The Prismatic Polyhedron and the Planar Reflector Supplementary Data

L. B. Cebik, W4RNL (SK)

The main article on prismatic polyhedrons and planar reflectors bypassed at least two interesting P3 driver possibilities in the interests of conserving space. These supplementary notes will fill in the gap for the P3 triangular driver, at least partially. Throughout these added notes, we shall employ the small planar reflector that is 0.5 m wide (across the face of the triangular P3 structure) and 0.6 m high (along the length of the P3 driver). In all cases, the reflector will set its wire-grid lengths by reference to the highest frequency in the sampling sequence, 800 MHz.

In addition, we shall not alter the dimensions of the P3 wire structure. In a few cases, we may change the characteristic impedance or the length of the phase lines that lead to a central feedpoint, but these changes will not affect the radiation patterns produced by the P3 driver itself.

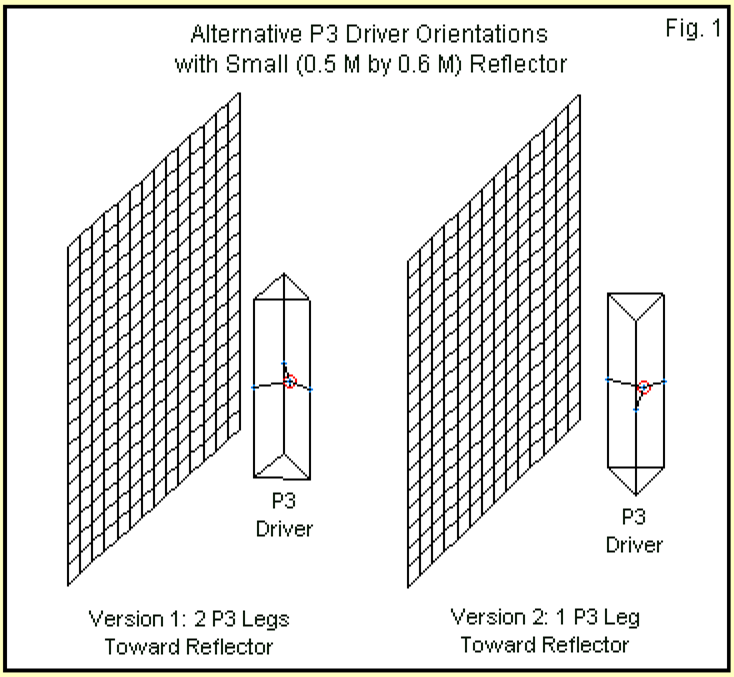
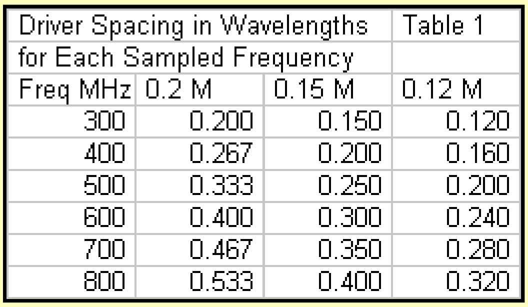


Fig. 1 shows one of the variables that we may introduce to the P3 driver in conjunction with a planar reflector. The original article set the driver as shown on the left. Version 1 places two legs of the triangle equidistant from the reflector surface at the closest approach. Version 2, on the right, shows the alternative orientation that places a single leg at the point of closest approach to the reflector, with the remaining legs more distant but still equally spaced from the reflector. From the triangle apex to the center of the opposite side, we have a distance of about 0.072 m (given the face dimension of 0.083 m). Variations in spacing for version 1 as small as 0.02 m produced noticeable changes in performance. Therefore, we might see performance variations just by changing how many legs are at a prescribed distance from the reflector.

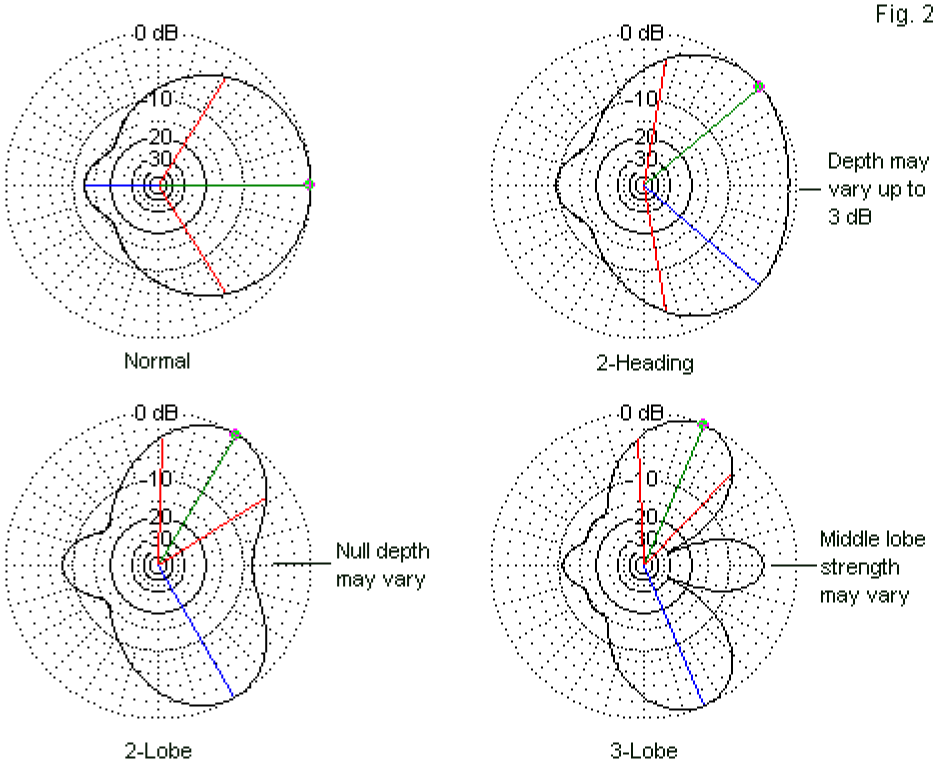
In the main article, we also fixed the spacing between the reflector and the driver's closest approach to 0.2 m, using only version 1 of the set-up. This restriction yielded consistent SWR curves for all modeling tests that changed the size of the reflector. However, we may equally fix the size of the reflector, as noted in our opening lines, and vary the spacing between the reflector and the driver. For these supplemental notes, we shall examine spacing values of 0.15 m and 0.12 m. **Table 1** translates these physical distances into distances in wavelengths for each of the sampled frequencies. As we did in the main article, we shall use 100-MHz increments and sample performance from 300 to 800 MHz.



Driver Spacing in Wavelengths			Table 1
for Each Sampled Frequency			
Freq MHz	0.2 M	0.15 M	0.12 M
300	0.200	0.150	0.120
400	0.267	0.200	0.160
500	0.333	0.250	0.200
600	0.400	0.300	0.240
700	0.467	0.350	0.280
800	0.533	0.400	0.320

If we combine the two sets of variations, we arrive at a matrix with 6 elements for our survey. The galleries of patterns shown in the main article provide us with a good familiarity with the patterns that we might obtain. Therefore, we may use **Fig. 2** as a reference or guide and show pattern variations as a set of notes attached to each sample. We shall continue to use azimuth or free-space H-plane patterns for a consistent set of references to the radiation characteristics for the modeled antennas.

Fig. 2



Depth may vary up to 3 dB

Null depth may vary

Middle lobe strength may vary

Typical Free-Space E-Plane Patterns: P3 Driver with Small Planar Reflector

The "normal" pattern consists of one forward lobes and one rearward lobe, as shown at the upper left. The beamwidth may vary, but the general outline does not change. At some higher frequency, the beamwidth grows to a point where the maximum gain does not appear along the main axis or bore sight of the antenna. Instead, we obtain two main headings, each angularly equidistant from the main axis. However, the forward lobe remains singular with a depression in gain along the bore sight that does not exceed 3 dB. A depression of 3 dB or more results in the pattern at the lower left. Since 3 dB marks the half-power point, each main heading now has its own calculated beamwidth. The depth of the null along the main array axis depends on two factors: the beamwidth of the individual lobes and the angular separation from the main axis. Of course, the dividing line between a 2-heading and a 2-lobe pattern is arbitrary, since it uses the half-power beamwidth convention as the dividing line. In reality, if we use small enough frequency increments, we may show patterns that approach a main-axis null of 3 dB and then pass it, and the progression will be smooth, with only lines on the plot to register the passage. A main-axis null of 2.9 dB and one of 3.1 dB will show not detectable differences in operational performance. Nevertheless, the distinction is useful. In the tabular data for 2-heading patterns, I shall indicate the depth of the main-axis null to provide an indication of how closely the pattern approaches the 3-dB limit.

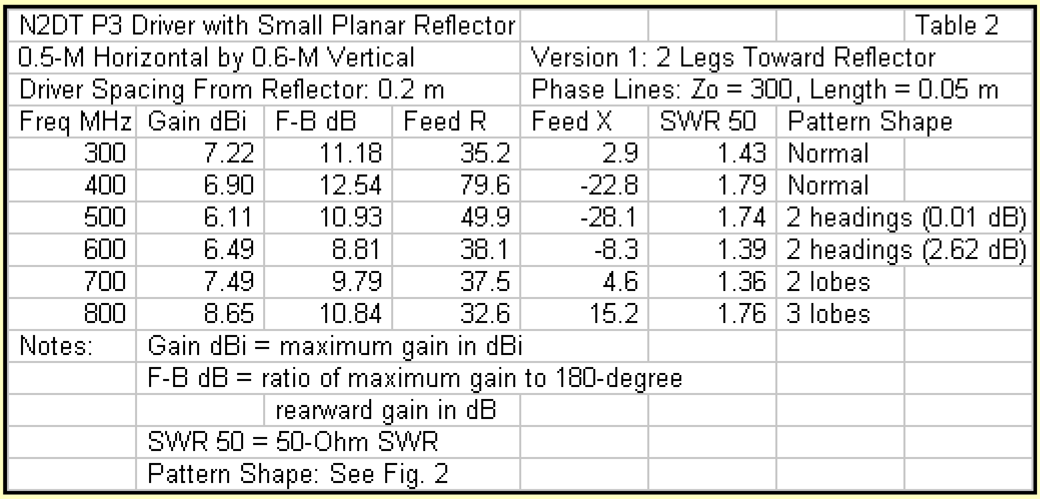
As the main lobes of a 2-lobe pattern diverge from the array axis, we find the development of a third forward lobe along the bore sight. When very small in strength compared to the 2 main lobes, we may ignore it. However, when the lobe approaches a strength that is only about 6 dB down from the maximum gain of the array, it is strong enough to affect operational performance. At roughly that point, we may call the radiation plot a 3-lobe pattern. The center lobe will increase in relative strength with further increases in frequency until the central lobe equals or exceeds the strength of the angular lobes. As long as the angular lobes have a strength that is within about 6 dB of the central lobes, we still have a 3-lobe pattern. Once the angular lobes fall below the arbitrary 6-dB limit, we may simply call them forward sidelobes. None of the patterns that we shall survey will even reach lobe-strength parity, so we shall not need to invoke the language of forward sidelobes. We should also note that a 3-lobe pattern may also show the beginnings of a 3-lobe rearward pattern, as illustrated by the lower right plot in **Fig. 3**.

The significance of these differences shows up in trying to set the frequency limits of a given array configuration. In general, 2-lobe and 3-lobe patterns are unusable for applications that call for maximum forward gain along the main array axis. Normal patterns, of course, are the most desirable. The 2-heading pattern represents a frontier between the usable and the unusable. Since the main-axis gain may range from 0.01 dB up to 3 dB lower than the peak gain value, the utility of the array for a given application depends upon the acceptable gain depression and the beamwidth that we can also accept. That decision rests upon project specification brought to the design process. Hence, we can make no judgment in the abstract. By noticing the frequency at which the 2-heading patterns emerge, we can mark the frontier region between the useful and the useless, leaving finer gradation for project-directed exercises.

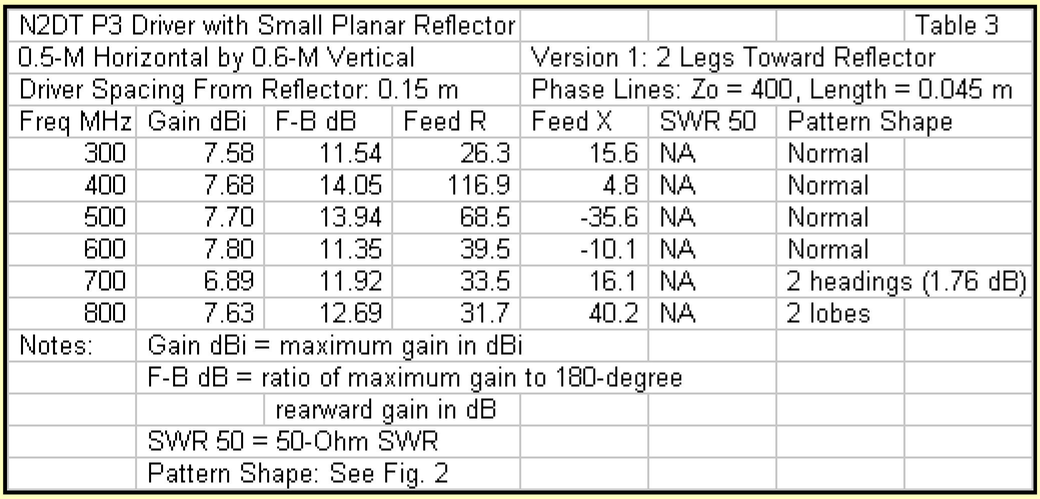
Version 1 Data

Table 2 through **Table 4** present the free-space modeling data for the version-1 P3 configuration with 2 legs toward the reflector. The tables progress from a driver-reflector spacing of 0.2 m to 0.12 m. We used the 0.2-m spacing in the main article to illustrate the effects of using the small reflector. Each table lists the sampled frequency, the maximum forward gain, and a front-to-back ratio. In all cases, the front-to-back ratio is the ratio in dB of the direct rearward gain at a tangent to the rear of the reflector to the maximum gain, at whatever angle that gain occurs. Each table also records the feedpoint resistance and reactance in Ohms. Only one of the tables (**Table 2**) records a 50-Ohm SWR value. The other tables record NA for "not applicable." As the spacing between the driver and the reflector decreases, no phase-line Zo and length combination yields an SWR bandwidth at any reference value that covers a significantly wide portion of the total passband in the survey. It might be possible to reset the physical dimensions of the P3 driver to yield a wide SWR bandwidth at some reference impedance, but this exercise does not explore that aspect of redesign. The redesign might also achieve its goal by using fatter element wires than the 0.015-m value used in these models. That option, however, falls outside what acceptable models can show.

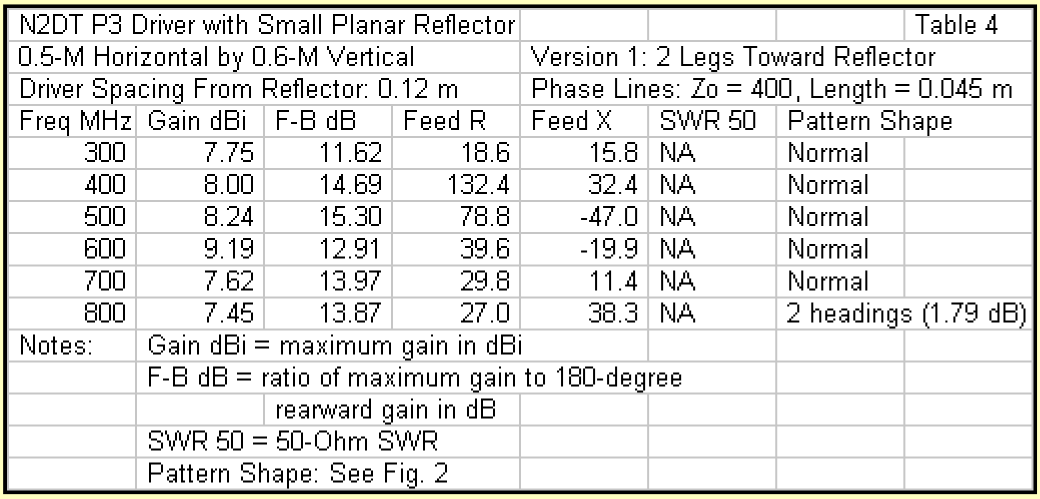
The final column of each table notes the type of H-plane pattern that appears on each of the sampled frequencies. Refer to **Fig. 2** for an orientation to the appearance of the patterns.



N2DT P3 Driver with Small Planar Reflector						Table 2
0.5-M Horizontal by 0.6-M Vertical				Version 1: 2 Legs Toward Reflector		
Driver Spacing From Reflector: 0.2 m				Phase Lines: Zo = 300, Length = 0.05 m		
Freq MHz	Gain dBi	F-B dB	Feed R	Feed X	SWR 50	Pattern Shape
300	7.22	11.18	35.2	2.9	1.43	Normal
400	6.90	12.54	79.6	-22.8	1.79	Normal
500	6.11	10.93	49.9	-28.1	1.74	2 headings (0.01 dB)
600	6.49	8.81	38.1	-8.3	1.39	2 headings (2.62 dB)
700	7.49	9.79	37.5	4.6	1.36	2 lobes
800	8.65	10.84	32.6	15.2	1.76	3 lobes
Notes:	Gain dBi = maximum gain in dBi					
	F-B dB = ratio of maximum gain to 180-degree					
		rearward gain in dB				
	SWR 50 = 50-Ohm SWR					
	Pattern Shape: See Fig. 2					



N2DT P3 Driver with Small Planar Reflector						Table 3
0.5-M Horizontal by 0.6-M Vertical				Version 1: 2 Legs Toward Reflector		
Driver Spacing From Reflector: 0.15 m				Phase Lines: Zo = 400, Length = 0.045 m		
Freq MHz	Gain dBi	F-B dB	Feed R	Feed X	SWR 50	Pattern Shape
300	7.58	11.54	26.3	15.6	NA	Normal
400	7.68	14.05	116.9	4.8	NA	Normal
500	7.70	13.94	68.5	-35.6	NA	Normal
600	7.80	11.35	39.5	-10.1	NA	Normal
700	6.89	11.92	33.5	16.1	NA	2 headings (1.76 dB)
800	7.63	12.69	31.7	40.2	NA	2 lobes
Notes:	Gain dBi = maximum gain in dBi					
	F-B dB = ratio of maximum gain to 180-degree					
		rearward gain in dB				
	SWR 50 = 50-Ohm SWR					
	Pattern Shape: See Fig. 2					



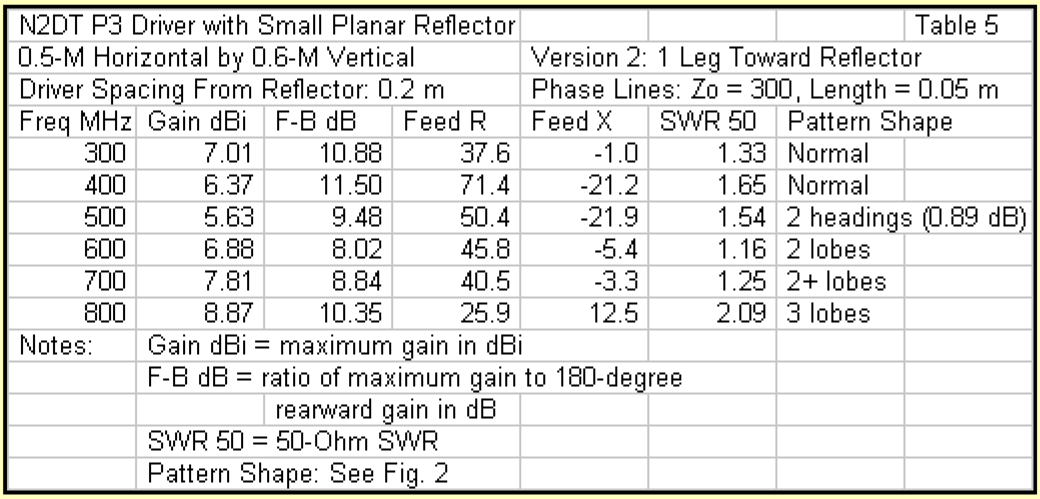
N2DT P3 Driver with Small Planar Reflector						Table 4
0.5-M Horizontal by 0.6-M Vertical				Version 1: 2 Legs Toward Reflector		
Driver Spacing From Reflector: 0.12 m				Phase Lines: Zo = 400, Length = 0.045 m		
Freq MHz	Gain dBi	F-B dB	Feed R	Feed X	SWR 50	Pattern Shape
300	7.75	11.62	18.6	15.8	NA	Normal
400	8.00	14.69	132.4	32.4	NA	Normal
500	8.24	15.30	78.8	-47.0	NA	Normal
600	9.19	12.91	39.6	-19.9	NA	Normal
700	7.62	13.97	29.8	11.4	NA	Normal
800	7.45	13.87	27.0	38.3	NA	2 headings (1.79 dB)
Notes:	Gain dBi = maximum gain in dBi					
	F-B dB = ratio of maximum gain to 180-degree					
		rearward gain in dB				
	SWR 50 = 50-Ohm SWR					
	Pattern Shape: See Fig. 2					

For version-1 arrays, several trends emerge from the tables. First, the maximum gain increases at virtually all frequencies with a closer spacing to the reflector. Second, the average front-to-back ratio also increases with a closer spacing between the driver and the reflector. Perhaps most notable among the consequences of closer spacing is the increasing frequency at which we obtain normal patterns. With a spacing of 0.12 m, we find normal patterns through 700 MHz, and even the 2-heading pattern may--under some circumstances--be declared usable.

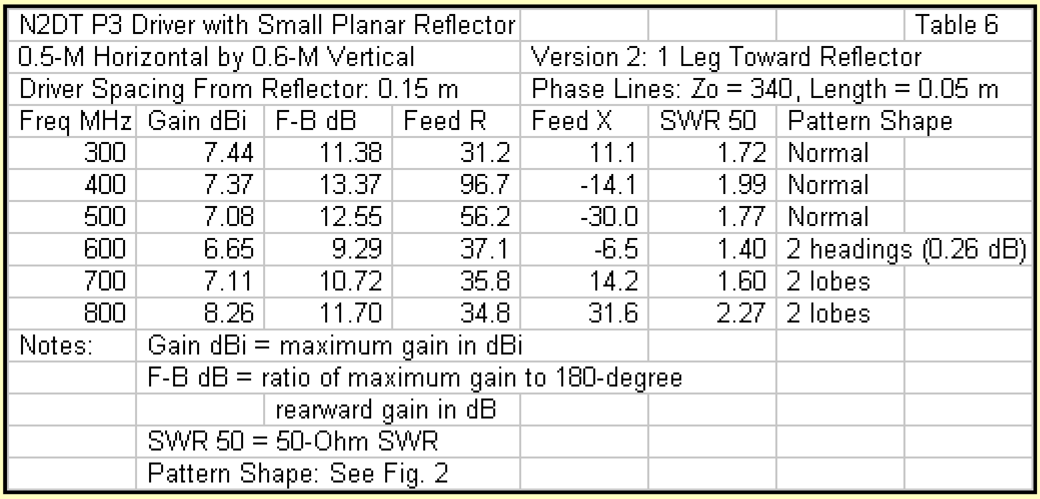
Offsetting the performance improvements that we obtain from bringing the driver and reflector closer together is the fact that the feedpoint impedance increases its range of values, a fact that precludes obtaining a standard and acceptable 2:1 SWR curve. For resistance values, the 0.2-m spacing yields resistances between 32 and 80 Ohms. At a 0.15-m spacing, the range increase to values of 26 and 117 Ohms. Further compressing the spacing gives us 18 to 132 Ohms. To obtain the performance benefits of the closest spacing, we would need to solve a rather complex matching challenge.

Version 2 Data

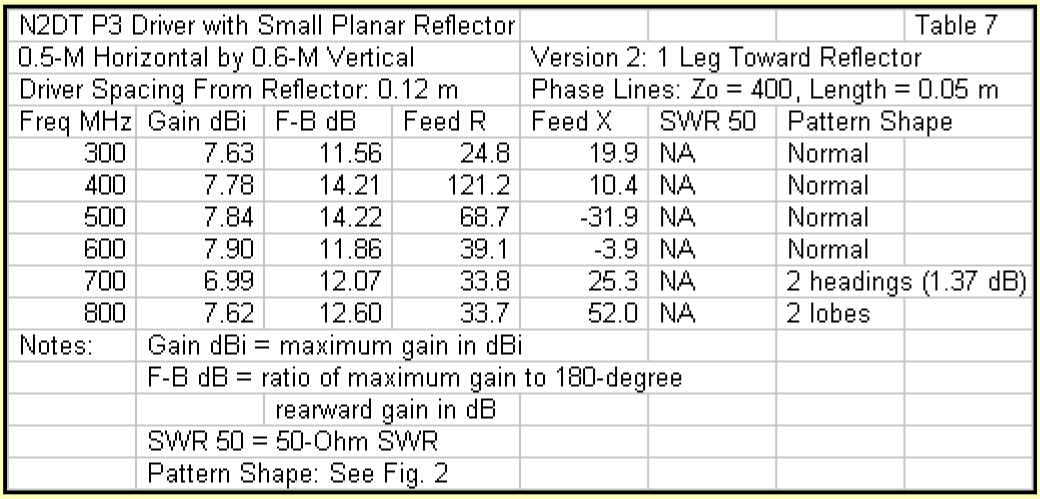
Table 5 through **Table 7** present the free-space modeling data for the version-2 configuration, with only one leg of the P3 driver closest to the reflector. Except for the specific data, the tables are identical in structure to the tables for the version-1 arrangement.



N2DT P3 Driver with Small Planar Reflector						Table 5
0.5-M Horizontal by 0.6-M Vertical				Version 2: 1 Leg Toward Reflector		
Driver Spacing From Reflector: 0.2 m				Phase Lines: Zo = 300, Length = 0.05 m		
Freq MHz	Gain dBi	F-B dB	Feed R	Feed X	SWR 50	Pattern Shape
300	7.01	10.88	37.6	-1.0	1.33	Normal
400	6.37	11.50	71.4	-21.2	1.65	Normal
500	5.63	9.48	50.4	-21.9	1.54	2 headings (0.89 dB)
600	6.88	8.02	45.8	-5.4	1.16	2 lobes
700	7.81	8.84	40.5	-3.3	1.25	2+ lobes
800	8.87	10.35	25.9	12.5	2.09	3 lobes
Notes:	Gain dBi = maximum gain in dBi					
	F-B dB = ratio of maximum gain to 180-degree					
		rearward gain in dB				
	SWR 50 = 50-Ohm SWR					
	Pattern Shape: See Fig. 2					



N2DT P3 Driver with Small Planar Reflector						Table 6
0.5-M Horizontal by 0.6-M Vertical				Version 2: 1 Leg Toward Reflector		
Driver Spacing From Reflector: 0.15 m				Phase Lines: Zo = 340, Length = 0.05 m		
Freq MHz	Gain dBi	F-B dB	Feed R	Feed X	SWR 50	Pattern Shape
300	7.44	11.38	31.2	11.1	1.72	Normal
400	7.37	13.37	96.7	-14.1	1.99	Normal
500	7.08	12.55	56.2	-30.0	1.77	Normal
600	6.65	9.29	37.1	-6.5	1.40	2 headings (0.26 dB)
700	7.11	10.72	35.8	14.2	1.60	2 lobes
800	8.26	11.70	34.8	31.6	2.27	2 lobes
Notes:	Gain dBi = maximum gain in dBi					
	F-B dB = ratio of maximum gain to 180-degree					
		rearward gain in dB				
	SWR 50 = 50-Ohm SWR					
	Pattern Shape: See Fig. 2					



N2DT P3 Driver with Small Planar Reflector						Table 7
0.5-M Horizontal by 0.6-M Vertical				Version 2: 1 Leg Toward Reflector		
Driver Spacing From Reflector: 0.12 m				Phase Lines: Zo = 400, Length = 0.05 m		
Freq MHz	Gain dBi	F-B dB	Feed R	Feed X	SWR 50	Pattern Shape
300	7.63	11.56	24.8	19.9	NA	Normal
400	7.78	14.21	121.2	10.4	NA	Normal
500	7.84	14.22	68.7	-31.9	NA	Normal
600	7.90	11.86	39.1	-3.9	NA	Normal
700	6.99	12.07	33.8	25.3	NA	2 headings (1.37 dB)
800	7.62	12.60	33.7	52.0	NA	2 lobes
Notes:	Gain dBi = maximum gain in dBi					
	F-B dB = ratio of maximum gain to 180-degree					
		rearward gain in dB				
	SWR 50 = 50-Ohm SWR					
	Pattern Shape: See Fig. 2					

Internally, the version-2 tables show the same progressions that we found in the version-1 tables. Maximum forward gain levels increase with smaller spacing values, as do front-to-back values. These improvements are especially notable for normal patterns, which increase in number as we close the driver-reflector spacing.

In addition to these gains, we discover that with a spacing of 0.15 m between the driver and the reflector, we may obtain a broadband 50-Ohm SWR curve, something that we could not achieve with the version-1 counterpart. *This result is important, since it indicates that the effective spacing between the driver and the reflector is not a function of the closest leg alone. Rather, it is a function of (roughly) the average distance of all 3 legs to the reflector.* We may further appreciate this fact by examining several other columns in the tables for both version 1 and version 2. First, the version-2 patterns show a smaller benefit in lobe structure than the version-1 patterns for the same physical spacing. The version-1 models show a 100-MHz improvement in acceptable patterns relative to the version-2 models at the same distance. (The improvement is only approximate due to the use of such widely spaced frequency increments.) Second, the version-2 gain values for a given spacing correspond most closely to the versions-1 gain values for the next wider spacing. Indeed, the impedance values for the version-2 array with a spacing 0.12 m (**Table 7**) closely coincide with the impedance values for the version-1 array with a spacing of 0.15 m (**Table 3**).

The P2 Driver and Variations in Spacing

In general, based upon our work in the main article, we should expect the P2 driver to act more like version 1 of the P3 than like version 2. The P2 driver is a rectangle, with phase-lines emerging from the center of each long wire to a central feedpoint. **Fig. 3** provides the outline of the P2 with a wire-grid planar reflector, which uses the 0.5-m by 0.6-m dimensions. As we did for the P3, we shall begin with a review of the performance with a driver-reflector spacing of 0.2 m, followed by surveys using 0.15 m and 0.12 m as the closer spacing values.

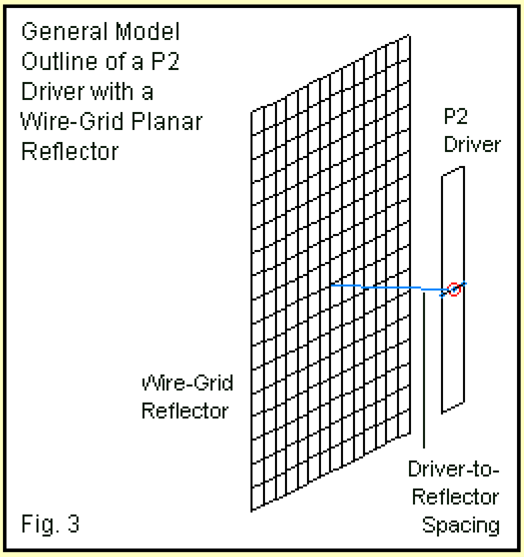
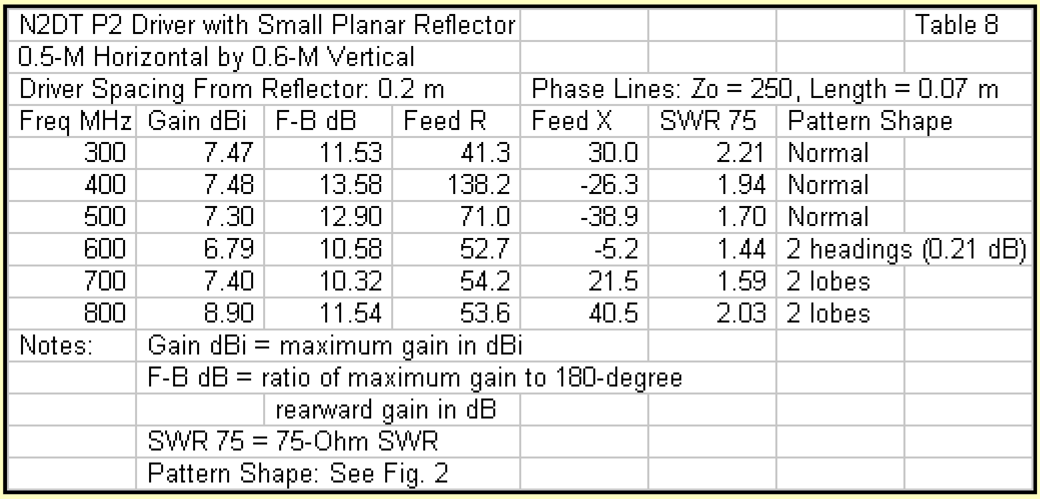
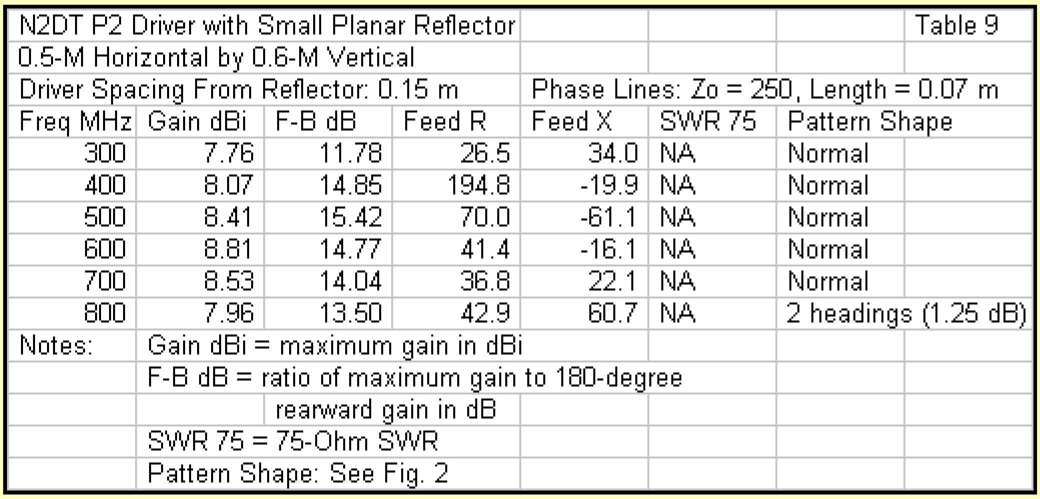


Fig. 3

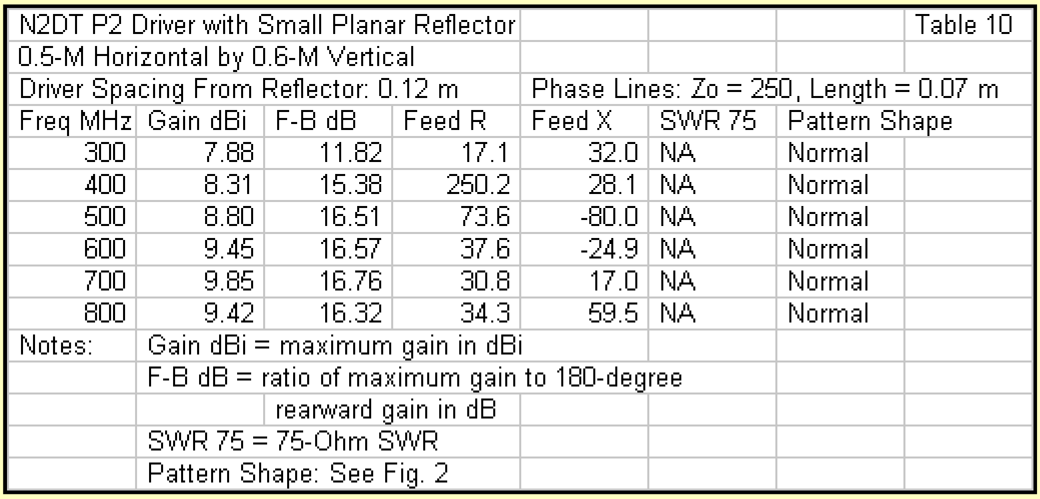
In some ways, we might expect the P3 driver to act as if it is closer to the reflector than the version-1 P3 driver, since the average distance to the driver is strictly 0.2 m. In contrast, even the version-1 P3 array underwent some effect from the single leg that was farther forward. **Table 8** through **Table 10** provide the data for the P2 array using the designated spacing values.



N2DT P2 Driver with Small Planar Reflector							Table 8
0.5-M Horizontal by 0.6-M Vertical							
Driver Spacing From Reflector: 0.2 m				Phase Lines: Zo = 250, Length = 0.07 m			
Freq MHz	Gain dBi	F-B dB	Feed R	Feed X	SWR 75	Pattern Shape	
300	7.47	11.53	41.3	30.0	2.21	Normal	
400	7.48	13.58	138.2	-26.3	1.94	Normal	
500	7.30	12.90	71.0	-38.9	1.70	Normal	
600	6.79	10.58	52.7	-5.2	1.44	2 headings (0.21 dB)	
700	7.40	10.32	54.2	21.5	1.59	2 lobes	
800	8.90	11.54	53.6	40.5	2.03	2 lobes	
Notes:	Gain dBi = maximum gain in dBi						
	F-B dB = ratio of maximum gain to 180-degree						
		rearward gain in dB					
	SWR 75 = 75-Ohm SWR						
	Pattern Shape: See Fig. 2						



N2DT P2 Driver with Small Planar Reflector							Table 9
0.5-M Horizontal by 0.6-M Vertical							
Driver Spacing From Reflector: 0.15 m				Phase Lines: Zo = 250, Length = 0.07 m			
Freq MHz	Gain dBi	F-B dB	Feed R	Feed X	SWR 75	Pattern Shape	
300	7.76	11.78	26.5	34.0	NA	Normal	
400	8.07	14.85	194.8	-19.9	NA	Normal	
500	8.41	15.42	70.0	-61.1	NA	Normal	
600	8.81	14.77	41.4	-16.1	NA	Normal	
700	8.53	14.04	36.8	22.1	NA	Normal	
800	7.96	13.50	42.9	60.7	NA	2 headings (1.25 dB)	
Notes:	Gain dBi = maximum gain in dBi						
	F-B dB = ratio of maximum gain to 180-degree						
		rearward gain in dB					
	SWR 75 = 75-Ohm SWR						
	Pattern Shape: See Fig. 2						



N2DT P2 Driver with Small Planar Reflector							Table 10
0.5-M Horizontal by 0.6-M Vertical							
Driver Spacing From Reflector: 0.12 m				Phase Lines: Zo = 250, Length = 0.07 m			
Freq MHz	Gain dBi	F-B dB	Feed R	Feed X	SWR 75	Pattern Shape	
300	7.88	11.82	17.1	32.0	NA	Normal	
400	8.31	15.38	250.2	28.1	NA	Normal	
500	8.80	16.51	73.6	-80.0	NA	Normal	
600	9.45	16.57	37.6	-24.9	NA	Normal	
700	9.85	16.76	30.8	17.0	NA	Normal	
800	9.42	16.32	34.3	59.5	NA	Normal	
Notes:	Gain dBi = maximum gain in dBi						
	F-B dB = ratio of maximum gain to 180-degree						
		rearward gain in dB					
	SWR 75 = 75-Ohm SWR						
	Pattern Shape: See Fig. 2						

If we compare the gain values in these tables with the gain values in **Table 2** through **Table 4**, we can confirm our expectation. The best way to make the comparison is to select a frequency at which we obtain a normal pattern for all options, perhaps 400 MHz. For each spacing value, the P2 array shows a higher gain and a higher front-to-back ratio. Of course, we cannot clearly sort the gain advantage that arises from the broadside pattern of the P2, but at 400 MHz, that effect is close to minimal. Hence, the P2 driver gives every appearance of acting like a driver that is closer to the reflector than either version of the P3.

The broadside gain effect of the P2 driver shows up more significantly as we increase the operating frequency and therefore obtain a greater differential between broadside and edgewise gain. At 500 MHz, the version-1 P3 driver with a spacing of 0.2 m is just entering the 2-heading phase of pattern evolution. However, the corresponding P2 array provides us with a normal pattern. In fact, regardless of spacing, the P2 array shows a slower development of multiple lobes than the version-1 P3. At the closest spacing, the P2 array provides normal patterns from 300 to 800 MHz.

The improved pattern development comes at a cost in terms of the feedpoint impedance. To obtain the improved pattern formation over a wider passband, we must accept (without altering the P2 shape) an ever-widening range of feedpoint impedance values within the passband. Whereas the version-1 P3 at 0.12 m showed feedpoint resistance values between 18 and 132 Ohms, the P2 array at the same spacing shows a range between 17 and 250 Ohms, with the extreme values occurring at adjacent frequencies in the survey (300 and 400 MHz). As a consequence, the SWR bandwidth no longer matches the pattern behavior bandwidth, even with the intermediate 0.15-m spacing value.

There is a general trend in gain values that also deserves note, since it occurs for all three arrays. The highest gain values occur at frequencies well above the 300-MHz starting point. The closer the spacing, the higher the frequency becomes for the highest gain that still yields a normal pattern.

This phenomenon results from our use of the small reflector size, which is more apt to about 600 MHz than to 300 MHz. It also leaves considerable territory for future exploration, that is, finding the optimum size reflector for the portion of the overall spectrum on which we might wish to operate a P2 or P3 array.

Conclusion

Experimenting with various configurations of the P3 array and examining alternative driver-reflector spacing values for both P2 and P3 arrays has turned up a number of further general conclusions. First, as we reduce the distance between the driver and the reflector, we increase the forward gain and the front-to-back ratio. As well, we increase the frequency span over with any configuration yields normal patterns. Comparing the two versions of the P3 and adding in the P2 driver showed that the effective distance from the reflector to the driver is roughly the average distance, accounting for all driver long legs.

Nevertheless, once we try to access the improved pattern behavior by shrinking the distance between the driver and the reflector, we almost immediately encounter significant variations in the SWR bandwidth curve. Adjusting the Zo and the length of the phase lines does not provide a means of compensating for this variation. Unless one could find an alternative set of driver dimensions that would restore the impedance values with a closer spacing between the driver and the reflector, the prismatic polyhedron will not achieve both good pattern behavior and a wide and usable SWR bandwidth simultaneously. The absence of coincidence between pattern behavior and SWR is the chief limitation in exploiting the prismatic polyhedron as a driver for an exceptionally wideband planar array.

From here, you may return to Part 1 to review the main text on planar reflectors and the P3. Or, you may proceed to Part 2, which covers the P3 used with corner reflectors.

Return to Main Index