Sneaking Up on 2-Element Common-Feed Quads
Part 2: Dual Band Quad Beams With Separate Feedpoints

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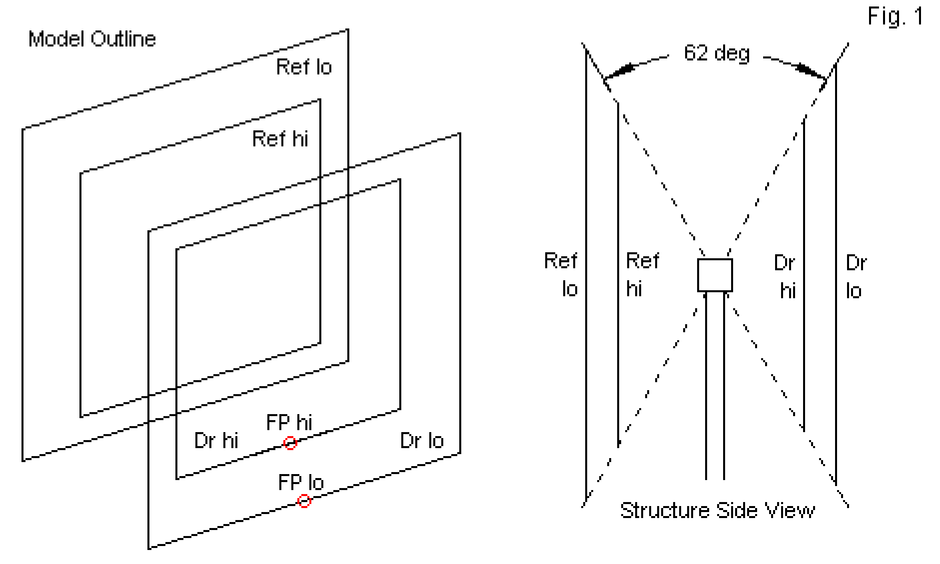
In Part 1 of this series, we defined our basic question about common-feedpoint multi-band quads this way:

> **What happens when we create a multi-band quad and provide it with a common driver feedpoint for all bands?**

We also set some limits to the exploration so that we might reduce the task to manageable proportions. We set a 2-band limit for the multi-band quads, although we shall examine one violation of the limit in this part. We also set a minimum frequency ratio of 1.3:1 between the bands included in the dual-band quads. (However, looking at adjacent upper HF ham-band combination might itself make a good study for the future.) We also noted the need to proceed in stages, looking at dual-band quads of 2 elements each using separate feedpoints for each band before we move on to joining the feedpoints. Our goal is to isolate insofar as possible whatever phenomena (physical or electrical) may be functions of using a common feedpoint and which may result simply from placing 2-element quad beams concentrically on a single support system.

A multi-band quad beam is a combination of monoband quad beams taken through successive modifications until arriving at the final form. To simplify the progression, I adopted spider construction for the beams, as shown in **Fig. 1**. In this part of our study, we shall use models like the one on the left to determine what modifications result from the proximity of the two antennas. The sketch of a side view of the resulting dual-band beam shows the spider arms and the nearly constant angle created by the driver and reflector elements for each band. Of course, for modeling runs and for operation, only one of the feedpoints would be active at any one time. The use of separate feedpoints and separate driver loops also helps assure that the models will automatically meet Average Gain Test (AGT) standards, so long as we segment each side so that the segment junctions for loops on different bands align reasonably well. A low-band to high-band segment/side ratio of 1.3 to 1.5 to 1 will generally satisfy this requirement by yielding AGT values from 0.998 to 1.002.

Fig. 1



General Outlines of 2-Element, 2-Band Quad Beams with Separate Feeds

To ease the design process, I selected monoband 2-element quads that have the broadest operating characteristics that I could devise. **Table 1** summarizes the dimensions of each beam in the upper HF series at the listed design frequencies. The side dimensions actually list half-sides for modeling convenience. A loop circumference is 8 times the listed length. Keep in mind that any revision to a loop dimension that may appear in subsequent tables will result in a revised circumference that differs by 8 times the listed factor from the monoband loop. The element separation is a full measure.

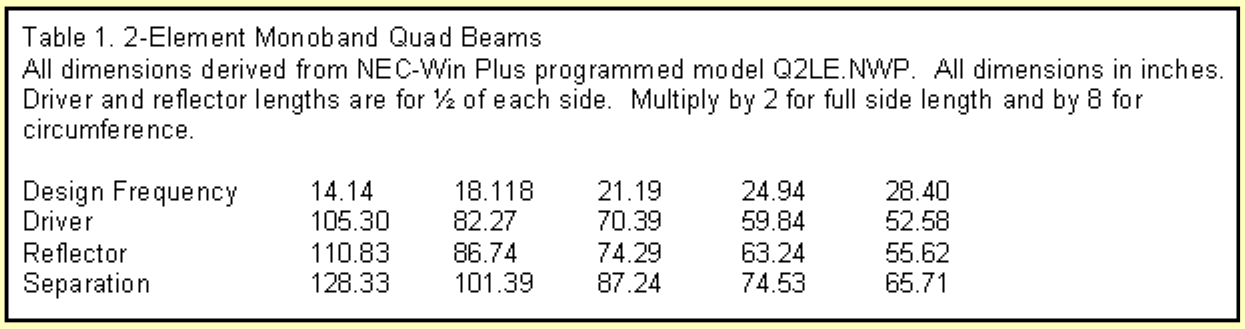


Table 1. 2-Element Monoband Quad Beams
All dimensions derived from NEC-Win Plus programmed model Q2LE.NWP. All dimensions in inches. Driver and reflector lengths are for ½ of each side. Multiply by 2 for full side length and by 8 for circumference.

Design Frequency	14.14	18.118	21.19	24.94	28.40
Driver	105.30	82.27	70.39	59.84	52.58
Reflector	110.83	86.74	74.29	63.24	55.62
Separation	128.33	101.39	87.24	74.53	65.71

Part 1 was devoted to examining these antennas, band by band, in sufficient detail to form a sort of data base that we might use as a reference in tracking the changes that occur (if any) when we form dual-band quads. For ready reference, **Table 2** summarizes the performance data for the monoband beams.

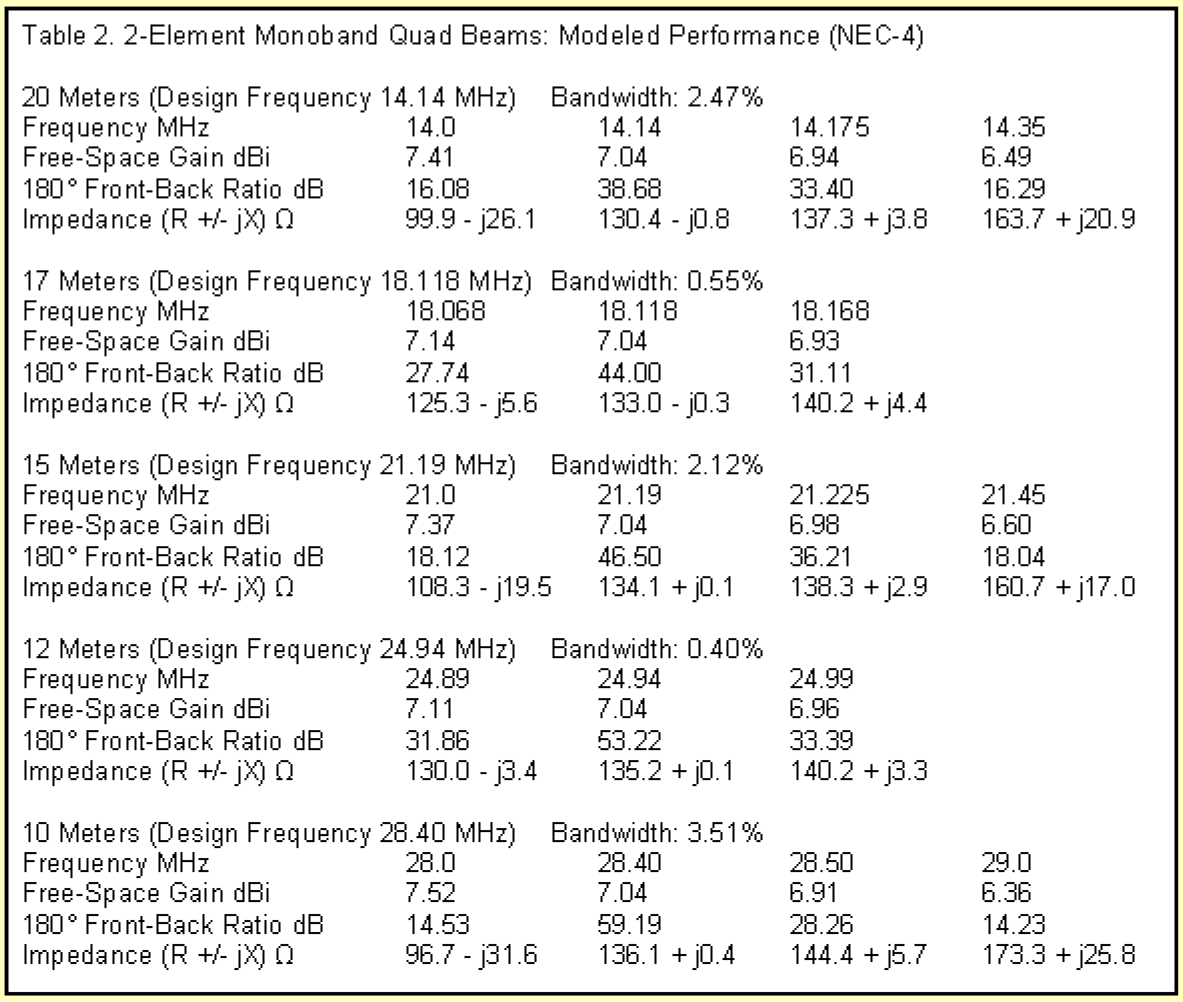
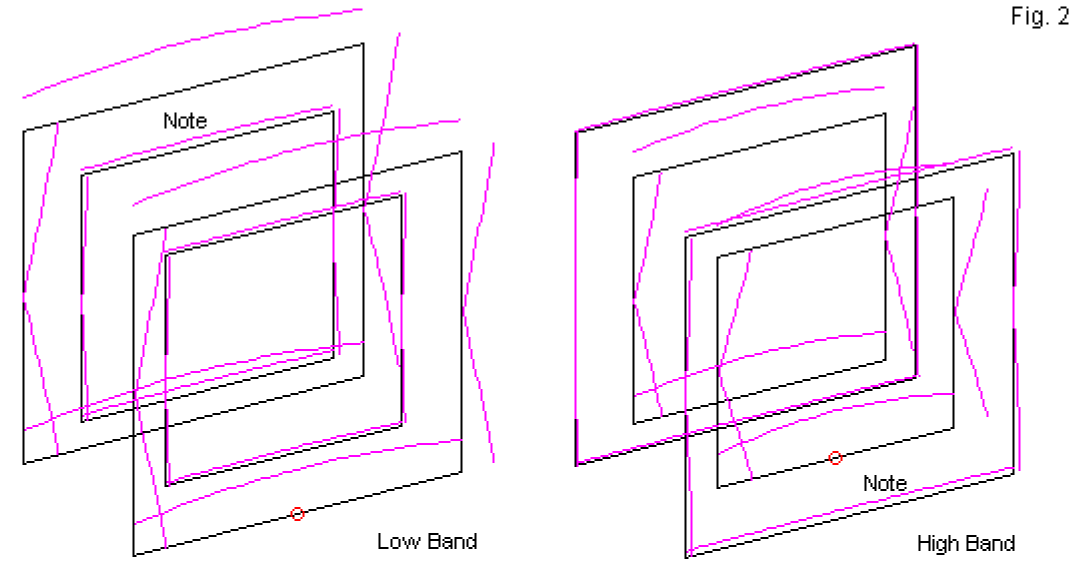


Table 2. 2-Element Monoband Quad Beams: Modeled Performance (NEC-4)

20 Meters (Design Frequency 14.14 MHz)	Bandwidth: 2.47%			
Frequency MHz	14.0	14.14	14.175	14.35
Free-Space Gain dBi	7.41	7.04	6.94	6.49
180° Front-Back Ratio dB	16.08	38.68	33.40	16.29
Impedance (R +/- jX) Ω	99.9 - j26.1	130.4 - j0.8	137.3 + j3.8	163.7 + j20.9
17 Meters (Design Frequency 18.118 MHz)	Bandwidth: 0.55%			
Frequency MHz	18.068	18.118	18.168	
Free-Space Gain dBi	7.14	7.04	6.93	
180° Front-Back Ratio dB	27.74	44.00	31.11	
Impedance (R +/- jX) Ω	125.3 - j5.6	133.0 - j0.3	140.2 + j4.4	
15 Meters (Design Frequency 21.19 MHz)	Bandwidth: 2.12%			
Frequency MHz	21.0	21.19	21.225	21.45
Free-Space Gain dBi	7.37	7.04	6.98	6.60
180° Front-Back Ratio dB	18.12	46.50	36.21	18.04
Impedance (R +/- jX) Ω	108.3 - j19.5	134.1 + j0.1	138.3 + j2.9	160.7 + j17.0
12 Meters (Design Frequency 24.94 MHz)	Bandwidth: 0.40%			
Frequency MHz	24.89	24.94	24.99	
Free-Space Gain dBi	7.11	7.04	6.96	
180° Front-Back Ratio dB	31.86	53.22	33.39	
Impedance (R +/- jX) Ω	130.0 - j3.4	135.2 + j0.1	140.2 + j3.3	
10 Meters (Design Frequency 28.40 MHz)	Bandwidth: 3.51%			
Frequency MHz	28.0	28.40	28.50	29.0
Free-Space Gain dBi	7.52	7.04	6.91	6.36
180° Front-Back Ratio dB	14.53	59.19	28.26	14.23
Impedance (R +/- jX) Ω	96.7 - j31.6	136.1 + j0.4	144.4 + j5.7	173.3 + j25.8

When we combine 2 (or more) quad beams concentrically to form a multi-band array, the elements will interact. Even with a frequency separation of at least 1.3:1 and totally separate loops for each band, we find that the active band elements will induce low-level but significant currents in some of the other loops. **Fig. 2** shows the current levels for one of the dual-band beams when operated at each of the 2 design frequencies and after undergoing the required modifications. We should attend mostly to the horizontal wires and their current magnitude curves.

Fig. 2



Element Interaction as Indicated by Relative Current Magnitude on Quad Loops

When operated on the lower band, in the left graphic, the larger loops show high current magnitude at the centers of the horizontal wires. However, note that the smaller loops are not inert. The smaller driver shows a relatively low peak current magnitude, but the peak value on the smaller reflector is appreciable. The element is active enough to become part of the overall radiating structure. The other elements require modification to compensate--if possible--for this activity if we are to restore to the degree possible the performance we obtained from the larger 2-element quad in its monoband form.

On the right, the smaller loops for the higher band are active, as indicated by the high current magnitude peaks at the centers of the horizontal wires. In this case, the larger driver loop shows a noticeable level of activity, enough to again require modification of the smaller loops to restore so far as possible monoband performance.

Two consequences follow from the interaction of the elements, even when we use separate feedpoints. One result gives us the design strategy for creating multi-band quads. Each modification to any loop will result in slight changes in the current level on other elements, even for the inert bands. Hence, a small change to a higher-band loop may require a change in previously set lower-band loops--and vice versa. The second result involves intra-band adjustments. Very tiny changes or tweaks to either the driver or the reflector of a monoband quad beam may not require an additional adjustment to the other element. However, larger changes in loop size for either the driver or the reflector will normally require changes in the other element to realign the operating properties across a given band. In most (but not quite all) cases of adjustments that we make in the dual-band quads, we shall have to adjust both the driver and the reflector, since a change in one will itself displace the performance curve.

The final design strategy usually becomes a random set of moves that we might characterize as "a little of this and a little of that," in each case seeing whether the change moves us in the correct direction. In the present situation, we are using a complex set of operating parameters to define the correct direction. We wish to place the peak 180-degree front-to-back ratio on the design frequency and see roughly equal front-to-back values at the band edges. The monoband quad gain curves give us a good idea of what gain values we should see across the band. As well, we wish to set the design-frequency feedpoint impedance close to resonance.

A portion of our work will be to see what patterns emerge in the required modifications occasioned by creating a dual-band quad with separate feedpoints. If the patterns are consistent in all of the models, then we might ease the design work of future quad builders. Knowing in what directions to modify the quad loops can save a great deal of time and prevent us from messing up the performance values to a degree that forces us to restart the design from scratch.

A 17-12-Meter 2-Element Quad Array Using Separate Feedpoints

Our first example of a dual-band quad beam with separate driver loops is for the narrow 17- and 12-meter band. On this band, we may use the band center frequencies for design (18.118 and 24.94 MHz). The frequency ratio is 1.38:1. Moreover, properties do not shift within the band limits by an amount that will give us any challenges for band-edge performance. If we can peak the performance on each band somewhere within the band, the result will generally be satisfactory across the band.

Table 3 shows the dimensions of the final version of the 17-12-meter combination. If you compare the numbers with the monoband values in **Table 1**, the changes seem slight. However, multiply the changes by 8 to see the effects on the circumference of each loop in the beam. In all of our beams, we are holding the spacing constant to reduce the number of variables that we must manipulate.

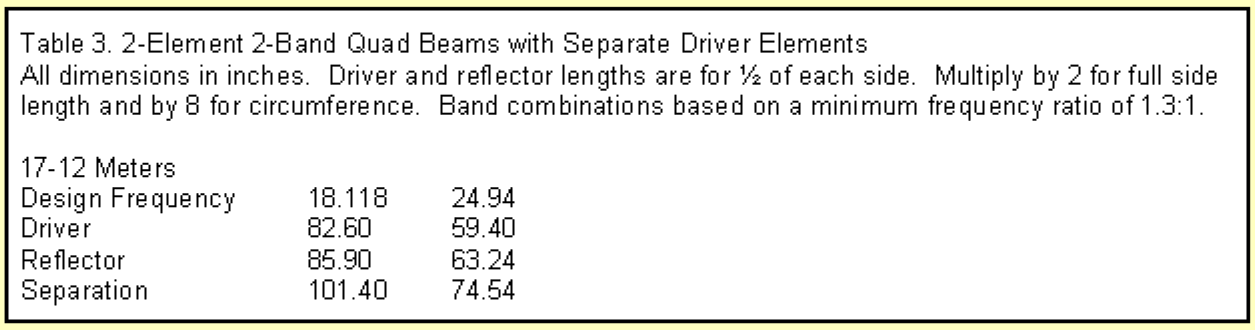


Table 3. 2-Element 2-Band Quad Beams with Separate Driver Elements
All dimensions in inches. Driver and reflector lengths are for ½ of each side. Multiply by 2 for full side length and by 8 for circumference. Band combinations based on a minimum frequency ratio of 1.3:1.

17-12 Meters		
Design Frequency	18.118	24.94
Driver	82.60	59.40
Reflector	85.90	63.24
Separation	101.40	74.54

The 17-meter driver increases its circumference by nearly 1.5", while the reflector for that band decreases by close to 3-3/8". In contrast, the 12-meter driver requires a circumference reduction of about 1-3/4", but the 12-meter reflector requires no change at all. In the presence of high-band elements, the low-band reflector swells, while the low-band driver shrinks. High-band elements either shrink (driver) or remain unchanged (reflector) in the presence of low-band elements. Let's remember these patterns when we look at other frequency combinations for subsequent dual-band quads.

Table 4 presents the performance data for our new dual-band 17-12 quad beam. Since both bands are narrow, we may dispense with graphed frequency sweeps, since the curves will be nearly straight lines throughout. Compare the performance values with those for the monoband versions in **Table 2**.

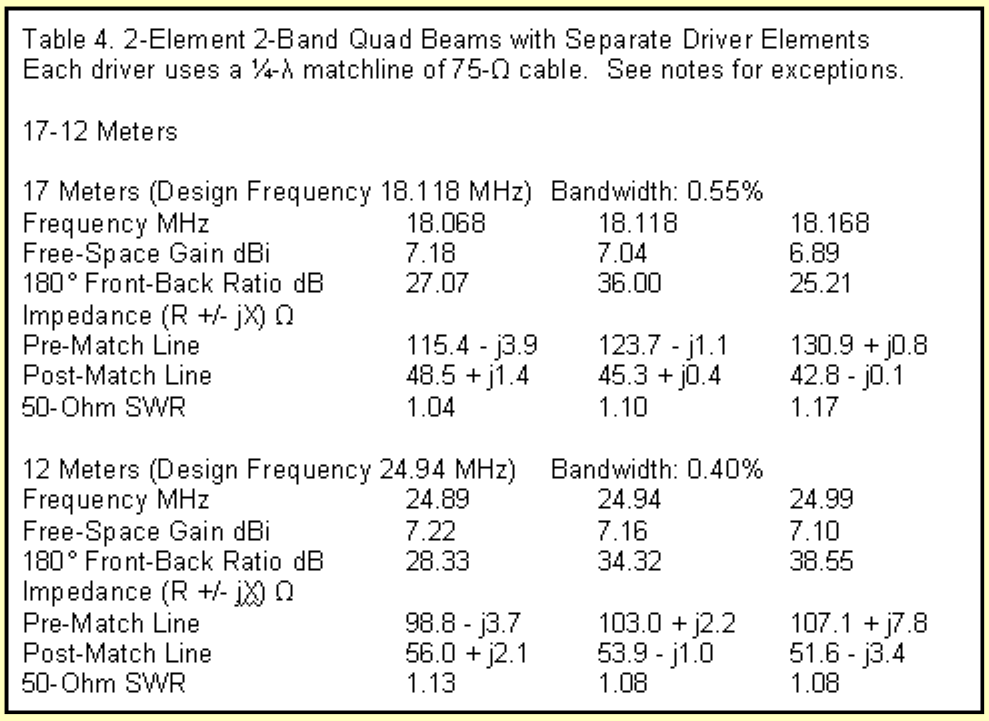


Table 4. 2-Element 2-Band Quad Beams with Separate Driver Elements
Each driver uses a ¼-λ matchline of 75-Ω cable. See notes for exceptions.

17-12 Meters

17 Meters (Design Frequency 18.118 MHz)	Bandwidth: 0.55%		
Frequency MHz	18.068	18.118	18.168
Free-Space Gain dBi	7.18	7.04	6.89
180° Front-Back Ratio dB	27.07	36.00	25.21
Impedance (R +/- jX) Ω			
Pre-Match Line	115.4 - j3.9	123.7 - j1.1	130.9 + j0.8
Post-Match Line	48.5 + j1.4	45.3 + j0.4	42.8 - j0.1
50-Ohm SWR	1.04	1.10	1.17

12 Meters (Design Frequency 24.94 MHz)	Bandwidth: 0.40%		
Frequency MHz	24.89	24.94	24.99
Free-Space Gain dBi	7.22	7.16	7.10
180° Front-Back Ratio dB	28.33	34.32	38.55
Impedance (R +/- jX) Ω			
Pre-Match Line	98.8 - j3.7	103.0 + j2.2	107.1 + j7.8
Post-Match Line	56.0 + j2.1	53.9 - j1.0	51.6 - j3.4
50-Ohm SWR	1.13	1.08	1.08

Perhaps the first notable performance feature is the seeming rise in the average gain on 12 meters. However, also note the 12-meter front-to-back values. The peak front-to-back value has moved upward in the band and is no longer exactly centered. The shift in the front-to-back curve also indicates a shift in the 12-meter gain curve. Since the gain rises as we decrease frequency, the higher gain levels indicate that the gain and front-to-back curves have moved together in the presence of the 17-meter elements. Comparing the 17-meter gain values in the dual-band quad with those of the monoband version, we find much less slippage. However, the front-to-back back value at the high end of the narrow band is quite a bit lower than in the monoband quad.

Perhaps the most noticeable difference between the monoband and dual-band versions of the quads involves the feedpoint impedance. The band-center impedance of the 17-meter quad drops about 10 Ohms relative to the monoband value, but the range of resistance across the band remains at 15 Ohms. On 12 meters, we find the greatest impedance decrease: about 30 Ohms resistive or a drop of about 24%. The range of variation in resistance across the band drops by a like amount.

The chief consequence of the changes in feedpoint impedance lies in the ability of 1/4-wavelength 75-Ohm match-lines to effect a close match to a 50-Ohm main feedline. On 17 and even on 12 meters, the mismatch is not significant. However, if the patterns set by this combination of beams hold for the other combinations that cover wider bands, we may see high 50-Ohm SWR values at the band edges on 20, 15, or 10 meters.

The 17-12-meter dual-band quad forms a good beginning exercise in combining quads. The narrow bandwidth of the two bands allows us to see patterns of physical and performance alteration without introducing the variables that a wider bandwidth might force upon us. Clearly, we cannot simply slap together monoband beams for 17 and 12 and expect peak performance. However, the physical changes to re-center performance are relatively small. As well, although the performance passband shifts slightly on at least one band, we may easily obtain a full-performance dual-band quad. Matching the lower feedpoint impedances appears to present no significant obstacles.

A 15-10-Meter 2-Element Quad Array Using Separate Feedpoints

Our second sample dual-band quads involves wider bands: 15 and 10 meters. As well, the monoband beams for these two bands did not use the band centers as the design frequencies, but slightly lower frequencies: 21.19 and 28.4 MHz. As the dimensions in **Table 5** show (when compared to the monoband dimensions in **Table 1**), we obtain the same patterns of element length adjustment in the 15-10 quad as in the 17-12 quad. The circumference of the 15-meter driver increases by a little over 1", while the 15-meter reflector shrinks by nearly 4 inches. The 10-meter driver decreases its circumference by nearly 2", but the reflector remains unchanged. I shall resist any temptation to create a set of equations for these changes, since we have two moderating changes from the 17-12 quad. First, the wire diameter as a fraction of a wavelength changes from one band to the next, since all models use AWG #14 copper wire. Second, the frequency ratio changes from one dual-band quad to the next. The 15-10-meter combination uses a design-frequency ratio of about 1.34:1.

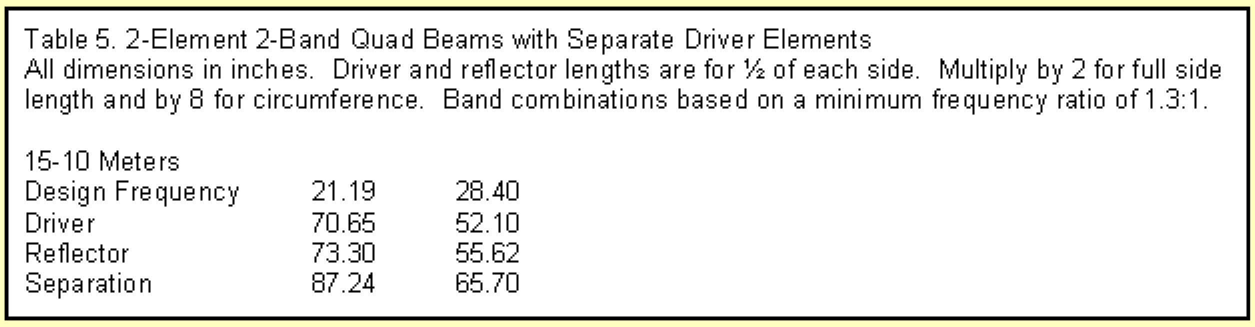


Table 5. 2-Element 2-Band Quad Beams with Separate Driver Elements
All dimensions in inches. Driver and reflector lengths are for ½ of each side. Multiply by 2 for full side length and by 8 for circumference. Band combinations based on a minimum frequency ratio of 1.3:1.

15-10 Meters		
Design Frequency	21.19	28.40
Driver	70.65	52.10
Reflector	73.30	55.62
Separation	87.24	65.70

Relative to the monoband performance values in **Table 2**, the dual-band performance numbers in **Table 6** reveal some patterns that would only be possible to see with the wider-band quads for bands like 15 and 10 meters. Since 15 and 10 meters have different bandwidths, we must be careful of cross-band transfer of changes. However, relative to the band-edge numbers in the monoband tables, the 15-meter performance in the dual-band design shows a much steeper gain decrease and generally lower band-edge front-to-back values. In contrast, again relative to monoband values, the 10-meter section of the dual-band quad shows a shallower gain curve and higher band-edge front-to-back values. The near-resonant (pre-match) impedance values for the two bands are comparable to those obtained with the 17-12 dual quad.

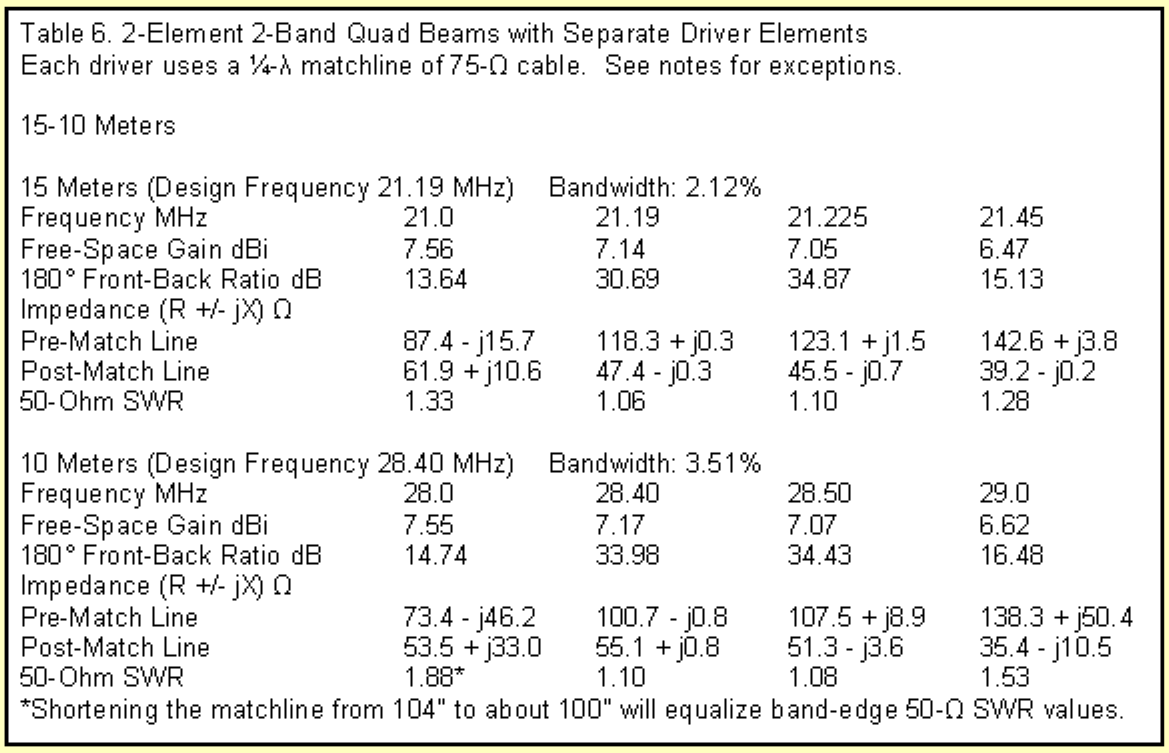


Table 6. 2-Element 2-Band Quad Beams with Separate Driver Elements
Each driver uses a ¼-λ matchline of 75-Ω cable. See notes for exceptions.

15-10 Meters

15 Meters (Design Frequency 21.19 MHz)	Bandwidth: 2.12%			
Frequency MHz	21.0	21.19	21.225	21.45
Free-Space Gain dBi	7.56	7.14	7.05	6.47
180° Front-Back Ratio dB	13.64	30.69	34.87	15.13
Impedance (R +/- jX) Ω				
Pre-Match Line	87.4 - j15.7	118.3 + j0.3	123.1 + j1.5	142.6 + j3.8
Post-Match Line	61.9 + j10.6	47.4 - j0.3	45.5 - j0.7	39.2 - j0.2
50-Ohm SWR	1.33	1.06	1.10	1.28

10 Meters (Design Frequency 28.40 MHz)	Bandwidth: 3.51%			
Frequency MHz	28.0	28.40	28.50	29.0
Free-Space Gain dBi	7.55	7.17	7.07	6.62
180° Front-Back Ratio dB	14.74	33.98	34.43	16.48
Impedance (R +/- jX) Ω				
Pre-Match Line	73.4 - j46.2	100.7 - j0.8	107.5 + j8.9	138.3 + j50.4
Post-Match Line	53.5 + j33.0	55.1 + j0.8	51.3 - j3.6	35.4 - j10.5
50-Ohm SWR	1.88*	1.10	1.08	1.53

*Shortening the matchline from 104" to about 100" will equalize band-edge 50-Ω SWR values.

As a cross-check on the reality of some of these values, **Fig. 3** provides sweep data on the 15-meter gain and 180-degree front-to-back values. Note that the peak front-to-back ratio is close to the band center, higher in frequency than the design frequency. The higher gain value at the low end of 15 meters confirms that the overall performance pattern has slipped upwards in frequency, just as we saw in a much smaller way with the 17-meter quad.

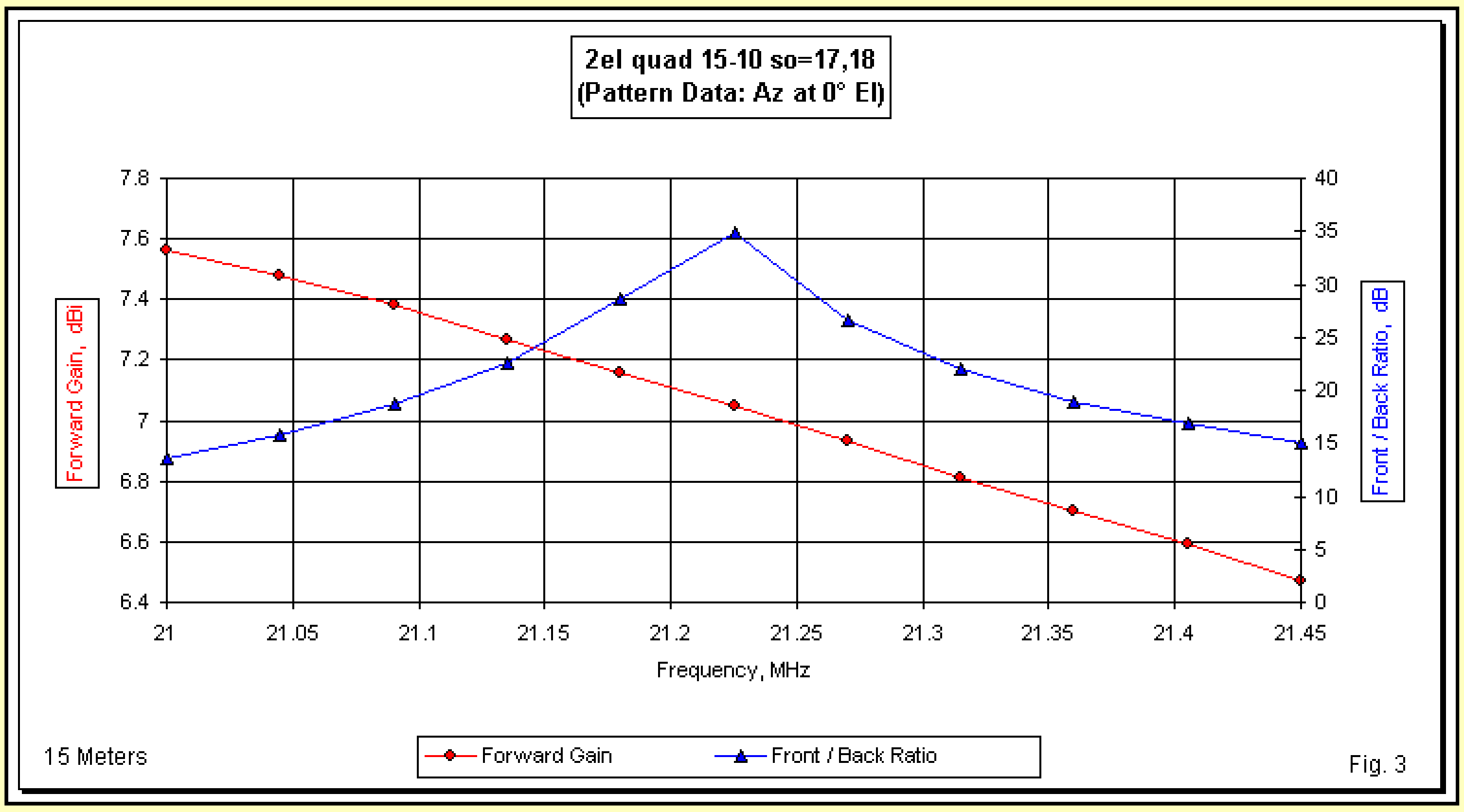


Fig. 3

Fig. 4 graphs the resistance, reactance, and 50-Ohm SWR values for the 15-meter section of the dual-band quad. These values presume a 1/4-wavelength 75-Ohm matchline between the loop feedpoint and the 50-Ohm main feedline. If we examine the pre-match impedance values for 15 meters with the monoband values, we find that the total change in resistance across the band is slightly higher in the dual-band quad, but the total change in dual-band 15-meter reactance is considerably smaller. As a result, the 1/4-wavelenghth matching section has little difficulty in effecting a wholly acceptable impedance situation relative to the 50-Ohm main feedline.

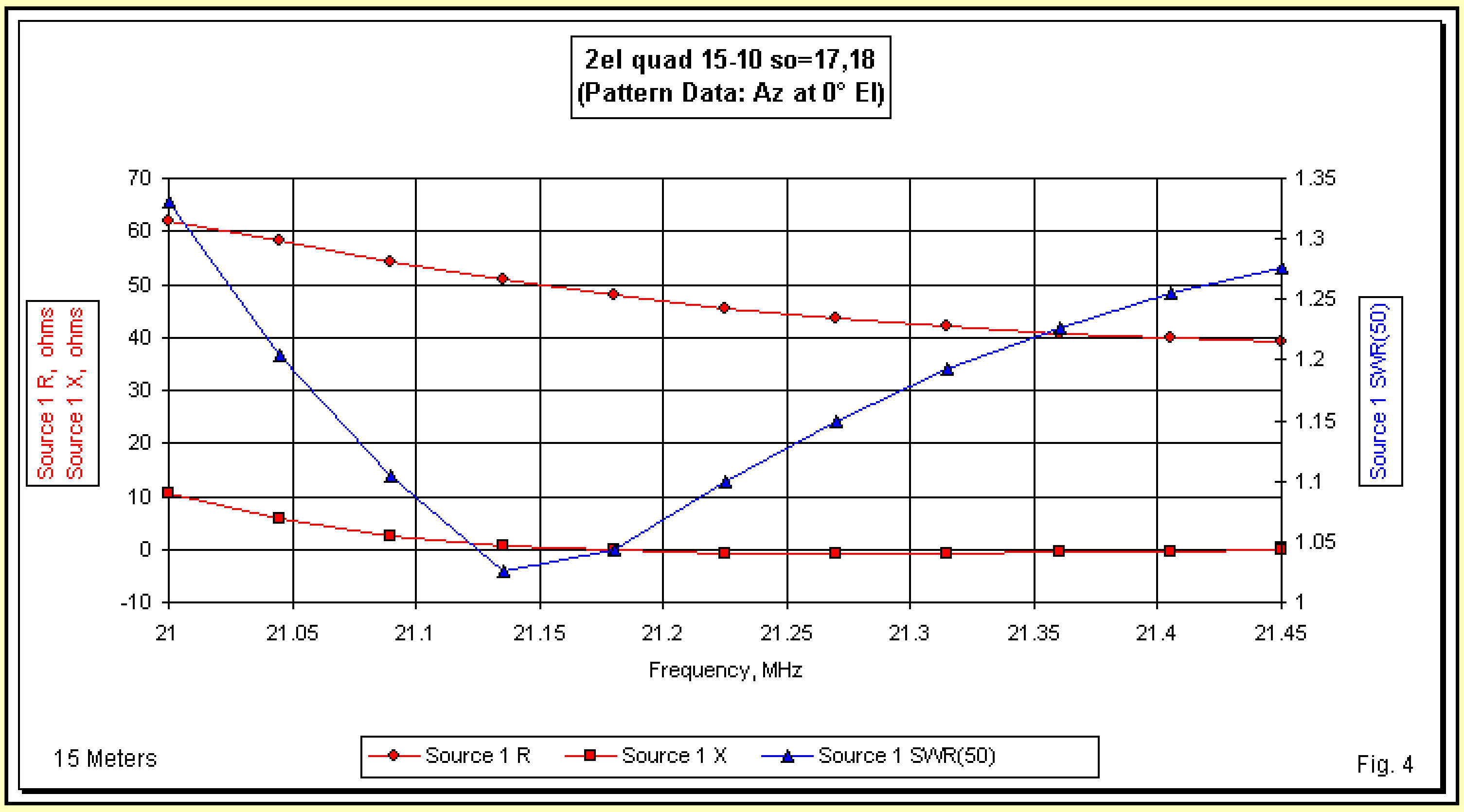


Fig. 4

The 10-meter loops form the inner elements of this dual-band quad, and 10 is the widest of the bands in the upper HF amateur region. The inner position of these loops appears to show some advantage in both gain and front-to-back ratio, as suggested by both the tabular values and the sweep graph in **Fig. 5**. The performance curves have slipped upward in the band relative to monoband values, similarly to the 12-meter values. However, relative to 10-meter monoband values, the gain curve decreases at a slower rate when the loops are part of the 15-10 quad. As well, the average of the band-edge front-to-back ratios is slightly higher than in the monoband version. (When we turn to a 20-15-meter dual-band quad, we shall be very interested in whether the values for 15 meters show any significant difference from the values that we reviewed earlier, once we give the loops for that band an inner position.)

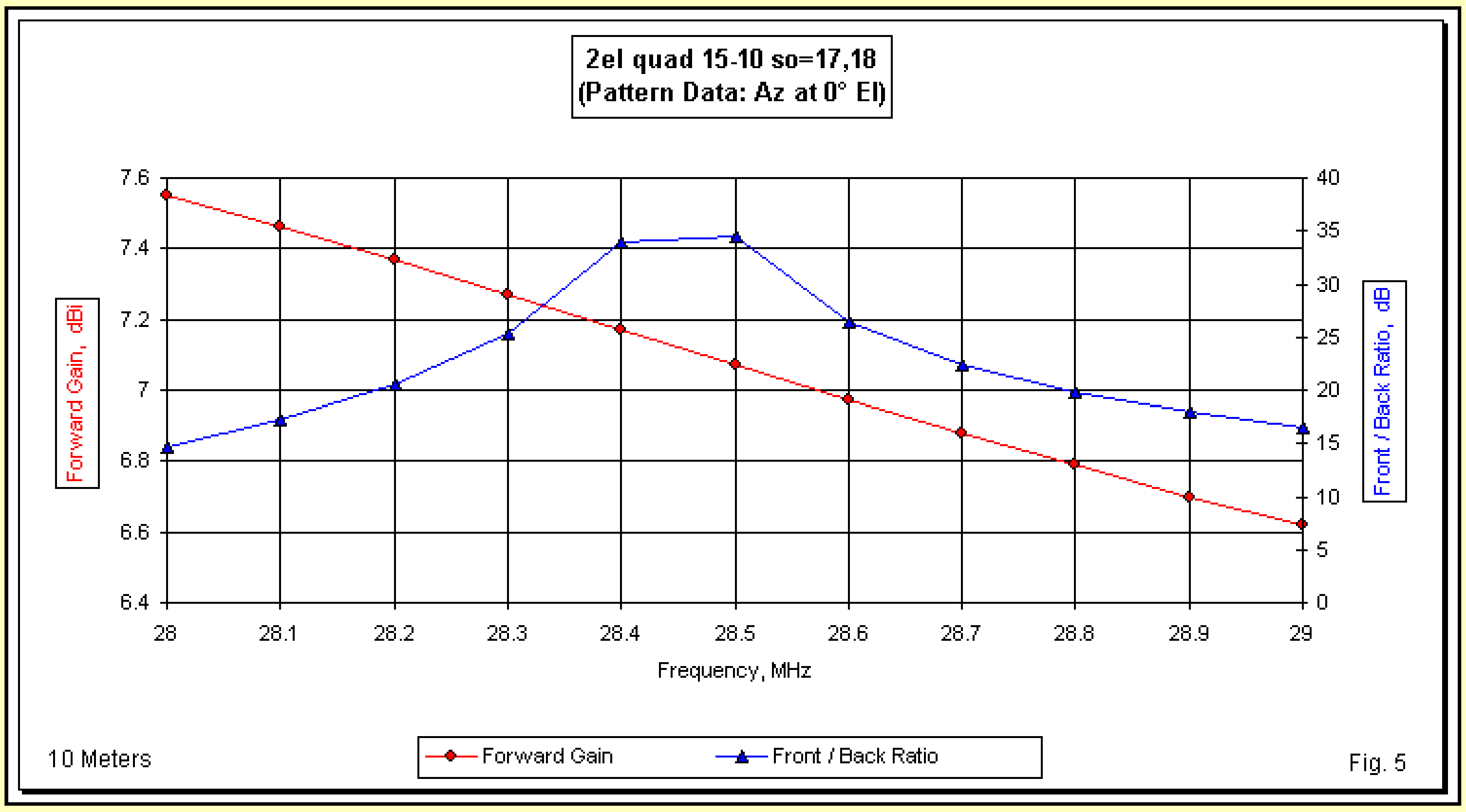


Fig. 5

The match-line values of resistance and reactance on 10 meters do not show the nearly straight lines that we obtained on 15 meters. One factor in the curves shown in **Fig. 6** is the very width of the band--over 1.5 times wider than 15 meters. A second and possibly more significant factor is the fact that the inner position of the 10-meter elements results in a significant departure in pre-matched values relative to the monoband version of the antenna. The total range of pre-match resistance is slightly lower than in the monoband quad, but the dual-band pre-match reactance shows a spread that is more than 1.6 times the range that we found in the monoband 10-meter quad. As a consequence, a simple 1/4-wavelength 75-Ohm line achieves an acceptable 50-Ohm SWR at 28.0 MHz with very little to spare.

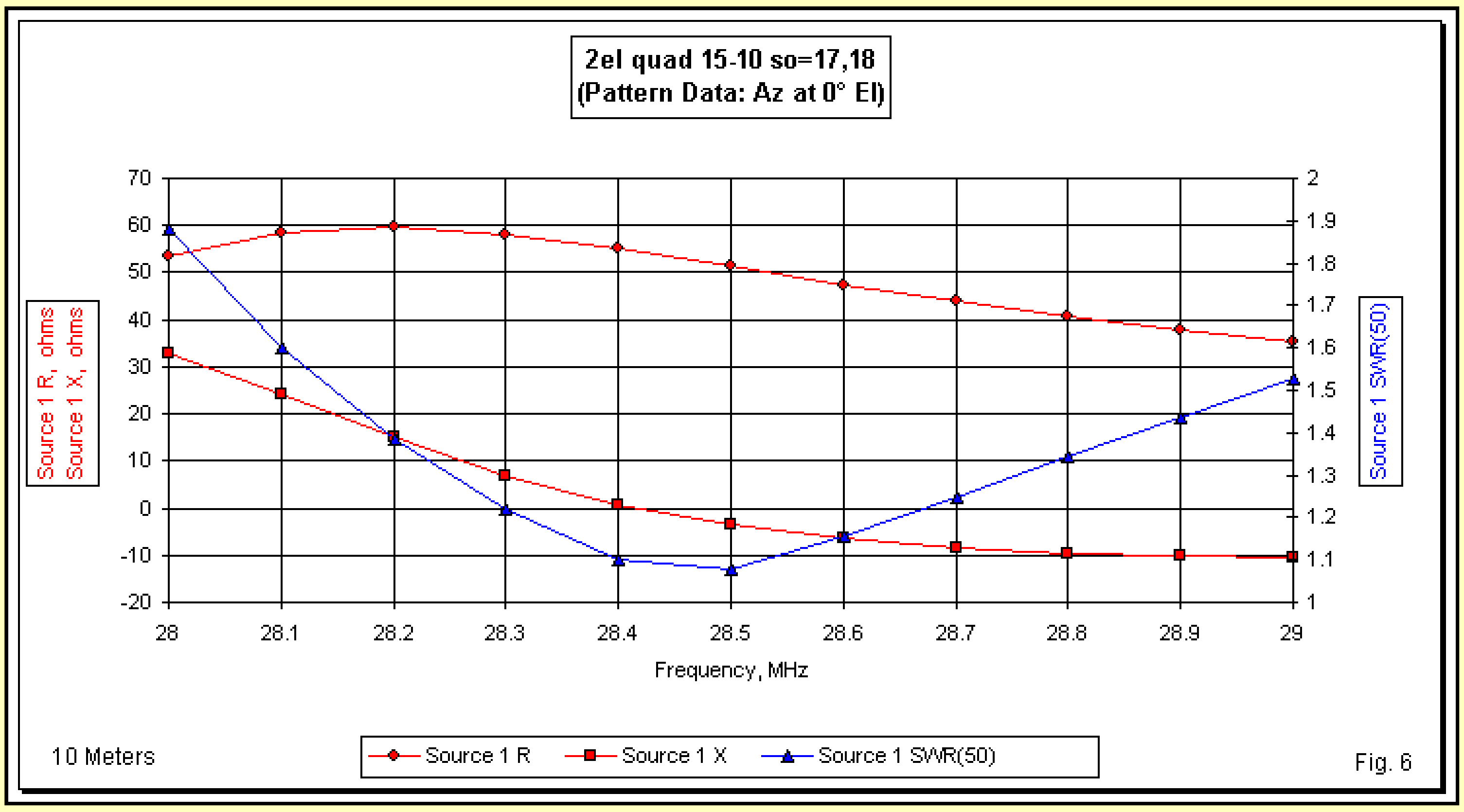


Fig. 6

Amateur antenna builders appear to have great difficulty in thinking about match-lines in increments other than 1/4 wavelength. Transmission lines effect a continuous impedance transformation along their length (except when perfectly matched to the antenna feedpoint load). Although the transformation calculations are more complex than for resistive loads, there are numerous aids to permit us to find the impedance transformation for virtually any line length. In many cases, we may obtain a flatter SWR curve across a given bandwidth by selecting a line length other than 1/4 wavelength. As noted in **Table 6**, a 75-Ohm line with an electrical length of about 100" will achieve a 10-meter SWR curve with more equal band-edge values than a 104" (1/4-wavlength) line. (Remember that all line lengths listed in inches are electrical lengths. Multiply these values by the velocity factor of the line used to obtain the required physical lengths of the match line.)

A 20-15-Meter 2-Element Quad Array Using Separate Feedpoints

The 20-15-meter dual quad is similar to the 15-10 quad in that both cover wider amateur bands. However, the frequency ratio is higher (1.5:1), while both bands are narrower that the 10-meter band. Nevertheless, most of the patterns developed as potentials in connection with the first two dual-band quads receive confirmation in the new model. As shown by a comparison of the dimensions in **Table 7** with those in **Table 1**, the outer 20-meter reflector increases its circumference by about 1-1/4", while the outer 20-meter driver circumference shrinks by nearly 3-3/4". The inner 15-meter reflector remains unchanged, but the inner 15-meter driver circumference decreases by about 2-1/8". Although wire size as measured in terms of a wavelength and the frequency ratio may play a role in the precise amount of modification required for any element in the dual quad, the positions of the elements determine the general patterns of increasing and decreasing loop size.

Table 7. 2-Element 2-Band Quad Beams with Separate Driver Elements
All dimensions in inches. Driver and reflector lengths are for ½ of each side. Multiply by 2 for full side length and by 8 for circumference. Band combinations based on a minimum frequency ratio of 1.3:1.

20-15 Meters		
Design Frequency	14.14	21.19
Driver	105.60	69.85
Reflector	109.90	74.29
Separation	128.34	87.24

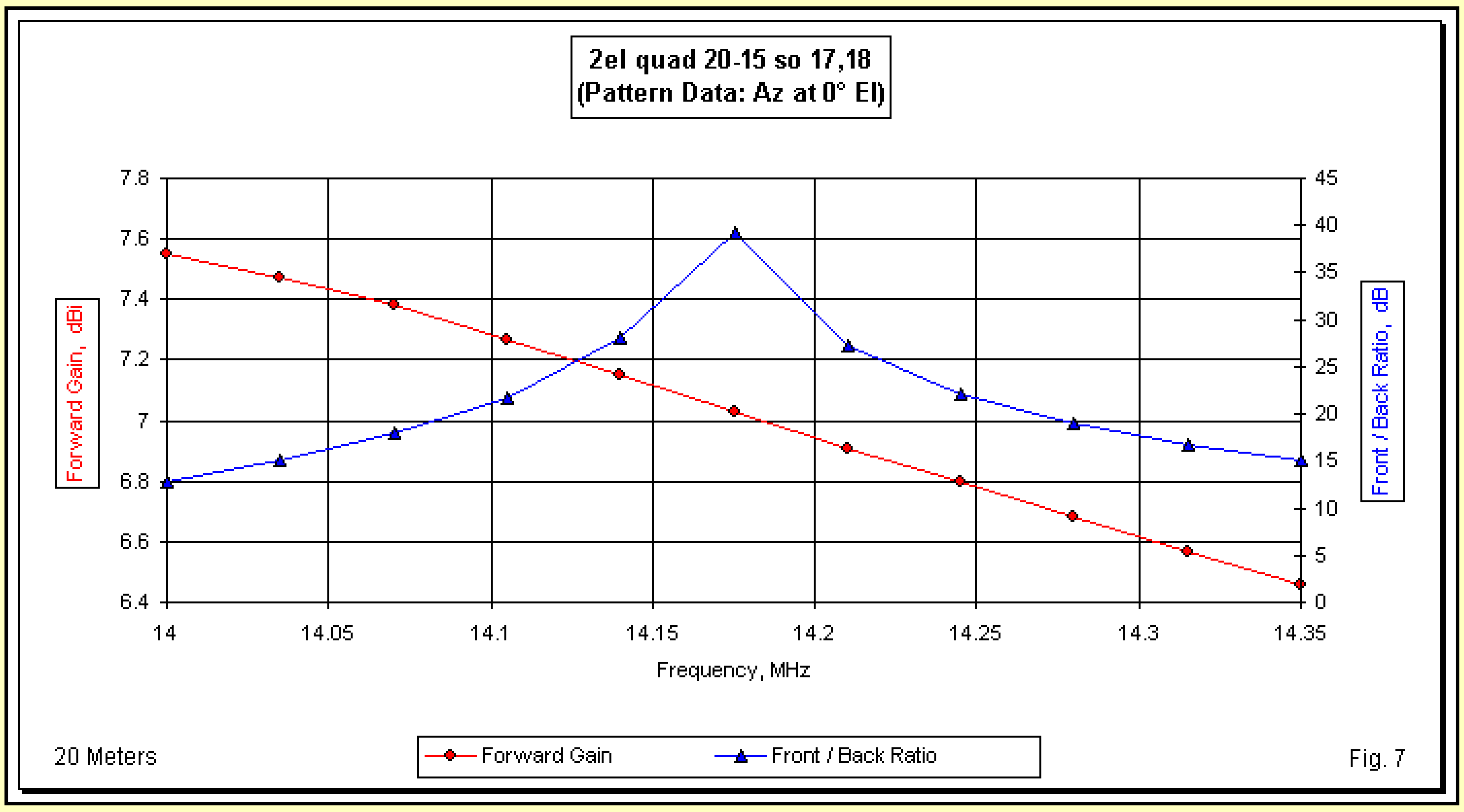
The performance values in **Table 8**, when compared to the monoband values in **Table 2**, again show the same patterns as in the 15-10-meter quad. On 20 meters, the dual-band gain curve shows a steeper decline than does the monoband curve. The 20-meter band-edge 180-degree front-to-back values are lower relative to monoband values. However, the inner 15-meter quad shows the opposite trends. Its gain curve is shallower than is the monoband curve, while the dual-band band-edge front-to-back ratios are equal to or higher than the monoband values. For both bands in the dual-band quad, the pre-match feedpoint impedance values track well with the values for the other dual-band quads in terms of the reductions relative to monoband versions of the antennas.

Table 8. 2-Element 2-Band Quad Beams with Separate Driver Elements
Each driver uses a ¼-λ matchline of 75-Ω cable. See notes for exceptions.

20-15 Meters

20 Meters (Design Frequency 14.14 MHz)	Bandwidth: 2.47%			
Frequency MHz	14.0	14.14	14.175	14.35
Free-Space Gain dBi	7.55	7.15	7.03	6.46
180° Front-Back Ratio dB	12.81	28.17	39.12	15.15
Impedance (R +/- jX) Ω				
Pre-Match Line	84.9 - j23.4	118.8 + j1.7	126.3 + j5.3	152.0 + j15.4
Post-Match Line	61.2 + j16.5	47.3 - j0.6	44.3 - j1.6	36.4 - j2.3
50-Ohm SWR	1.43	1.06	1.13	1.38
15 Meters (Design Frequency 21.19 MHz)	Bandwidth: 2.12%			
Frequency MHz	21.0	21.19	21.225	21.45
Free-Space Gain dBi	7.43	7.16	7.11	6.80
180° Front-Back Ratio dB	18.25	34.20	36.50	19.76
Impedance (R +/- jX) Ω				
Pre-Match Line	87.0 - j29.0	108.1 - j0.6	111.9 + j4.0	135.1 + j30.1
Post-Match Line	57.0 + j18.6	51.4 + j0.5	49.7 - j1.4	39.4 - j7.4
50-Ohm SWR	1.45	1.03	1.03	1.34

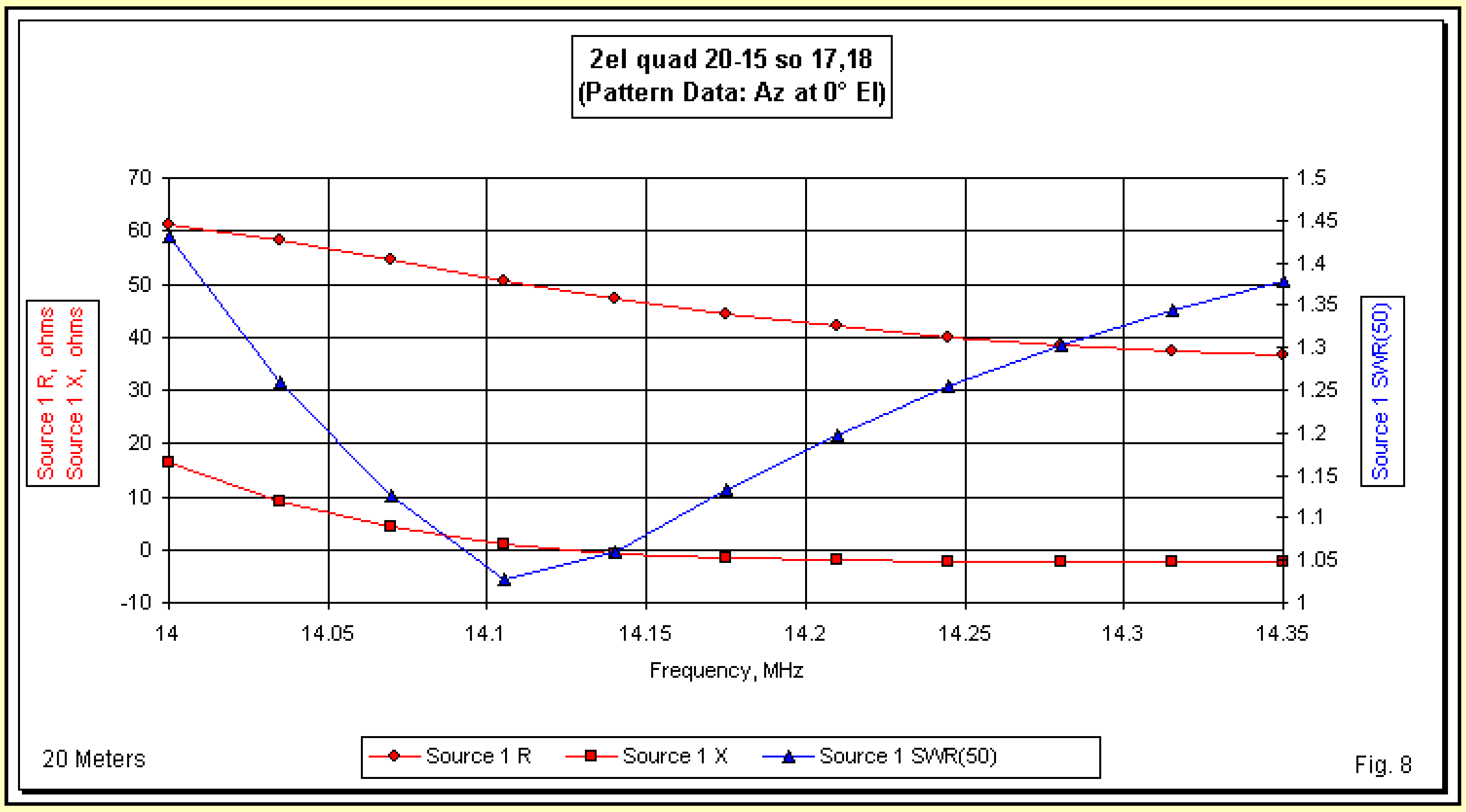
Like the 15-meter section of the 15-10-meter quad, the 20-meter section of the new model shows the same drift upward in frequency, as shown in **Fig. 7**. The steeper gain curve of the 20-meter section relative to the monoband model results in the low end showing higher gain and the high end showing lower gain than in the monoband 20-meter antenna. The 20-meter front-to-back curve now peaks at mid-band rather than at the design frequency, with the low end of the band showing a front-to-back ratio under 13 dB.



20 Meters

Fig. 7

Allowing for a small difference in bandwidth as a percentage of the center frequency, the 20-meter dual-quad matched impedance values are remarkably parallel to those of the 15-meter section of the 15-10-meter quad. The 50-Ohm SWR curve is quite tame, since the outer section elements tend to reduce the reactance excursion across the band, relative to the monoband 20-meter quad. At the same time, the resistance range only moves upward slightly. Hence, SWR curve only peaks at 1.43:1 after a 1/4-wavelength 75-Ohm matching line.



20 Meters

Fig. 8

15-meters becomes the inner loop set on this dual-band quad. Not only is the gain curve somewhat shallower than on the monoband version, but as well, the curve is almost half as steep as the 15-meter gain curve on the 15-10-meter dual-band quad. The inner position of 15 meters also results in differences in the band-edge front-to-back ratio values. They are slightly better than the monoband values, but 4-5-dB better than the values for 15-meters when that band occupies the outer position in a dual-band situation. Compare the curves in **Fig. 9** with those of **Fig. 5**, along with the corresponding values in the relevant tables. Of course, we see the upward overall frequency shift in both performance categories.

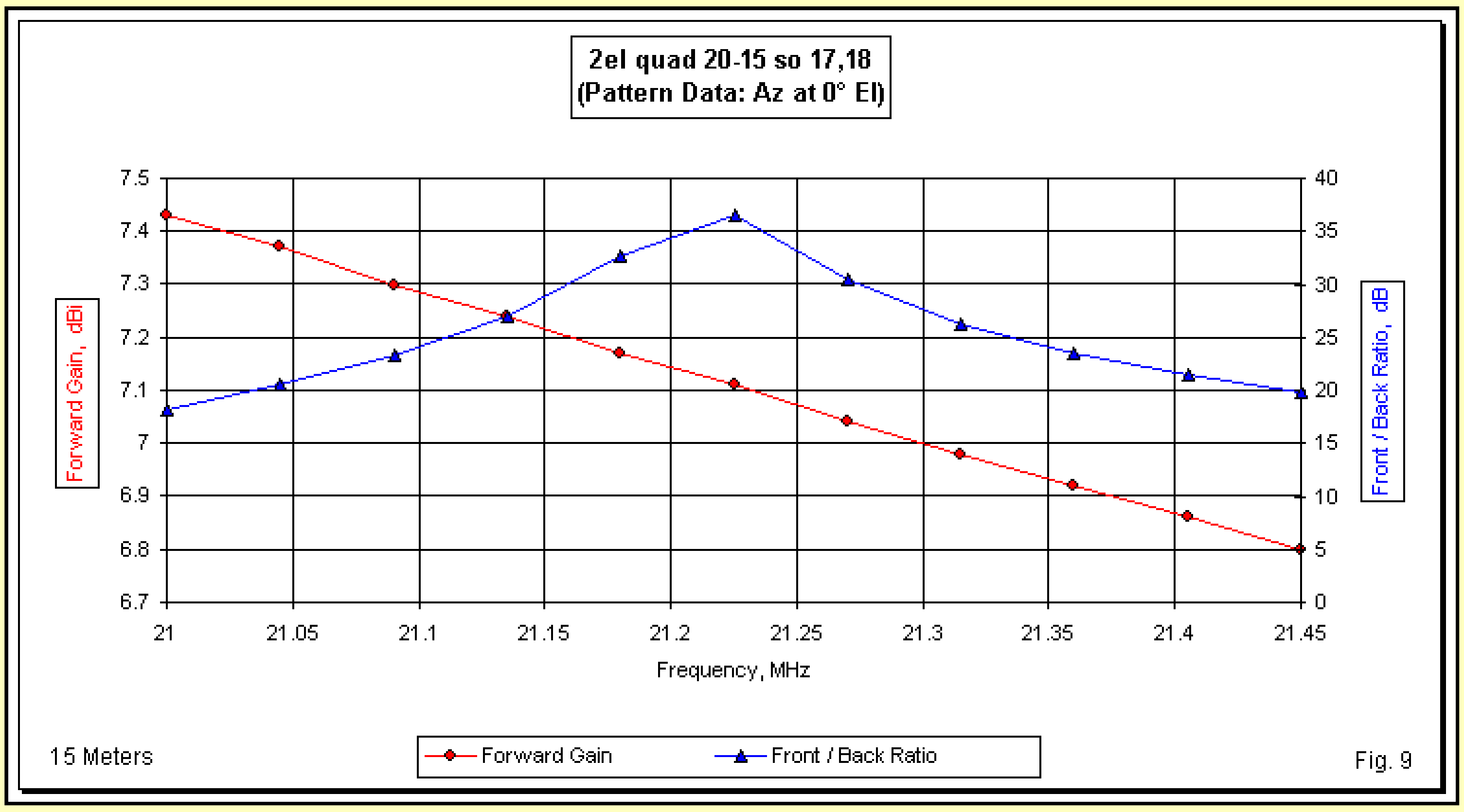


Fig. 9

With respect to impedance values, the inner position loses its advantage due to the greater drop in the resonant pre-match feedpoint impedance relative to a monoband quad. However, the fact that 15-meters is only 60% as wide as the first MHz of 10 meters allows the use of a standard 1/4-wavelength 75-Ohm matching line with good results. The matched resistance and reactance curves are relatively flat, despite the 50-Ohm excursion in the pre-matched reactance value. As a result, the 15-meter 50-Ohm SWR curve is almost identical to the SWR curve for 20 meters in this dual-band quad.

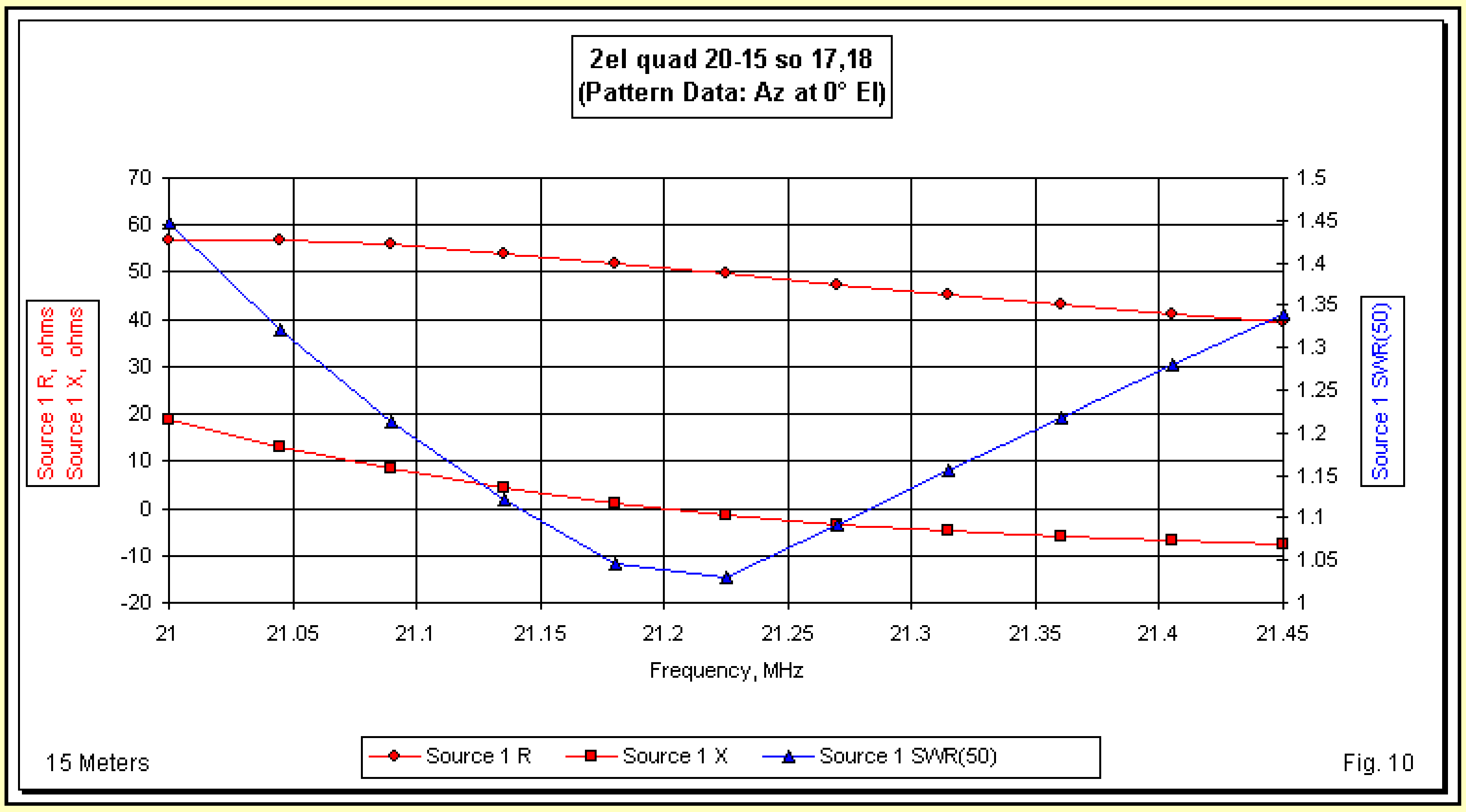


Fig. 10

The three dual-band quads that meet the basic requirements for this exploration all show the same patterns in physical and performance modifications relative to their monoband origins. The size of outer reflector increases, while outer drivers diminish. Inner reflectors require no change, whereas inner drivers shrink. The resulting performance patterns tend to shift gain and front-to-back curves slightly upward in the band, while allowing the pre-match feedpoint impedances to be near resonance on the original design frequencies. Both feedpoint impedances decrease, the outer by about 10 Ohms, the inner by about 25 to 30 Ohms. For the antennas derived from the original monoband designs, both bands of the dual-band versions allow use of a standard 1/4-wavelength 75-Ohm line section for matching. However, for some bands, line length adjustment may yield a better match across a given band, especially for the inner quad of the pair.

The slight upward frequency shift in the gain and front-to-back curves may seem troublesome to someone seeking a perfect reproduction of the monoband curves. Further tweaking might indeed be possible. However, in most cases, I limited loop dimension changes to 0.1" increments, meaning a 0.8" inch change in the overall loop circumference. Anything more finicky would likely be impossible to replicate in most shops, and construction variables will likely override even the level of model precision that I used. Nevertheless, one may be able to move the gain and front-to-back curves downward in frequency slightly by making loop adjustments in 0.01" increments for each half side.

A 20-15-10-Meter 2-Element Quad Array Using Separate Feedpoints

The terms of this exercise permit only 1 possible 3-band quad. Although 2-band quads are the main focus of the investigation, all of the basic materials were available to design the 3-band antenna. As well, a 3-band quad would answer--at least provisionally, since we would make only one model--some lingering questions about the 2-band versions. The physical and performance dimensions and values show very distinct patterns depending upon whether the loops for a given band are inner or outer quads. So one might relevantly ask the following questions. 1. Would the outer band loops remain at the same dimensions and with the same performance if we place 2 bands of quad inside? 2. Would the inner band loops retain their dimensions if we add 2 bands of quads outside them? 3. What happens to the dimensions and performance of the middle loops now that they are no longer either inner or outer loops? To obtain a first order set of answers, we must violate one of the guiding restraints. We must use a frequency ratio of 2:1 between the outer quad (20 meters) and the inner quad (10 meters). In advance, we might expect that the 20-meter loop might exert more influence on 10-meter dimensions and performance than the other way around. The 20-meter elements will be close to resonance as 2-wavelength loops when we activate the 10-meter quad.

The tri-band dimensions appear in **Table 9** for comparison with several other dimensional tables in this part of our exploration. The 20-meter dimensions are exactly the same as they were in the dual-band quad using 20 meters as the outer band. The 10-meter reflector is the innermost element of that type and has the same dimensions as both the monoband and the dual-band quads. However, the 10-meter driver undergoes further shrinkage from the monoband 10-meter driver and is now shorter even than the driver for the same band as the inner loop in a dual-band quad. It is quite likely that the further reduction in driver length is a function of two inseparable factors: the presence of the 20-meter driver and the required dimensional change in the 15-meter driver for its middle position in the array.

Table 9. 2-Element 3-Band Quad Beams with Separate Driver Elements
All dimensions in inches. Driver and reflector lengths are for ½ of each side. Multiply by 2 for full side length and by 8 for circumference. Band combinations based on a minimum frequency ratio of 1.3:1.

20-15-10 Meters			
Design Frequency	14.14	21.19	28.40
Driver	105.60	70.10	51.90
Reflector	109.90	73.50	55.62
Separation	128.34	87.24	65.70

On 15 meters, we encounter the most interesting dimensions. The driver is smaller than when it is the outer loop on a dual-band quad but larger than when it is the inner loop. Conversely, the reflector is longer than when it is an outer loop but shorter than when it is an inner loop.

Table 10 provides a summary view of the performance of the tri-band quad. I shall reserve commentary on the band-by-band performance until we can survey the sweep graphs for each band. However, the pre-match impedances deserve special note. The 20-meter near-resonant impedance is the same as it was when 20-meters served as the outer quad on a 2-band antenna. The 15-meter pre-match impedance at the design frequency is closely comparable with the impedances of all of the inner drivers for the 2-band quads. On 10 meters, the pre-match impedance drops to 92 Ohms, partly due to the further shortening of that element and--most likely--partly due to interactions of the 10-meter elements with the elements of both lower bands.

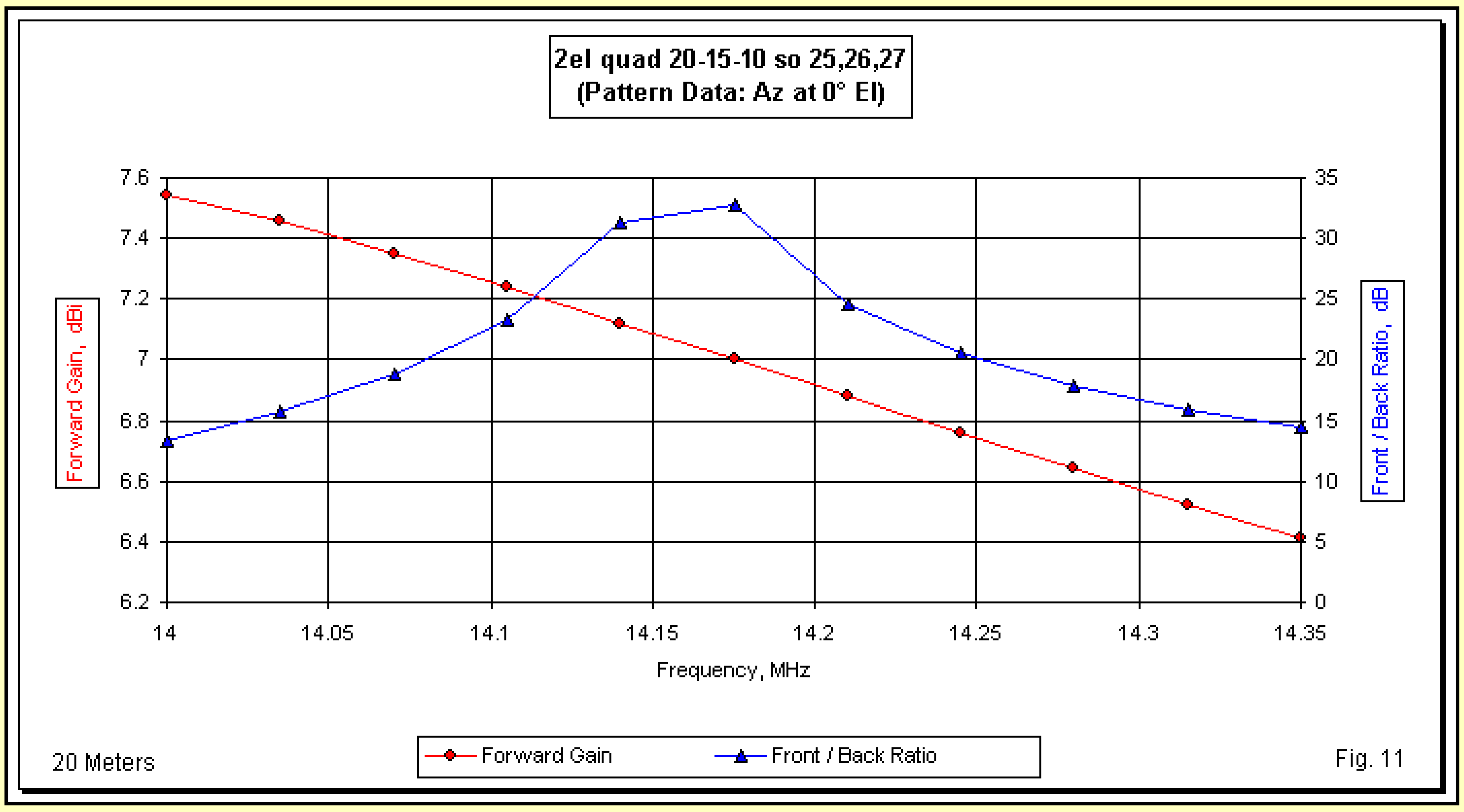
Table 10. 2-Element 3-Band Quad Beams with Separate Driver Elements
Each driver uses a ¼-λ matchline of 75-Ω cable. See notes for exceptions.

20-15-10 Meters

20 Meters (Design Frequency 14.14 MHz)	Bandwidth: 2.47%			
Frequency MHz	14.0	14.14	14.175	14.35
Free-Space Gain dBi	7.54	7.12	7.00	6.41
180° Front-Back Ratio dB	13.30	31.37	32.80	14.38
Impedance (R +/- jX) Ω				
Pre-Match Line	85.8 - j24.0	119.2 - j0.8	126.4 + j2.3	149.5 + j11.4
Post-Match Line	60.4 + j16.5	47.1 + j0.4	44.4 - j0.6	37.2 - j1.4
50-Ohm SWR	1.42	1.06	1.13	1.35
15 Meters (Design Frequency 21.19 MHz)	Bandwidth: 2.12%			
Frequency MHz	21.0	21.19	21.225	21.45
Free-Space Gain dBi	7.49	7.11	7.03	6.57
180° Front-Back Ratio dB	16.88	37.31	28.18	14.96
Impedance (R +/- jX) Ω				
Pre-Match Line	79.1 - j24.9	105.9 - j1.2	110.6 + j1.9	135.5 + j15.7
Post-Match Line	63.2 + j19.6	52.4 + j0.8	50.2 - j0.5	40.6 - j3.4
50-Ohm SWR	1.52	1.05	1.01	1.25
10 Meters (Design Frequency 28.40 MHz)	Bandwidth: 3.51%			
Frequency MHz	28.0	28.40	28.50	29.0
Free-Space Gain dBi	7.59	7.28	7.19	6.79
180° Front-Back Ratio dB	15.08	29.40	28.54	16.16
Impedance (R +/- jX) Ω				
Pre-Match Line	66.6 - j49.1	91.9 + j1.6	98.6 + j12.9	131.7 + j62.3
Post-Match Line	46.8 + j31.0	61.2 - j4.1	57.6 - j11.2	36.9 - j22.8
50-Ohm SWR	1.88*	1.24	1.29	1.83

*10-meter matchline is 95", rather than 104".

The 20-meter performance curves in **Fig. 11** are almost indistinguishable from those of the 20 meter elements in the 20-15-meter dual-band quad. The curves show the characteristic slight up-shift in frequency. Even the band-edge front-to-back ratio values are similar to those in the 2-band antenna.



Equally similar to the curves for 20 meters in the 2-band quad are the tri-band 20 meter matched impedance curves in **Fig. 12**. The pre-matched resonant impedance on the design frequency is virtually identical to the value for the 2-band model, and the resistance and reactance changes across the band are within a few Ohms of those of the 2-band model. As a consequence, a 1/4-wavelength 75-Ohm matching line provides a very satisfactory SWR curve with a maximum value of 1.42:1.

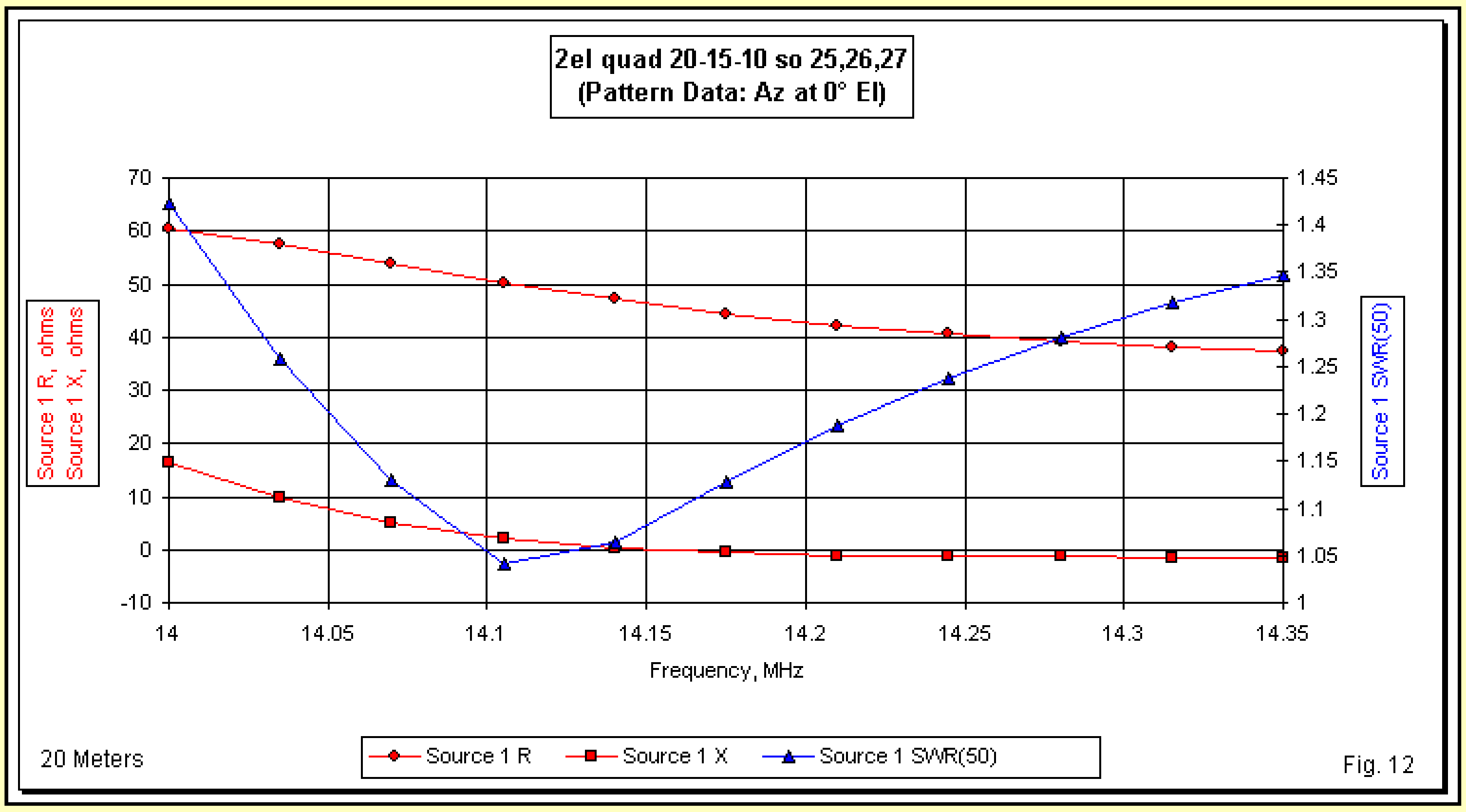


Fig. 12

Since the 15-meter elements of the tri-band, separate-feed quad differ from both the monoband version and from the 2-band versions using either an inner or an outer position, we expect at least some difference in the performance curves. The rate of change in gain across the 15-meter band is one measure of similarity and difference. In the tri-band quad, the rate is greater than in the monoband 15 meter quad and also greater than when the 15-meter elements form the inner loops of a 2-band quad. However, the rate is lower than when the 15-meter loops form the outer elements of a 2-band antenna. See **Fig. 13**. Corresponding to these differences--which are small but distinct--are differences in the band-edge values of the 180-degree front-to-back ratio. In the tri-band version, they are lower than in the monoband version and lower than when 15 meters forms the inner elements of a 2-band quad. However, the values are higher than those for 15 meters as the outer quad in a 2-band antenna. Nevertheless, in both categories of performance, the central position of the elements allows us to return the curves to their monoband position, that is, with the front-to-back peak at or very near to the design frequency.

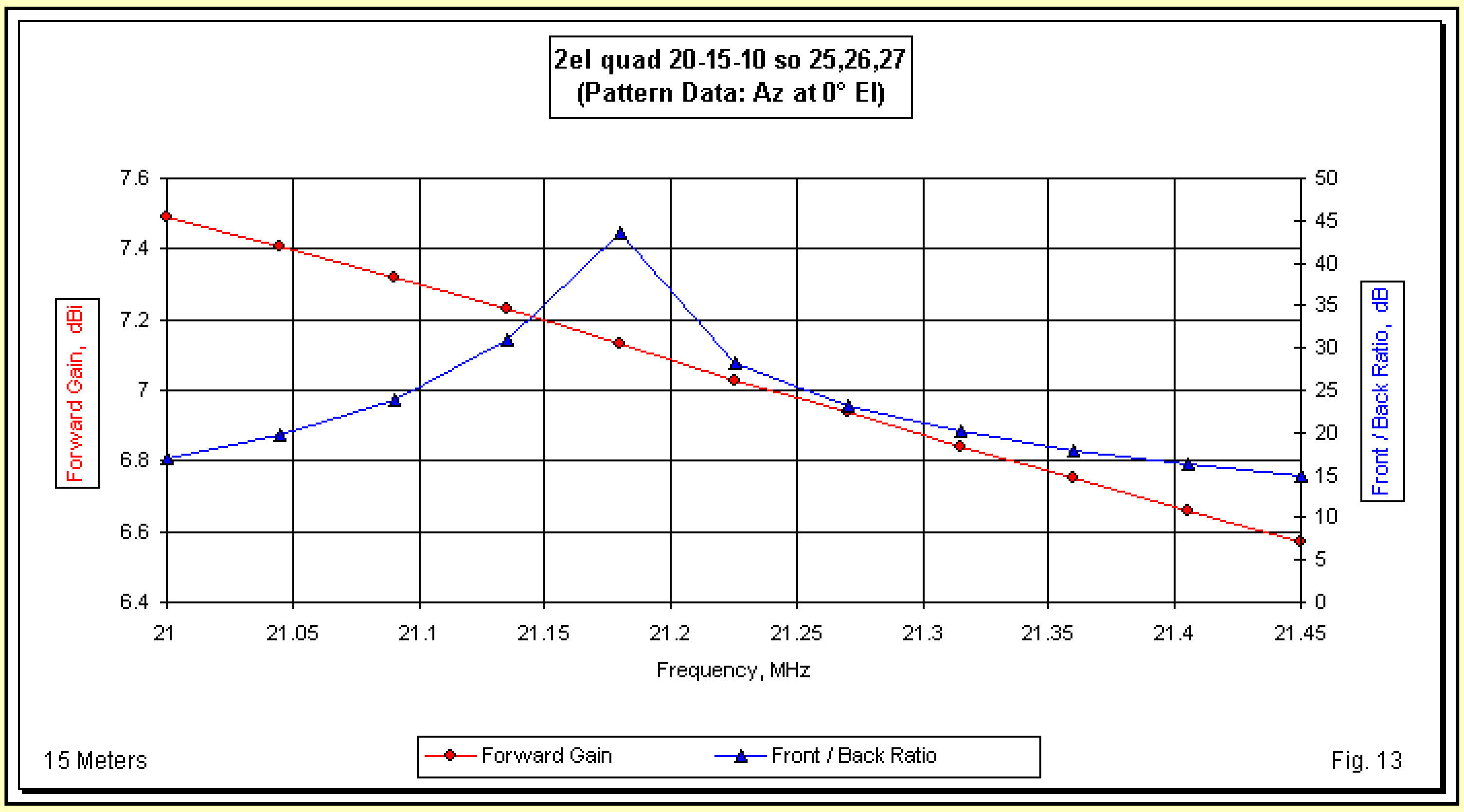


Fig. 13

Despite the normalcy of the gain and front-to-back curves, the pre-matched impedance of the 15-meter band most resembles values that we obtain for the inner quad of a 2-band model, as shown in **Fig. 14**. As a result, the standard 1/4-wavelength 75-Ohm matchline yields a 50-Ohm SWR curve that is higher a the low end of the band. The curve is similar to the one for the 15-meter section of the 20-15 2-band quad, but with a slightly higher value at the low end of the band and a slightly lower value at the high end of te band. An adjustment to the matchline length would equalize the band edge values and reduce the maximum value below 1.5:1.

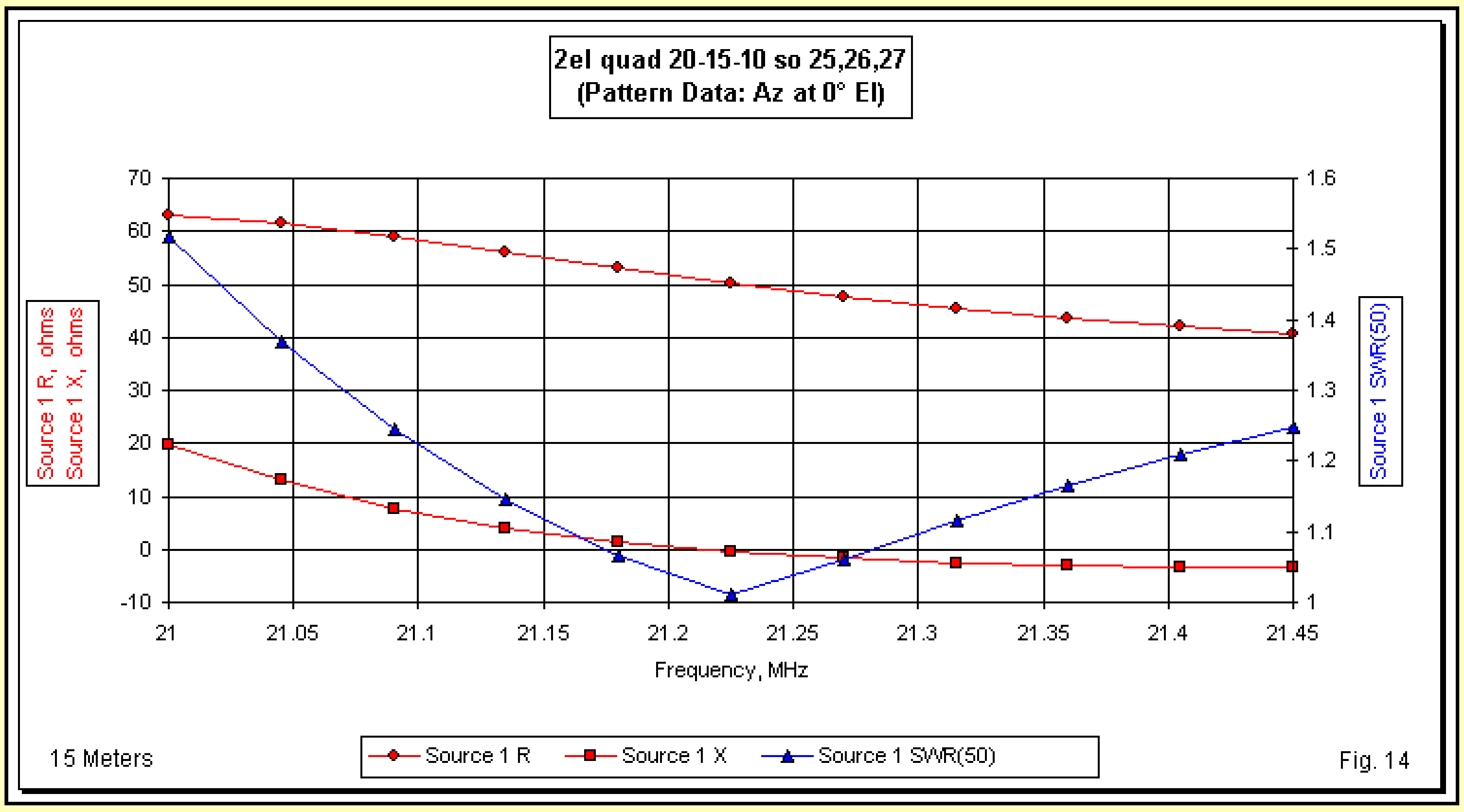


Fig. 14

The 10-meter elements form the inner elements of the tri-band quad. The inner elements tend to show the lower rate of gain change in 2-band quads, and this trend continues in the tri-band model. The rate of gain change is lower than in both other models using 10-meter elements. The band-edge front-to-back ratio values match those of the 15-10 meter quad and are higher than the values shown by the monoband model. The overall front-to-back curve has a somewhat shallow appearance, especially when compared to the monoband version. The peak front-to-back ratio occurs on about 28.44 MHz, but it scarcely exceeds 30 dB, compared to a value of nearly 60 dB in the monoband version. (Of course, in a practical quad, the exceptionally sharp and narrow-band peak might not be obtained, even on a monoband quad.)

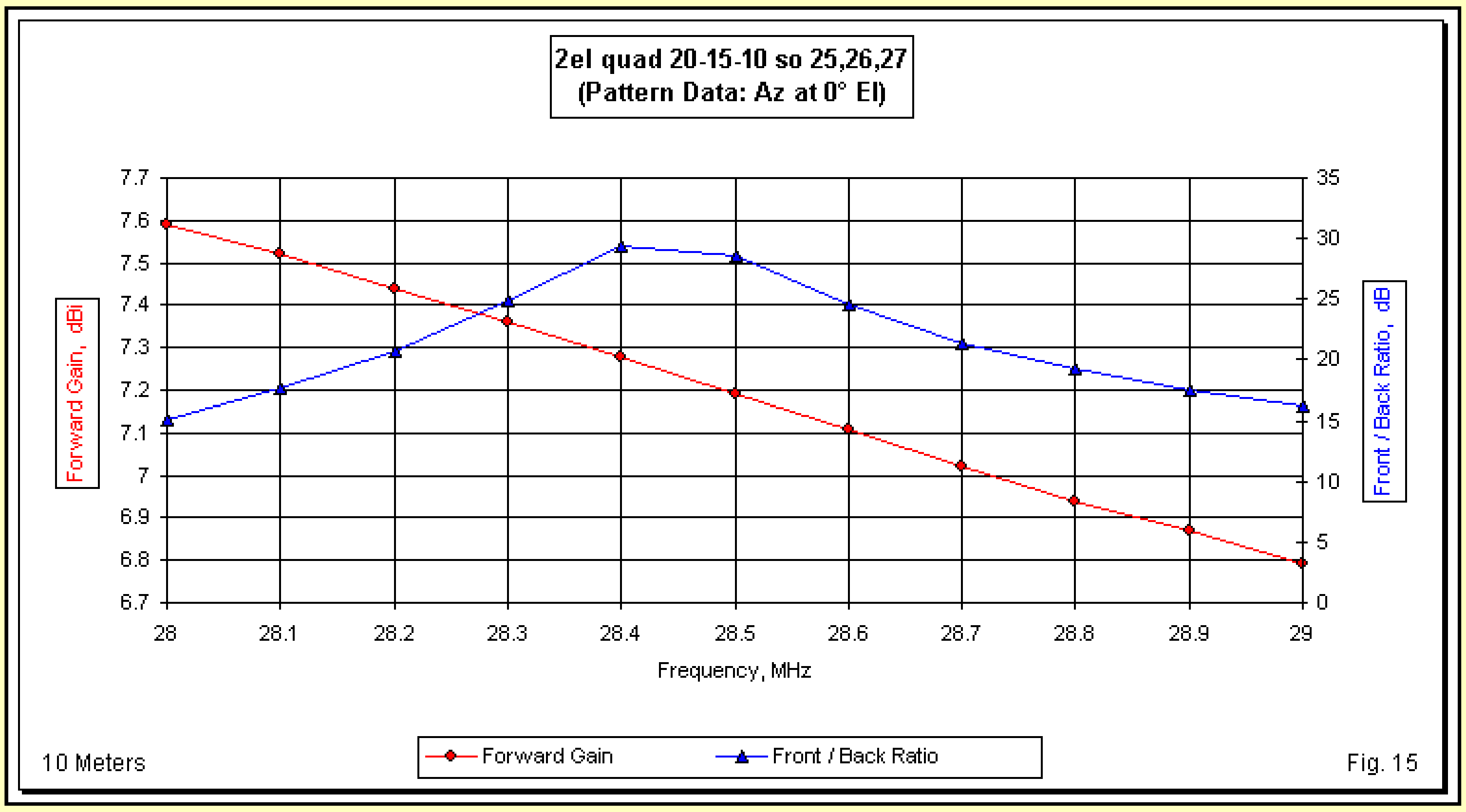


Fig. 15

The pre-matched impedance of the 10-meter elements starts with a low resonant value (about 92 Ohms) and also shows rather wide excursions of both resistance and reactance across the wide 10-meter band. A 75-Ohm matching line is not ideal for the situation, although using the prescribed length shown in **Table 10**, the 50-Ohm impedance remains below 1.9:1 at both ends of the passband.

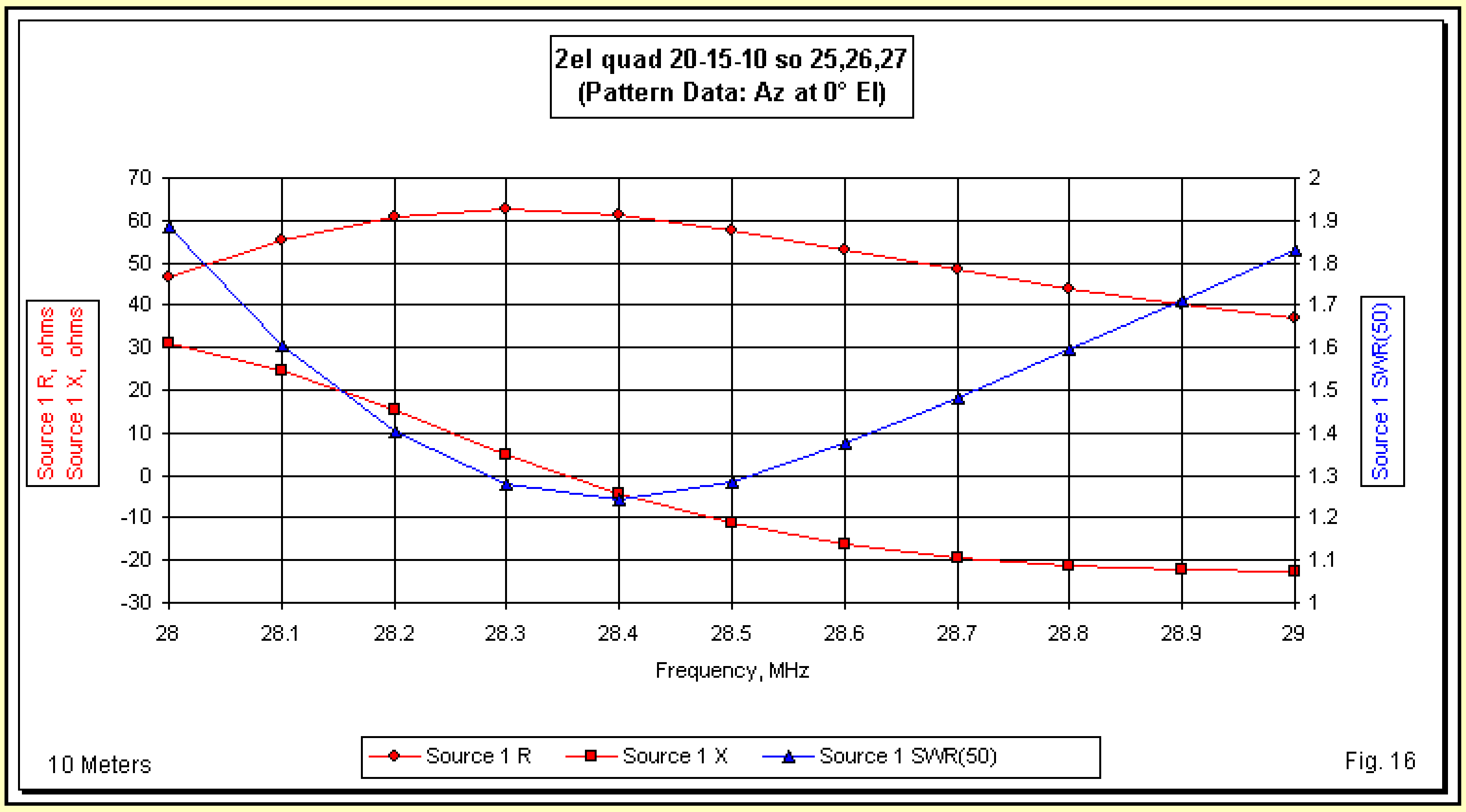


Fig. 16

The most usual strategy employed to improve the 10-meter SWR situation is to revise the 10-meter elements so that they provide a more acceptable--higher--resonant feedpoint impedance. However, the gain or the front-to-back performance may suffer as a result of these changes. Alternatively, one might lower the design frequency and limit the SWR passband to an upper frequency of about 28.8 MHz.

Despite the strain of obtaining an adequate SWR spread across the 10-meter band, the tri-band quad provides overall performance that is fully adequate to most needs on all 3 bands. Separate drivers and match-lines for each band allow for a remote switching system. As well, one may make fine (in contrast to basic) adjustments to loop lengths without significant change on the other bands. In the end, the performance of the tri-band quad is similar to the performance of the 2-band quads and of the monoband quads.

Conclusion to Part 2

In this part of our exploration, we have examined the physical and performance changes occasioned by combining monoband beams into several 2-band beams and one 3-band array, using separate drivers for each included band. Throughout, we remained true to the original monoband designs by retaining the element spacing. Thus, each spider quad shows almost identical angles between the driver and reflector elements for each band. The angles are close enough to each other so that non-conductive spacer rods can easily allow a builder to fix the spacing. However, in a quad (or other parasitic 2-element beam), the spacing tends to be less sensitive to change than the element lengths.

The exercise has shown us what physical modifications occur as a result of simple element interaction between quads on the same support system when the frequency ratio between quads is between 1.3:1 and 1.5:1. This step has been necessary in order for us to be able to separate alterations of quad dimensions or of performance due to the use of a common feedpoint from alterations that are basic to placing 2 quads on the same arms.

In the final part of this exploration, we shall deal directly with 2-band quads using a common feedpoint. We shall encounter only 3 new models: 17-12 meters, 15-10 meters, and 20-15 meters. For reasons that will become clear in our examination of these models, we shall set aside the tri-band quad. However, in its place are a series of fundamental modeling questions. Therefore, we shall not begin the last part by looking at 2-band quad performance. Instead, our first question will involve the proper way to model a common-feedpoint quad driver set.

Go to Part 3

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