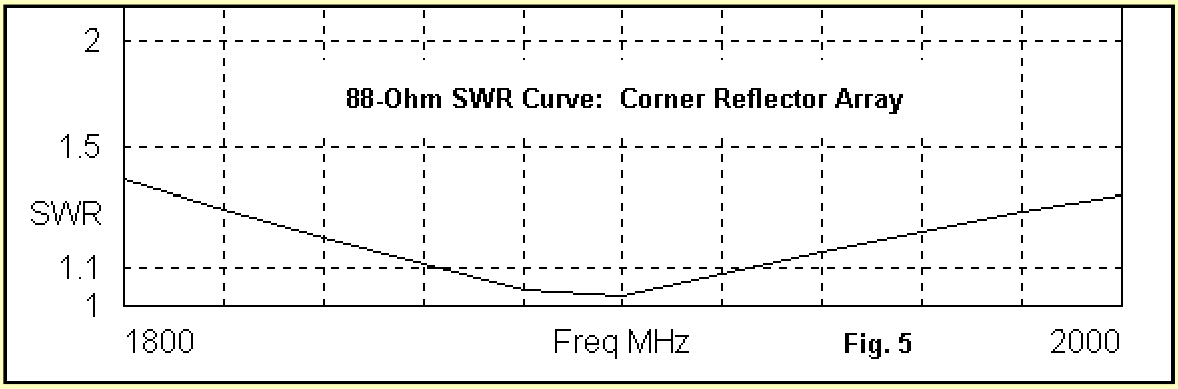


Fig. 5

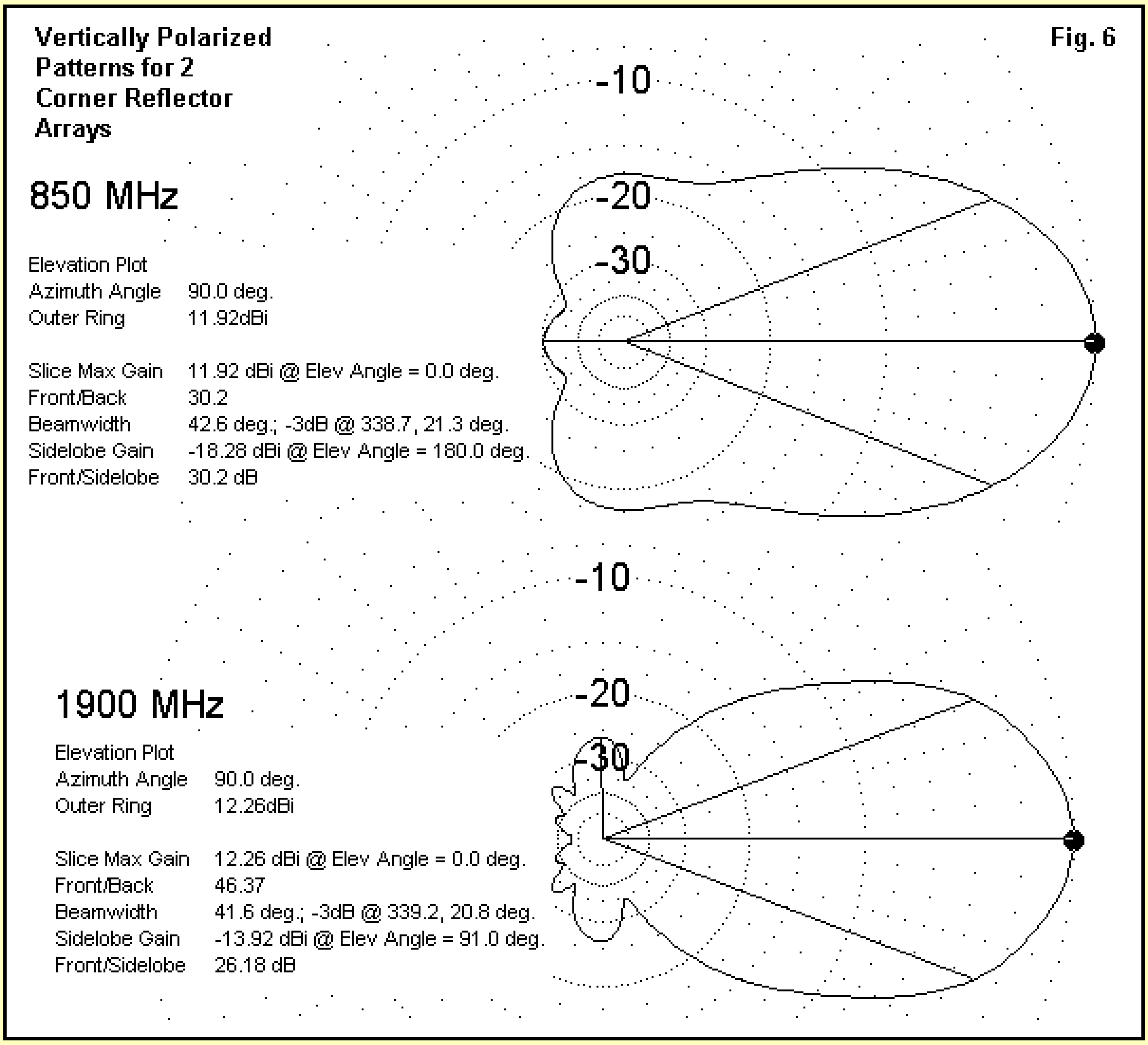
Had we reduced the diameter of the driver to 0.125", we would have seen a more normal reactance curve with a net change of 39 Ohms. Reducing the diameter of the driver, with adjunct changes in its length, increases the band-edge SWR value. Halving the diameter value given would increase the band-edge value by about 0.1 to 0.2. The corner reflector thus shows its stability with varying materials across a wide frequency range.

Vertical Polarization

The azimuth patterns that we have so far viewed are free space patterns. Reduce their values by about 2.1 dB to obtain the antenna's gain over a dipole. The resulting numbers will apply for any given height over any given terrain.

For most Yagi designs below lengths that can be considered very long, positioning the antenna to obtain vertical polarization tends to yield a significantly wider beam width than when placed for horizontal polarization. In addition, side-lobe development--both forward and rearward--becomes quite pronounced, although hardly ever reaching the point of making the antenna unusable. Without element ends to confined side-lobe development, the vertically polarized Yagi places significant energy into them.

Corner reflector are not immune to these effects, although in some cases, the effects are smaller than with Yagis of corresponding gain. See **Fig. 6**.



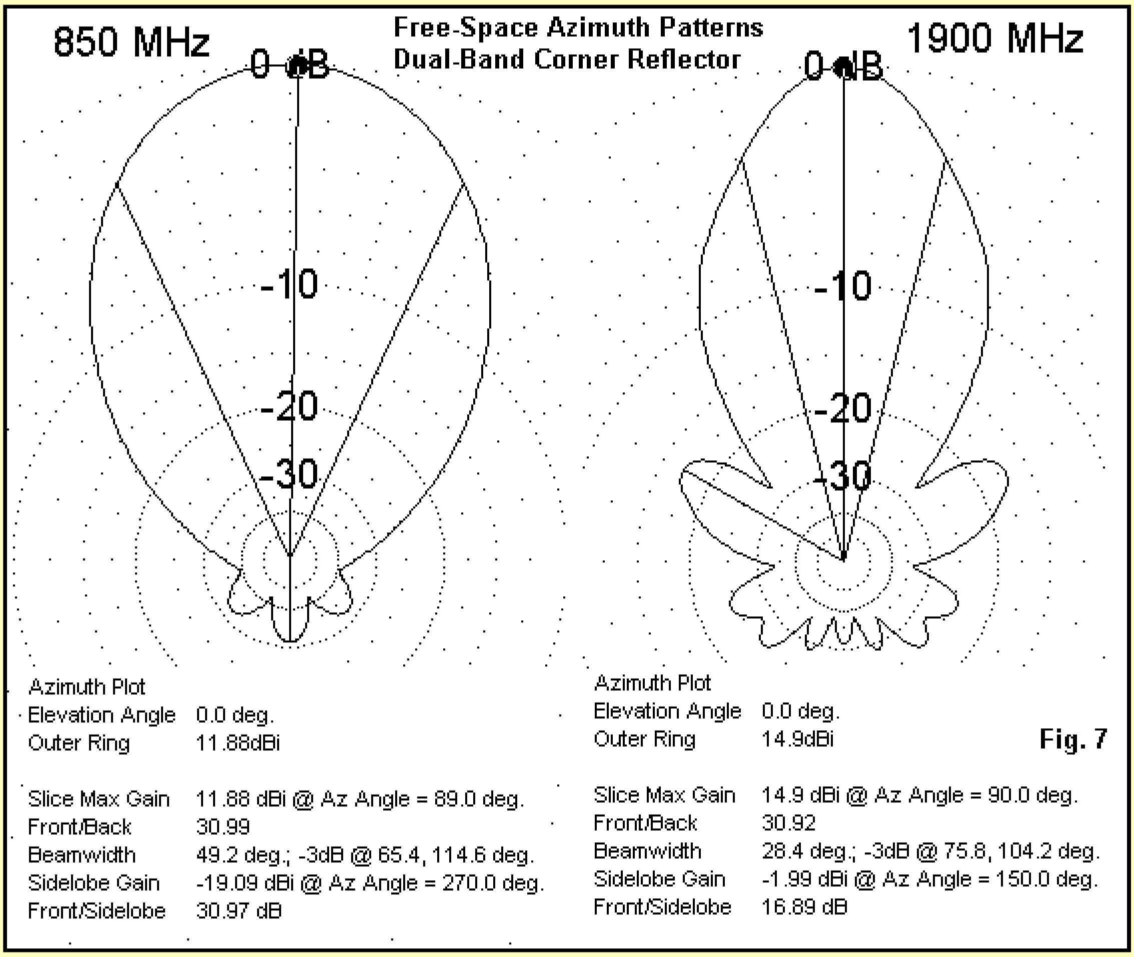
The 850 MHz pattern of the vertically positioned corner reflector shows a considerable amount of energy to the sides. However, the -3 dB beamwidth is actually narrower than when the antenna is horizontally positioned (see **Fig. 2**). The high-band model also shows a similar phenomenon, although less pronounced due to the very high front-to-back ratio of the design used here. Compare the pattern in **Fig. 6** with the one in **Fig. 4**. The narrowed beamwidth is especially notable, but not as much as the ovalization of the forward lobe.

Nevertheless, both corner reflectors make excellent arrays to use with either horizontal or vertical polarization for the bands in question.

A 2-Band Version

A question that arose in course of these design studies was whether it is possible to develop a 2-band version of the array in order to be able to cover both bands with a single reflector. In general, the project seemed initially doomed because the high-band driver appeared to require a position closer to the reflector apex than the low-band driver. The result is excessive "illumination" of the low-band driver, which placed a small null in the center of the high-band pattern.

However, if we are willing to accept some pattern changes on the high band, we can design a 2-band version of the corner reflector. The pattern changes appear in **Fig. 7**.



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Azimuth Plot
Elevation Angle    0.0 deg.
Outer Ring         11.88dBi

Slice Max Gain     11.88 dBi @ Az Angle = 89.0 deg.
Front/Back         30.99
Beamwidth          49.2 deg.; -3dB @ 65.4, 114.6 deg.
Sidelobe Gain      -19.09 dBi @ Az Angle = 270.0 deg.
Front/Sidelobe     30.97 dB
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```
Azimuth Plot
Elevation Angle    0.0 deg.
Outer Ring         14.9dBi

Slice Max Gain     14.9 dBi @ Az Angle = 90.0 deg.
Front/Back         30.92
Beamwidth          28.4 deg.; -3dB @ 75.8, 104.2 deg.
Sidelobe Gain      -1.99 dBi @ Az Angle = 150.0 deg.
Front/Sidelobe     16.89 dB
```

Fig. 7

The low band pattern changes are too slight to mention. The high-band changes show the results of the low-band driver playing a role in the formation of the pattern. The forward side lobes result from the fact that the low-band driver approaches the length of an extended double Zepp relative to the high-band frequencies.

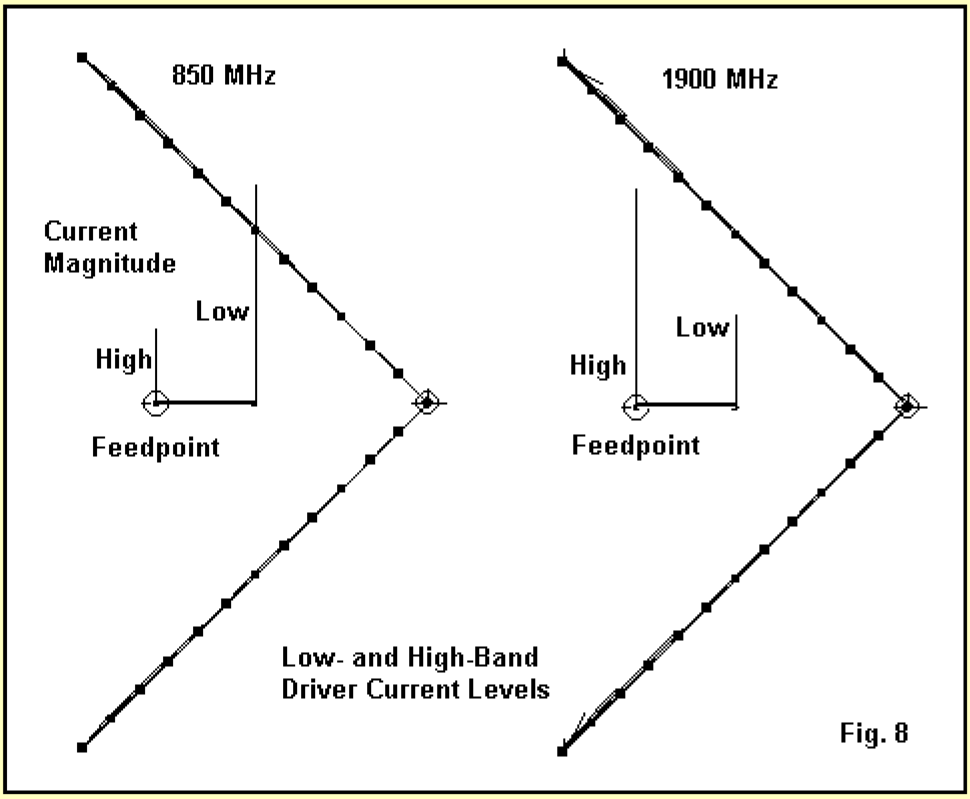

Fig. 8

Fig. 8 shows the relative current magnitudes on the dual driver elements for the middle of the low band and the middle of the high band. On the low band, the current (about 40% of that on the low-band driver) on the forward short driver has little effect, since it functions at best as a low-efficiency director. On the high band, however, the rearward low-band driver with about 40% of the main driver current exerts a more significant effect on the pattern, largely because the peak current positions lie beyond the edges of the shorter driver.

The actual driver system is a pair of phase fed dipole elements. Both are 0.25" in diameter, with the low-band driver spaced 5.7" from the reflector apex. The shorter high-band driver is 9.0" from the apex. The low-band driver is 5.7" long, while the high-band driver is 3.3" long. Note that the low-band driver is positioned normally relative to the independently driven array we have already examined. The high-band driver is longer than it would be for independent use in an array.

The two drivers are connected by an 80-Ohm phase line, with a reversal of connections. Such a line can be constructed of aluminum or other metal straps or bars. For 0.5" wide straps, the required spacing is about 0.23". For 0.375" straps, the spacing is 0.17", while 0.625" straps need 0.28" of spacing. One set of elements requires holes in the facing strap to effect the reverse connection, and the dipole ends will be slightly out of alignment vertically so that the elements can pass each other. Because any given deviation from "perfect" construction tends to have larger effects with increasing frequency, I would recommend that the offset construction be applied to the low-band driver.

The assembly is design for a 75-Ohm feed system, with the feeder connected to the front or high-band driver. **Fig. 9** shows the 75-Ohm SWR curves for the two bands. Although not truly outstanding, these curves should be quite serviceable for the array.

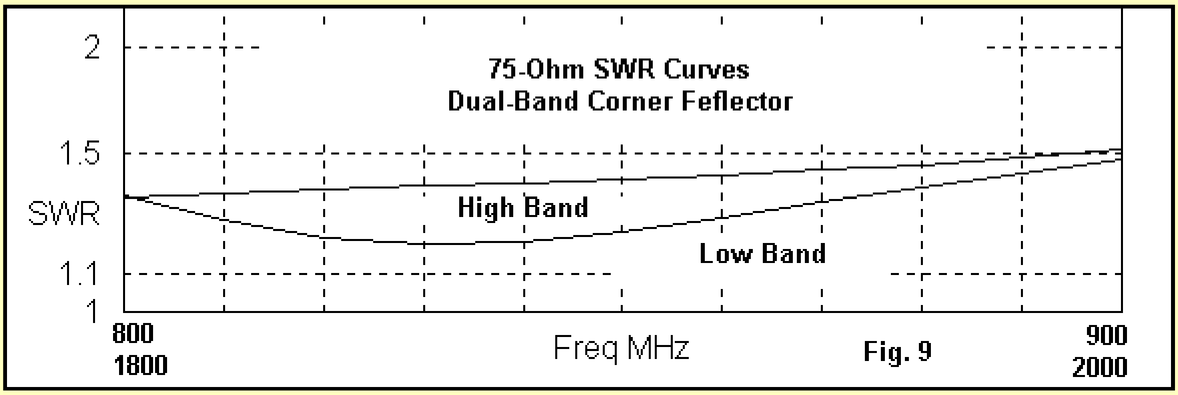

Fig. 9

The following table provides band-edge and mid-band performance figures for the 2-band corner reflector array.

Frequency MHz	**Gain dBi**	**F-B Ratio dB**	**Feed Impedance (R +/- jX Ohms)**	**75-Ohm VSWR**
Low-Band				
800	**11.51**	**31.34**	**64.2 + j 17.8**	**1.349**
850	**11.88**	**30.99**	**61.2 + j 0.2**	**1.225**
900	**12.26**	**29.74**	**51.4 - j 4.7**	**1.469**
High-Band				
1800	**13.34**	**29.27**	**75.6 - j 21.7**	**1.333**
1880	**14.90**	**30.92**	**69.0 - j 23.6**	**1.401**
1900	**15.15**	**30.83**	**67.7 - j 29.0**	**1.517**

The low-band performance almost exactly tracks the performance of the monoband version we studied. Of course, there are variations in the feedpoint impedance values relative to the monoband version. However, for the high band, note the increasing gain and the fairly wide range (1.8 dB) of variation across the band. Since all gain values exceed those of the monoband high-band model, the variation is likely to be acceptable.

In general, I would not recommend attempting construction of the 2-band corner reflection in anything less than a very well-equipped shop that permits both precision construction and accurate measurement for adjustment. The number of variables involved in the driver assembly call for more than casual assembly of approximate component pieces.

A Few Construction Suggestions

Casual construction of either monoband version of the corner reflector array is another matter--one well within shop capabilities. **Fig. 10** sums up a few initial suggestions.

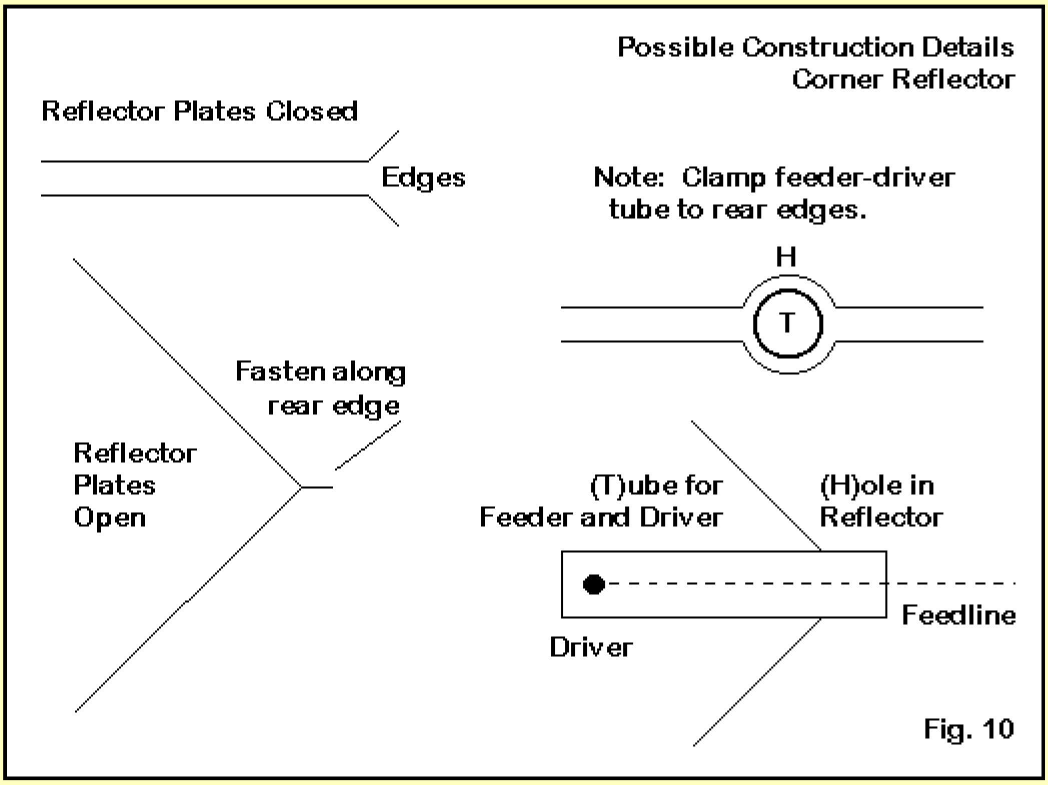

Fig. 10

The reflector plates can be formed from flat plate by using a metal brake or even a bench vise with metal or wooden extensions to create the angular edges. A 0.5" to 1.0" edge lip on each plate, bent to 45 degrees, will allow mating of the two plates to create the correct assembly. A series of nuts and bolts along the joined edges will secure the reflector well-enough for indoor use.

Before assembly--indeed, before bending--it is wise to plan for the feeder tube. The right portion of the sketch shows a hole in the center of the reflector apex. Although a round tube is shown, a square or rectangular polycarbonate or substitute version can be used. Each plate from the bend forward needs to be opened for half the tube. In general, extend the opening about 1.414 times the radius of the tube (or half the vertical face of a rectangular tube). Also remove metal from the edges so that the tube can pass all the way through the reflector apex.

You can secure the tube to the edge flange with metal strips that form clamps. For indoor use, such clamps will be more than secure enough if they are simply very tight across the tube. Being able to loosen the clamps to permit driver positioning is wise. Added metal straps can be placed at the outer corners of the reflector apex flange to hold u-bolts or other mounting hardware.

The dipole might well be made from copper tubing (or craft-store brass) so that you can solder the feedline leads directly to each half of the dipole. Avoid adding excessive lumps to the dipole. As well, a toothpick or other short piece of wood dowel (fiberglass would be best if available in this thin diameter) can run across the gap in the dipole inside the tubing to ensure alignment of the two sides. How the dipole is affixed to the tube depends on the material at hand, but a very slightly undersized slot at the front of the tube might allow a useable pressure fit.

Setting up the corner reflector involves aiming and adjusting. First, set the reflector for the correct polarization. Next, aim the reflector array at the target relay antenna, using signal strength as a guide. Then, slide the dipole forward and backward from its initial position until both the transmitted and received signal are maximum. Finally, clamp the dipole tube in place. Although this procedure does not qualify as precision adjustment, it may well suffice to bring signals in both directions well above the threshold of reliability.

If a 9 by 12 by 22 inch assembly can fit available space and if greater signal reliability is needed on either of the two bands we have considered (or anywhere in between as well), then a corner reflector array from the pantry and plumbing shop might be the easiest (and cheapest) route to success.

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