4b. Stacking 2-Element, 5-Band Quads

L. B. Cebik, W4RNL (SK)

Because there appears to be interest in the stacking potential of quads, especially 2-element, 5-band quads, I decided to stack a pair of models and seed what they would do. I used 24' spacing between array centers. I first ran the single array in free space, followed by the pair in free space, for a relative gain and general property check. I then placed the lower quad 50' up and the higher 24' above that to see if ground would create any undesirable effects. Details of the dimensions of the quads used in this preliminary exploration of stacking appear in Part 4 of this series.

The KC6T Planar 5-Band Quad

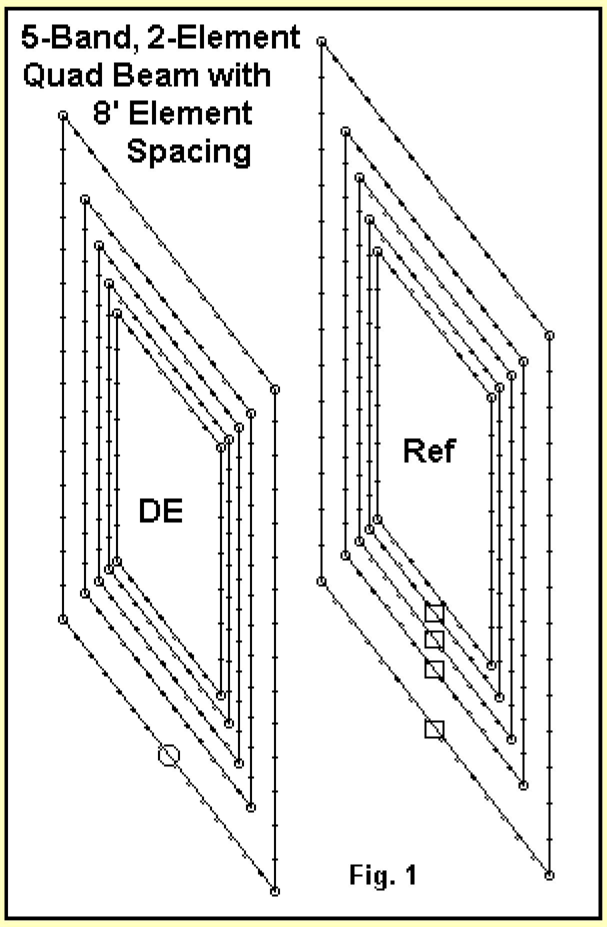


Fig. 1

The quads used in this initial run are models in NEC-4 of the KC6T quad in April, 1992 *QST* (p.52), one of the finest planar quad designs I have found with a constant 8' spacing, as shown in **Fig. 1**. It uses loading capacitance (modeled as a value of C and not as a value of -jX) in the reflector to set the operating frequency and my models are self-resonant without a matching network. The models have been set for the most desirable combination of gain, F-B, and impedance at mid-band to reveal the rate of change of these parameters both above and below the design frequency. **Fig. 2** shows an outline of the stacked pair of planar quads.

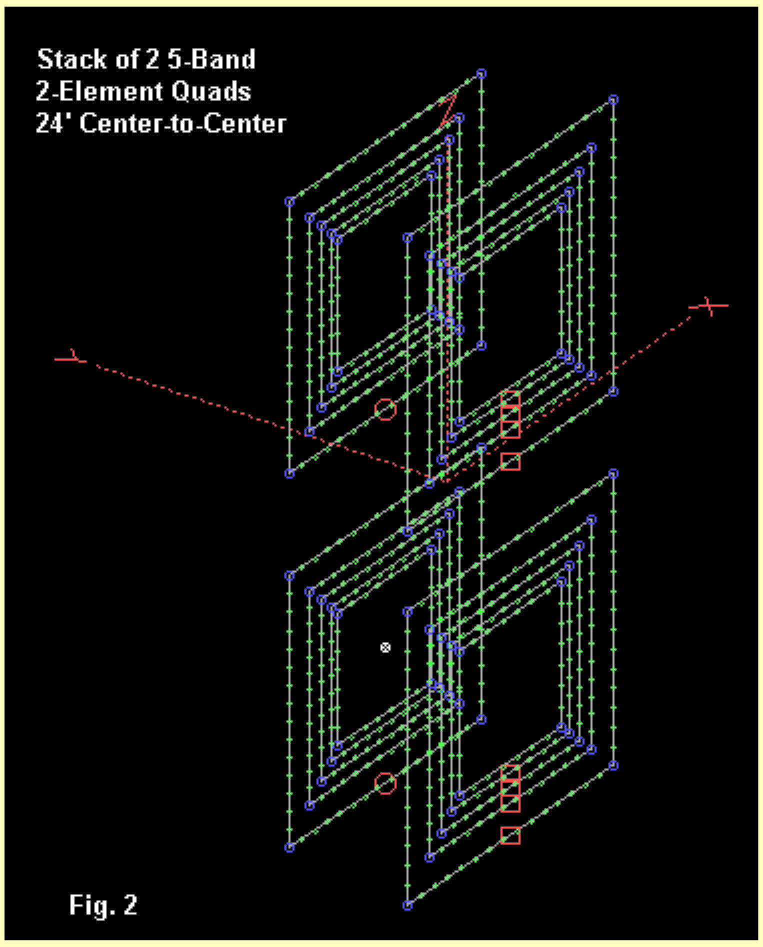


Fig. 2

The data consists of gain in dBi, TO angle (where relevant), F-B, beamwidth, feed Z(s) and 75-Ohm SWR (for which the original array had been set).

KC6T Quad in Free Space

Fq	Gain	F-B	B/W	Feed Z	SWR-75
14.0	7.6	8.3	69	34.7-45.6	3.10
14.175	7.2	24.0	73	76.6+ 1.6	1.03
14.35	6.4	11.6	76	112.2+ 9.4	1.52
18.118	7.3	31.7	74	69.5+ 1.7	1.08

21.0	7.7	12.6	72	47.3-30.0	1.96
21.225	7.3	34.4	75	69.5+ 1.7	1.08
21.45	6.7	14.2	77	89.6+19.3	1.34
24.94	7.2	30.6	76	77.0+ 0.3	1.03
28.0	7.7	14.5	75	65.9-54.2	2.15
28.5	7.5	22.8	77	75.4- 0.3	1.01
29	7.3	37.1	78	87.1+50.1	1.87

2 KC6T Quads stacked 24' apart in Free Space: Z1 (upper entry) = lower quad; Z2 (lower entry) = upper quad. Since both quads are fed on the lower element, some differentials in values are normal.

Fq	Gain	F-B	B/W	Feed Z 1/2	SWR-75 1/2
14.0	9.0	11.3	70	64.6-18.9	1.36
				66.7-20.4	1.30
14.175	8.8	20.4	73	120.8+23.2	1.70
				117.2+13.5	1.60
14.35	8.3	12.4	75	164.8+14.3	2.22
				154.2+12.3	2.07
18.118	9.5	21.5	73	86.8+ 3.6	1.17
				85.9+ 4.1	1.16
21.0	10.1	12.9	72	56.3-29.9	1.71
				56.1-29.6	1.71
21.225	9.9	22.3	75	81.3+ 1.3	1.09
				81.1+ 1.8	1.09
21.45	9.5	13.3	77	104.1+14.6	1.44
				104.2+15.2	1.45
24.94	10.2	23.1	77	84.1- 5.0	1.14
				84.6 -4.9	1.15
28.0	10.8	15.1	75	70.0-57.0	2.16
				70.2-56.7	2.15
28.5	10.7	23.5	77	79.7- 2.2	1.07
				79.9- 2.0	1.07
29	10.5	26.8	78	92.5+48.6	1.84
				92.7+48.9	1.85

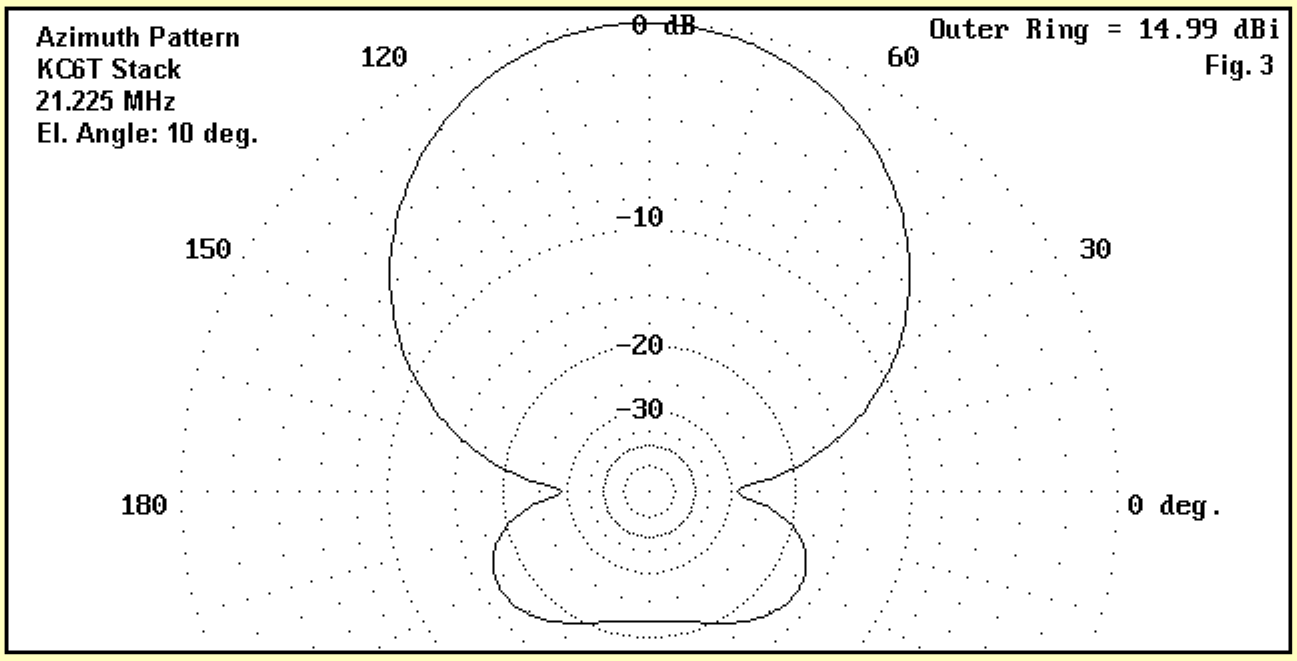
Stacking Gain averaged by bands:

20	17	15	12	10
1.6	2.2	2.6	3.0	3.2 dB

2 KC6T Quads stacked 24' apart in 50' and 74' above average ground: Z1 (upper entry) = lower quad; Z2 (lower entry) = upper quad. Since both quads are fed on the lower element, some differentials in values are normal.

Fq	Gain	F-B	B/W	Feed Z 1/2	SWR-75 1/2	TO
14.0	13.6	11.7	71	64.2-19.1	1.37	15
				66.6-20.0	1.36	
14.175	13.4	20.5	74	117.0+19.6	1.63	14
				120.1+18.5	1.66	
14.35	13.0	12.1	76	156.4+20.5	2.13	14
				162.8+ 8.5	2.18	
18.118	14.4	21.6	74	87.7+ 4.5	1.18	11
				85.3+ 3.5	1.15	
21.0	15.1	13.1	72	56.7-29.8	1.70	10
				55.8-29.7	1.72	
21.225	15.0	22.0	75	82.3+ 1.1	1.10	10
				80.5+ 2.1	1.08	
21.45	14.6	13.1	78	105.1+13.4	1.45	10
				103.8+16.3	1.45	
24.94	15.4	22.1	77	82.7- 5.8	1.13	8
				86.2 -5.5	1.17	
28.0	15.9	14.9	75	69.1-56.1	2.15	8
				69.3-57.5	2.18	
28.5	15.8	22.9	77	79.3- 0.9	1.06	7
				78.7- 1.9	1.06	
29	15.7	26.5	79	92.7+50.2	1.87	7
				91.8+49.6	1.86	

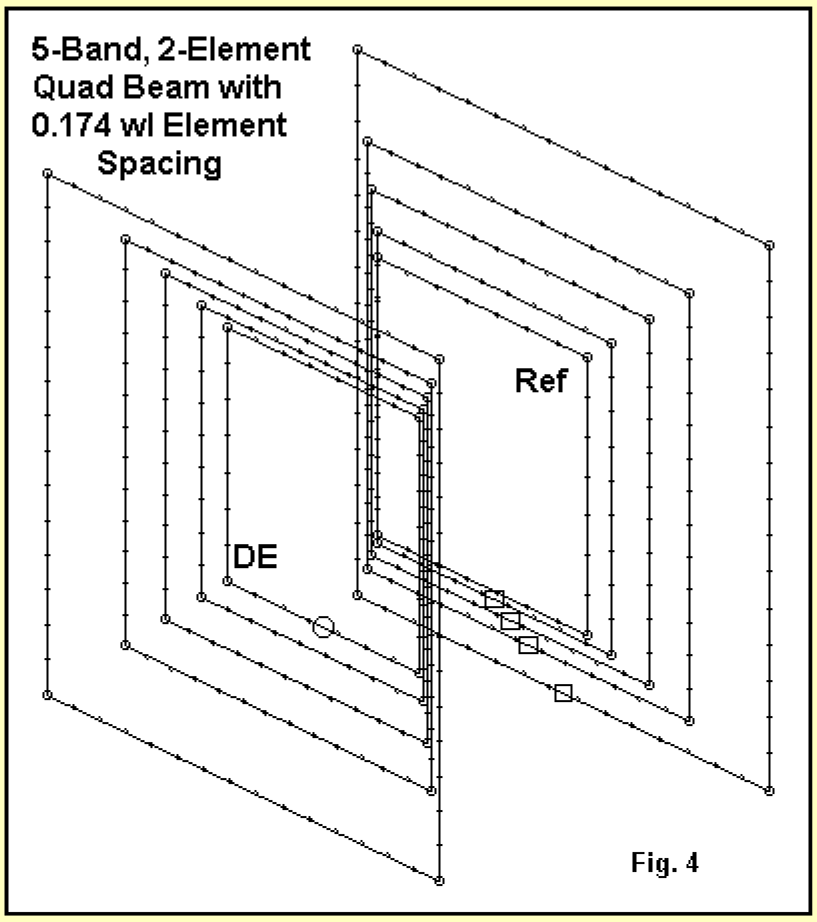
As is clearly evident, the particular quad design explored here does not suffer from being placed over ground at 50' for the center of the bottom array and at 74' for the center of the top array. The front-to-back and impedance values hold closely to their free-space values--sufficiently so that I could not think of recommending a design change. In addition, stacking appears to shift the operating parameters to provide operating bandwidth in the stack that is superior to that of the single array. Assuming that an in-phase feedline harness can be devised, the coax run should bring virtually all SWR values under 2:1 at the shack. For the stacks, they are all well within rig-tuner range without excessive loss.



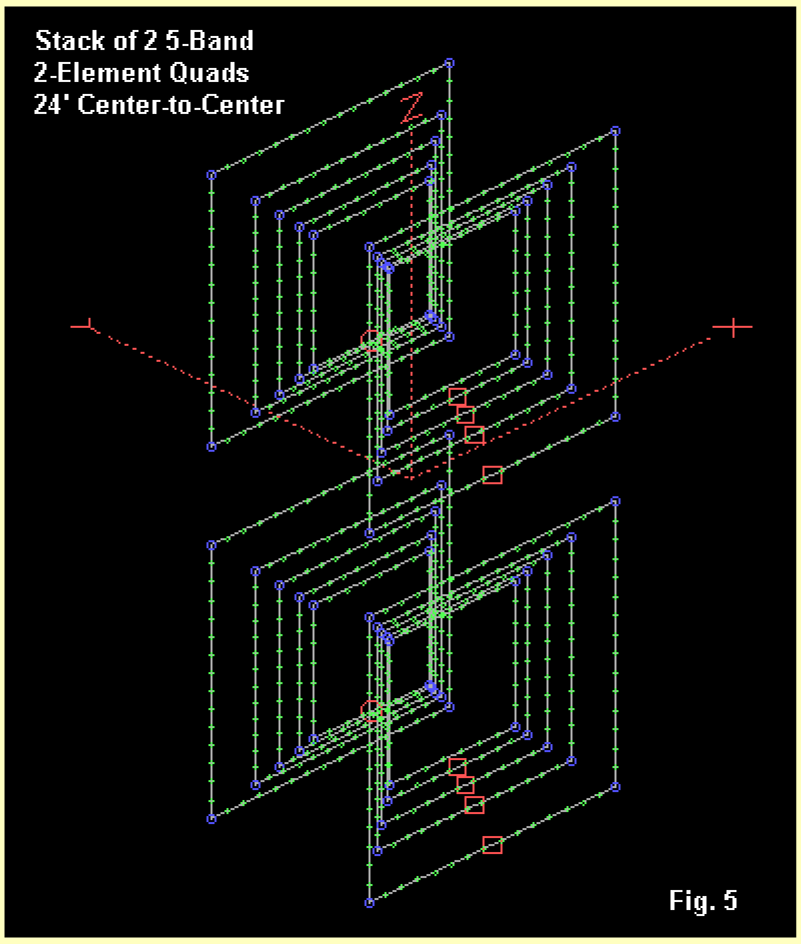
For reference, **Fig. 3** shows the azimuth pattern at mid-band in 15 meters for the array over ground.

A 0.174 WL Spaced Spider Quad

The following data apply to a stack of 2 spider-construction 2-element, 5-band quads, spaced 24' center-to-center. The element spacing of this model is 0.174 wavelength. The spacing is wider than most commercial spider quads, which range from about 0.11 to 0.13 wavelength. An outline appears in **Fig. 4**. Clear in the sketch are the reflector loads, similar to those used on the KC6T model. See Part 4 of this series for details.



As with the KC6T planar model, the series of tables begin with data for a single array in free space, followed by a stack of 2 in free space. The last table places the antennas at 50' and 74', respectively, above good soil. **Fig. 5** shows the outline of the pair of spider quads in their stack.



The data consists of gain in dBi, TO angle (where relevant), F-B, beamwidth, feed Z(s) and 75-Ohm SWR (for which the original array had been set).

0.174-WL Spider Quad in Free Space

Fq	Gain	F-B	B/W	Feed Z	SWR-75
14.0	7.6	9.2	71	76.6-22.8	1.35
14.175	7.1	23.4	75	117.3- 2.1	1.57
14.35	6.3	11.8	79	129.7- 1.7	1.73
18.118	7.1	25.3	76	92.8+ 8.7	1.27
21.0	7.6	12.0	73	53.1-13.5	1.50
21.225	7.1	29.1	77	79.7+20.2	1.31
21.45	6.5	14.3	80	105.8+36.5	1.70
24.94	7.0	29.8	76	69.3+ 2.2	1.09
28.0	7.4	20.4	77	48.5-39.8	2.17
28.5	7.2	32.1	79	58.5+16.7	1.42
29	6.9	18.1	81	70.5+70.1	2.54

2 0.174-WL Spider Quads stacked 24' apart in Free Space: Z1 (upper entry) = lower quad; Z2 (lower entry) = upper quad. Since both quads are fed on the lower element, some differentials in values are normal.

Fq	Gain	F-B	B/W	Feed Z 1/2	SWR-75 1/2
14.0	8.9	11.4	72	131.1- 1.3	1.83
				136.4-14.9	1.85
14.175	8.7	26.4	75	196.0- 4.7	2.61
				170.9- 9.5	2.29
14.35	8.2	16.4	78	196.9-32.2	2.71
				180.6-18.0	2.44
18.118	9.4	26.4	76	119.5+10.0	1.61
				117.9+11.0	1.59
21.0	10.0	12.3	73	62.5-10.7	1.27
				62.2-10.5	1.27
21.225	9.8	30.3	77	93.6+24.4	1.44
				93.1+24.7	1.44
21.45	9.3	14.3	80	126.9+35.9	1.89
				126.5+36.6	1.89
24.94	10.1	33.1	78	76.3+ 1.4	1.03
				76.7+ 1.6	1.03
28.0	10.5	20.2	77	49.9-39.5	2.11
				50.1-39.3	2.10
28.5	10.3	26.4	79	60.1+18.5	1.42
				60.2+18.7	1.42
29	10.1	17.9	81	73.2+73.7	2.61
				73.3+74.1	2.62

Stacking Gain averaged by bands:

20	17	15	12	10
1.6	2.2	2.7	3.0	3.3 dB

2 0.174-WL Spider Quads stacked 24' apart in 50' and 74' above average ground: Z1 (upper entry) = lower quad; Z2 (lower entry) = upper quad. Since both quads are fed on the lower element, some differentials in values are normal.

Fq	Gain	F-B	B/W	Feed Z 1/2	SWR-75 1/2	TO
14.0	13.6	11.8	73	135.1- 3.0	1.80	15
				137.6-11.6	1.85	
14.175	13.4	28.7	76	183.4+ 0.3	2.45	14
				182.1-11.4	2.44	
14.35	12.9	15.8	79	197.1-16.3	2.65	14
				182.9-29.1	2.51	
18.118	14.3	28.1	76	121.3+11.0	1.64	12
				116.6+10.3	1.56	
21.0	15.0	12.6	74	62.9-10.4	1.26	10
				61.8-10.6	1.28	
21.225	14.9	29.6	77	94.9+24.4	1.45	10
				92.1+25.0	1.44	
21.45	14.4	14.0	80	128.5+34.6	1.89	10
				125.7+38.2	1.90	
24.94	15.3	29.8	78	75.5+ 0.2	1.01	9
				78.0+ 1.7	1.05	
28.0	15.7	19.9	77	49.1-38.9	2.12	8
				49.4-39.8	2.14	
28.5	15.5	25.5	79	59.6+19.5	1.49	7
				59.3+18.8	1.44	
29	15.4	17.5	81	73.2+75.0	2.65	7
				72.7+74.6	2.64	

The main line of the numbers for the spider quad are similar to those of the planar quad. However, certain deviations are worth noting. First, the spider quad impedance values for the upper and lower antennas differ somewhat more than comparable figures for the planar model. It would appear that especially the outer bands (17 and most radically 20 meters) are susceptible to changes. Second, the 20-meter--and to a lesser extent, the 10-meter--antennas alter impedance values when placed into the stack-- enough to require retuning of these portions of the arrays. The spider construction leaves the impression that either it leaves the individual band elements more exposed to external influence or that the planar quad is more immune to external influence--perhaps two ways of saying the same thing. The bottom line remains that spider construction quads are likely to need more than a little reformulation when placed in a closely spaced stack.

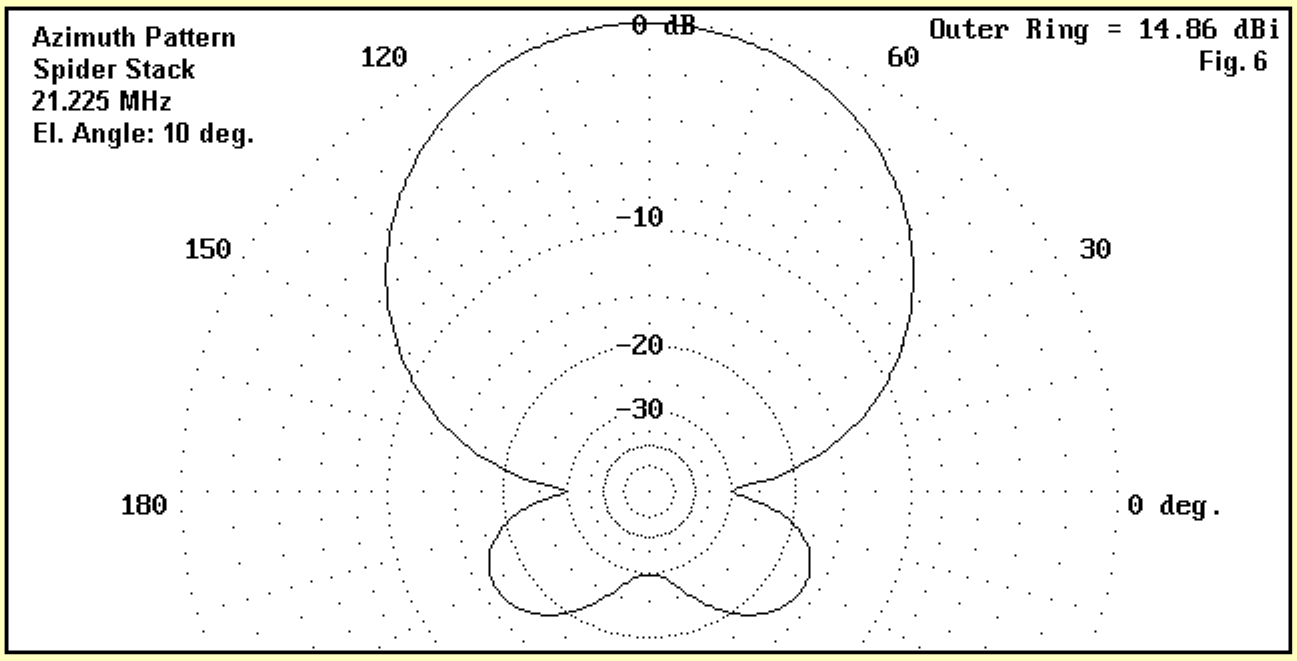


Fig. 6 shows the 15-meter azimuth pattern at mid-band over ground for reference.

A 0.125 WL Spaced Spider Quad

The following data apply to a stack of 2 spider-construction 2-element, 5-band quads, spaced 24' center-to-center. The element spacing of this model is 0.125 wavelength, narrower than the preceding spider quad and closer to commercial implementations of the design, which range from about 0.11 to 0.13 wavelength. An outline appearing in **Fig. 4** is close enough to the present design not to need a new sketch, although this design uses exactly pruned reflectors with no loading. See Part 4 of this series for details.

As with the other models, the series of tables begin with data for a single array in free space, followed by a stack of 2 in free space. The last table places the antennas at 50' and 74', respectively, above good soil.

The data consists of gain in dBi, TO angle (where relevant), F-B, beamwidth, and feed Z(s). Due to the variability of the feedpoint impedances, an SWR column would be meaningless and has been omitted.

0.125-WL Spider Quad in Free Space

Fq	Gain	F-B	B/W	Feed Z
14.0	7.6	7.6	69	40.6-45.1
14.175	7.2	28.9	73	84.2- 0.1
14.35	6.4	12.8	76	117.7+ 5.6
18.118	7.2	32.4	73	60.9- 0.5
21.0	7.6	12.0	71	31.5-38.6
21.225	7.2	24.7	74	52.9+ 0.2
21.45	6.6	12.3	77	76.4+24.5
24.94	7.3	25.8	74	41.5+ 0.1
28.0	7.8	13.7	72	30.9-61.1
28.5	7.5	20.3	74	40.0- 0.3
29	7.2	15.6	76	50.4+54.7

2 0.125-WL Spider Quads stacked 24' apart in Free Space: Z1 (upper entry) = lower quad; Z2 (lower entry) = upper quad. Since both quads are fed on the lower element, some differentials in values are normal.

Fq	Gain	F-B	B/W	Feed Z 1/2
14.0	8.9	9.6	70	72.1-18.4
				73.2-20.7
14.175	8.8	22.2	73	130.0+24.9
				126.5+13.3
14.35	8.3	14.8	76	180.0+13.4
				163.1- 9.3
18.118	9.4	21.1	73	74.3+ 5.3
				73.5+ 5.0
21.0	10.0	11.8	71	36.8-37.4
				36.7-37.4
21.225	9.8	19.3	74	60.3+ 3.0
				60.0+ 3.0
21.45	9.4	11.7	77	88.7+25.7
				88.2+26.0
24.94	10.3	21.1	74	45.4- 0.8
				45.3- 0.7
28.0	10.8	13.8	72	32.1-62.4
				32.3-62.3
28.5	10.6	18.1	74	41.5- 0.9
				41.6- 0.7
29	10.4	14.1	76	52.6+54.5
				52.7+54.7

Stacking Gain averaged by bands:

20	17	15	12	10
1.6	2.2	2.6	3.0	3.1 dB

2 0.125-WL Spider Quads stacked 24' apart in 50' and 74' above average ground: Z1 (upper entry) = lower quad; Z2 (lower entry) = upper quad. Since both quads are fed on the lower element, some differentials in values are normal.

Fq	Gain	F-B	B/W	Feed Z 1/2	TO
14.0	13.6	9.8	70	71.6-18.7	14
				73.1-20.0	
14.175	13.5	23.0	74	125.2+21.4	14
				130.6+18.3	
14.35	13.0	14.3	76	170.4+21.6	14
				172.2+ 4.0	
18.118	14.4	21.3	74	74.8+ 6.3	11
				73.2+ 4.2	
21.0	15.0	11.9	71	37.0-37.2	10
				36.6-37.4	
21.225	14.9	19.0	75	61.0+ 3.2	10
				59.5+ 3.0	
21.45	14.5	11.5	77	90.0+25.2	10
				87.4+26.7	
24.94	15.4	20.9	74	45.1- 1.5	9
				46.0- 0.5	
28.0	15.9	13.7	72	31.8-62.0	8
				31.9-62.6	
28.5	15.7	17.8	74	41.3- 0.2	7
				40.9- 0.8	
29	15.6	14.0	76	52.6+55.4	7
				52.1+55.1	

The narrower spacing of the 0.125-WL spider design results in a narrower operating bandwidth, which shows up most clearly in the front-to-back curves that one can infer from the data. As well, when stacked, the sharp peak of the front-to-back curve does not need to be displaced much to appear as a significantly lower mid-band value, as in the charts for stacked versions of the design.

One disaadvantage of the more closely spaced spider design is that equal excursions of reactance across any given band--relative to the wider-spaced spider--will result in steeper SWR curves, due to the lower initial resistive component of the feedpoint impedance. As a result, the problem of obtaining a good match for all portions of all five bands may become a major challenge.

Wider Spacing

Experimental modeling with larger quad arrays in stacks suggests that wider spacing may effect greater isolation between bays. This intial 24' spacing is between 5/8 and 2/3 wavelength on 20 meters--and proportionally greater on the other bands. Hence, the major effect of modest increases in spacing from one array center to the other would be primarily on 20 and 17 meters.

Therefore, I reran the 0.125-wavelength spider array with a spacing of 30' or about 5/6 wavelength on 20 meters. I will provide the entire data set, including the single array free space information, to ease the process of making internal comparisons within the data. However, comparisons with the preceding data set are also very relevant to deciding what spacing may be best for this type of quad array.

0.125-WL Spider Quad in Free Space

Fq	Gain	F-B	B/W	Feed Z
14.0	7.6	7.6	69	40.6-45.1
14.175	7.2	28.9	73	84.2- 0.1
14.35	6.4	12.8	76	117.7+ 5.6
18.118	7.2	32.4	73	60.9- 0.5
21.0	7.6	12.0	71	31.5-38.6
21.225	7.2	24.7	74	52.9+ 0.2
21.45	6.6	12.3	77	76.4+24.5
24.94	7.3	25.8	74	41.5+ 0.1
28.0	7.8	13.7	72	30.9-61.1
28.5	7.5	20.3	74	40.0- 0.3
29	7.2	15.6	76	50.4+54.7

2 0.125-WL Spider Quads stacked 30' apart in Free Space: Z1 (upper entry) = lower quad; Z2 (lower entry) = upper quad. Since both quads are fed on the lower element, some differentials in values are normal.

Fq	Gain	F-B	B/W	Feed Z 1/2
14.0	9.3	7.7	69	57.2-39.2
				56.8-39.7
14.175	9.4	18.5	73	109.5+ 6.9
				106.9+ 6.5
14.35	8.9	14.5	76	156.0- 0.1
				153.3+ 3.1
18.118	10.1	19.8	74	71.3- 0.7
				71.1- 0.4
21.0	10.6	12.6	71	34.9-39.9
				34.9-40.0
21.225	10.4	17.8	75	59.6- 1.7
				59.6- 1.6
21.45	9.9	10.5	77	85.7+17.4
				85.7+17.5
24.94	10.7	23.0	74	43.5- 2.6
				43.5- 2.6
28.0	11.1	15.0	72	31.4-62.3
				31.4-62.4
28.5	10.9	18.4	75	41.7- 1.8
				41.7- 1.8
29	10.7	13.3	76	53.2+51.9
				53.3+51.9

Stacking Gain averaged by bands:

20	17	15	12	10
2.1	2.8	3.2	3.3	3.4 dB

2 0.125-WL Spider Quads stacked 30' apart in 50' and 80' above average ground: Z1 (upper entry) = lower quad; Z2 (lower entry) = upper quad. Since both quads are fed on the lower element, some differentials in values are normal.

Fq	Gain	F-B	B/W	Feed Z 1/2	TO
14.0	13.9	8.0	70	56.8-39.4	14
				57.1-39.3	
14.175	14.0	19.2	73	106.7+ 6.5	14
				109.1+ 7.1	
14.35	13.5	14.0	76	153.1+ 3.8	13
				155.6+ 0.0	
18.118	14.9	20.0	74	70.9+ 0.3	11
				71.1- 1.2	
21.0	15.5	12.6	71	35.2-39.7	9
				34.5-39.9	
21.225	15.3	17.5	76	60.9- 1.2	9
				58.6- 0.9	
21.45	14.8	10.4	78	87.7+16.6	9
				85.5+19.7	
24.94	15.7	22.6	75	42.9- 3.4	8
				44.2- 3.4	
28.0	16.2	14.7	72	31.1-62.0	7
				31.0-62.1	
28.5	16.0	18.0	75	41.3- 1.0	7
				41.4- 1.3	
29	15.8	13.1	77	52.2+53.1	7
				53.4+52.6	

The changes created by increasing the spacing are subtle. Increasing the height of the overall array by 6' changes the TO angle by only a fraction of a degree on any one band. If the change shows up in the chart, it is largely a function of rounding to the nearest degree. Gain is up, more on the lower bands than on the upper, but always under an average of a half dB. The front-to-back ratio appears to be down slightly--or the peak may have shifted in frequency so that it no longer coincides with the design frequency.

The chief merit of increasing the center-to-center spacing of the arrays to 30' shows up in the impedance column. First, the impedance values are closer to those for the single array in free space. Second, the differentials between upper and lower bay impedances are reduced. The latter effect is greater on the lowest bands but is evident to some degree on all bands. The benefit of this change from the more closely spaced stack is that once you have achieved the best arrangement for matching the main feedline to the drivers for an individual array, you can rely on that arrangement to satisfy the needs of the stack.

On paper, the added 6' of stacking space may seem little. However, it can make significant differences in bending forces on the stack mast. Whether it is wiser to shorten the stack and wrestle with the matching or to be assured of matching and increase the strength (and weight) of the mast is a stacker's decision.

Conclusion

I have been hesitant in the past to recommend stacking multi-band quads, given the fact that a quad is already a stack in itself. However, these figures suggest that--if one can handle the matching, the mechanicals, and the weather--the enterprise may prove worthy, even with relatively close spacing, as used in these models. The results--so far--suggest that planar designs may be the best behaved in a closely spaced stack in the sense of needing the least post-stacking adjustments.

There has been a predilection to overestimate the desirability (at least electrically) of the spider design because it provides each band with the same spacing in terms of wavelengths. However, as noted in Part 4, that intuition of benefit encompasses only part of what is going on with a 5-band 2-element quad. Element interaction plays a role in giving the planar design a degree of both stability from band to band and gain that is reduced as we move the elements from a single plane. Indeed, there are limits to this process, and these show up in 3-element designs and in efforts to add VHF frequencies to planar quads using the existing support arms. The mechanical differences in the schemes are, of course, beyond the scope of this modeling study.

As always, differences of design may yield different stacking results. As well, different stacking spacings may yield differences. The results also apply only to 5-band quads using separate ot switched feeds. Common feed system stacking results have not yet been explored. Every design should be thoroughly modeled before capital investment.

Go to Monoband Quads of More Than 2 Elements

Return to Quad Model Index

Return to Amateur Radio Page