Short Multiband LP for Feeding Parabolic Reflectors
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In 2012 Ben Lowe, K4QF, wrote an article about a conventionally designed LP for feeding a data reflector on 1296 and 2304. He based his design on work by the inventors of the LP who worked at Collins the same time he did. That was Robert Carrel. Ben had built and tested the feed on a networking rod parabolic reflector at the SEVHF conference in 2006. He has given me permission to use data and illustrations from his paper.

In about 1962 at a talk at the St. Louis Engineer's Club by one of the LP inventors, Duhammel or Carrel, I noticed that the active element lengths and spacings were very similar to a 3 element parasitic yagi. So I asked how much of the current in the non resonant elements was from their impedance connected to the feed line and how much was coupled like in a yagi. The answer I got was that coupling was all from the feed line. My analysis does not agree with that. I find considerable coupling between elements in W8JK mode as sell as sourced by the feed line. Ignoring element to element coupling does simplify analysis but introduces errors. W8JK in his 1956 McGraw Hill book Antennas was very clear about the effect of coupling between dipoles fed out of phase.

Thus far it has been assumed that there are no heat losses in the antenna system. In many antennas such losses are small and can be neglected. However, in the flat-top antenna such losses may have considerable effect on the gain. Therefore, the question of losses and of radiating efficiency will be treated in this section in connection with a discussion of arrays of two closely spaced, out-of-phase elements. The term "closely-spaced" will be taken to mean that the elements are spaced $\frac{1}{4}$ wavelength or less.

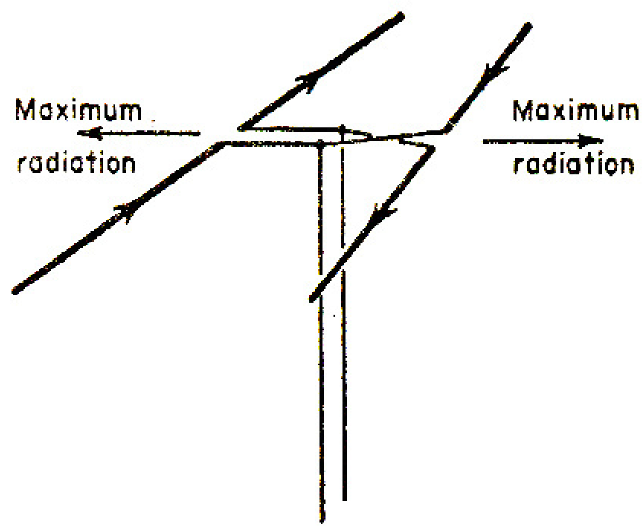


FIG. 11-14. Flat-top beam antenna with closely spaced elements carrying equal out-of-phase currents.

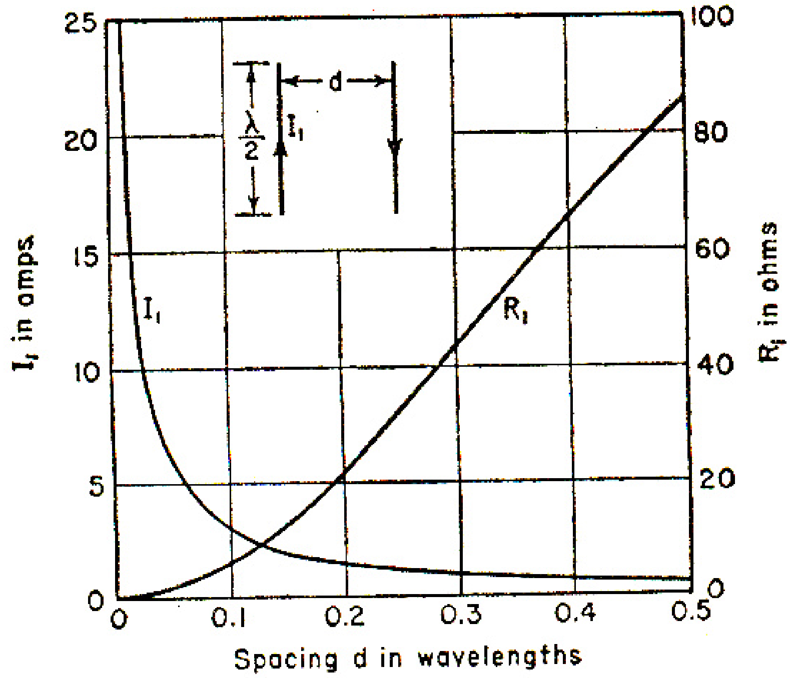
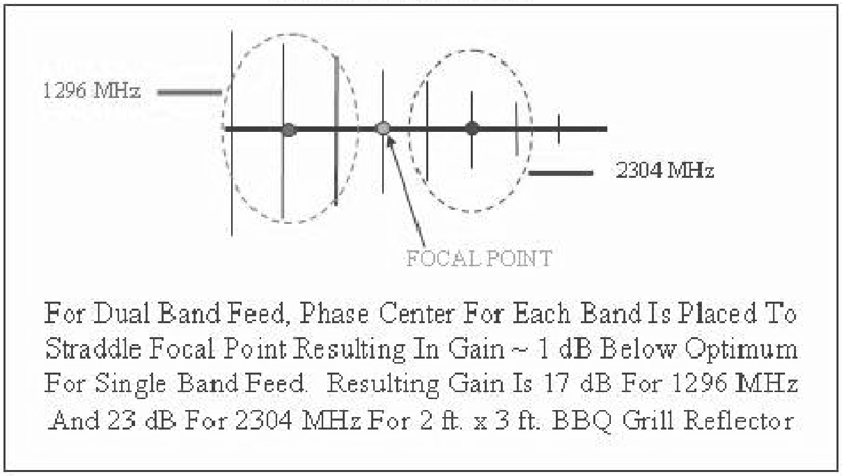


Fig. 11-15. Current I_1 and radiation resistance R_1 in each element of a flat-top beam antenna as a function of the spacing. The current is calculated for a constant input power of 100 watts to the array.

Ben had to compromise the feed location on the boom because the phase center for 1296 was near the longest elements and for 2304 was near the smallest element.

PHASE CENTER OF FEED SHOULD BE PLACE AT FOCAL POINT OF PARABOLIC FOR OPTIMUM PERFORMANCE



From Ben Lowe's paper DUAL BAND 23-13 CM ANT.pdf. This shows the compromises to use a standard LP as a dish feed.

I modeled Ben's antenna and the current is greatest in the resonant element and some less in the adjacent 26% longer and 21% shorter elements. The model shows currents in all of the elements far from resonance. The magnitudes depend on how far from resonance.

The following page is from Ben Lowe's paper DUAL BAND 23-13 CM ANT.pdf.

LOG PERIODIC DIPOLE DESIGN

INPUTS:

Elevation Beamwidth:	101	deg.
Azimuth Beamwidth:	78	deg.
Gain:	4.2	dB
Fmax =	2500	MHz
F min =	900	MHz

Element Lengths: (Dia. = 1/16 in.)

Element #, L#	Length, cm.	Length, In.
1	19.67	7.74
2	15.54	6.12
3	12.27	4.83
4	9.70	3.82
5	7.66	3.02
6	6.05	2.38
7	4.78	1.88
8	3.78	1.49
9	2.98	1.17
10	2.36	0.93

Element Spacing	Dist., cm.	Dist., in.	Total, in.
	0.254	0.100	0.100
1-2	5.310	2.091	2.191
2-3	4.195	1.652	3.842
3-4	3.314	1.305	5.147
4-5	2.618	1.031	6.178
5-6	2.068	0.814	6.992
6-7	1.634	0.643	7.635
7-8	1.291	0.508	8.143
8-9	1.020	0.401	8.545
9-10	0.806	0.317	8.862
	0.254	0.100	8.962
Total =	22.763	8.962	8.962
		Total+0.1	9.062

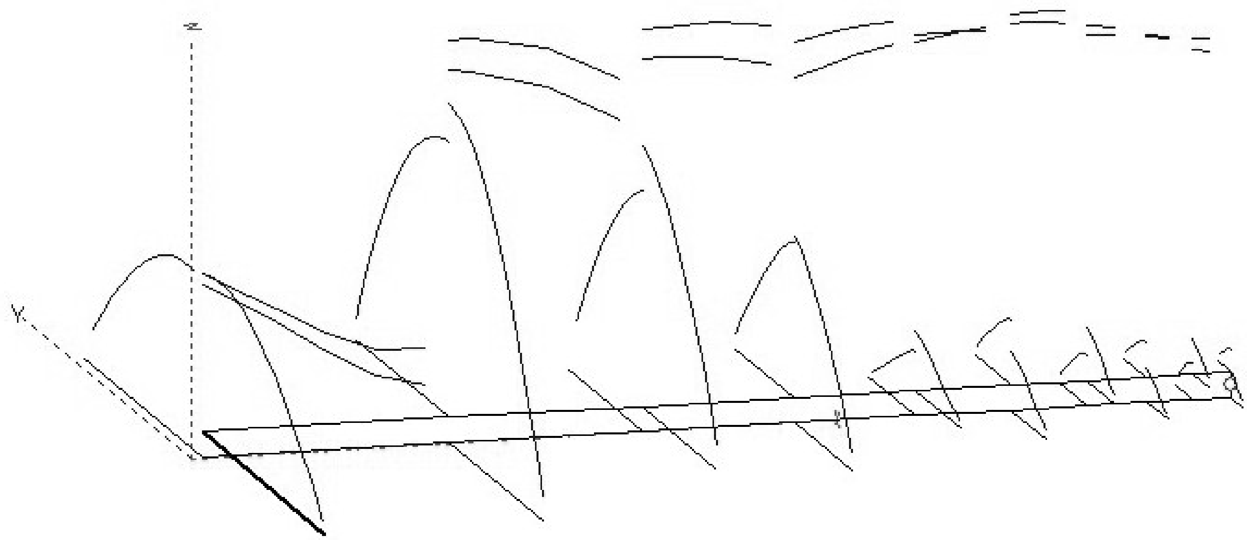
Feeder Spacing

Z = 276*log(2A/d) for A/d > 2.5

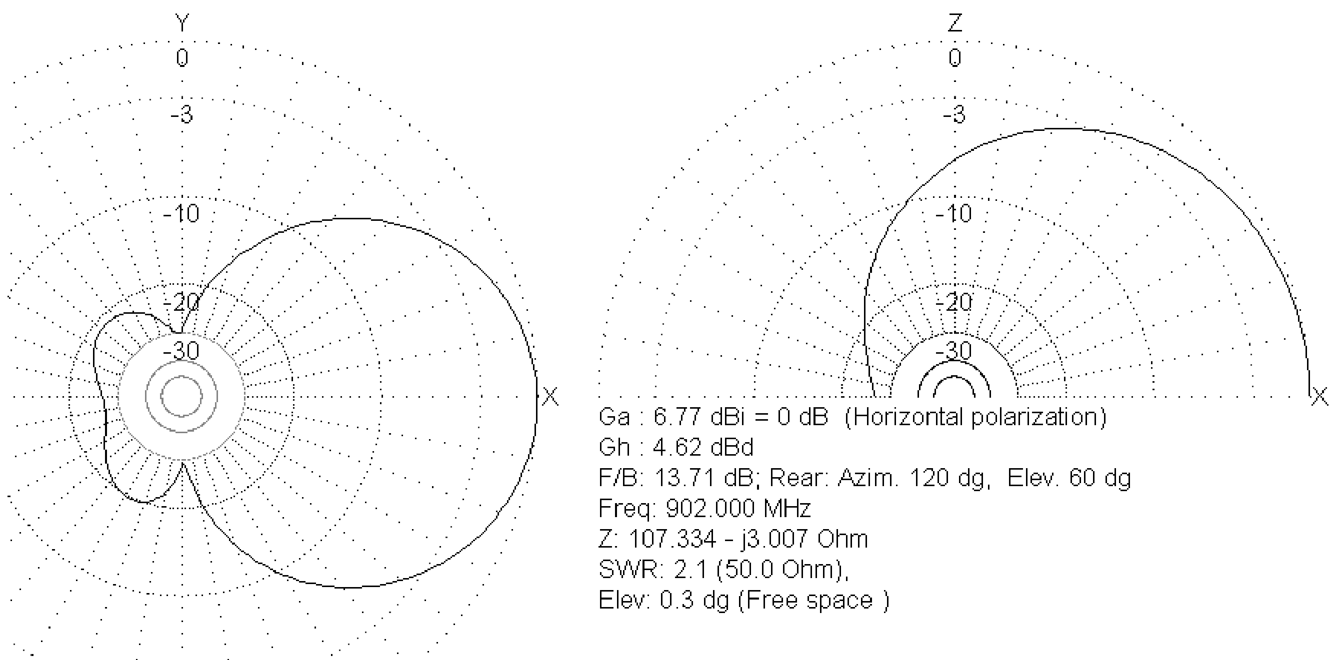
let Z =	100	ohms
A/d =	1.152	
let d =	3/16	in., Feeder Dia.
d =	0.188	In.
A =	0.216	in. ~ 7/32 in., Spacing

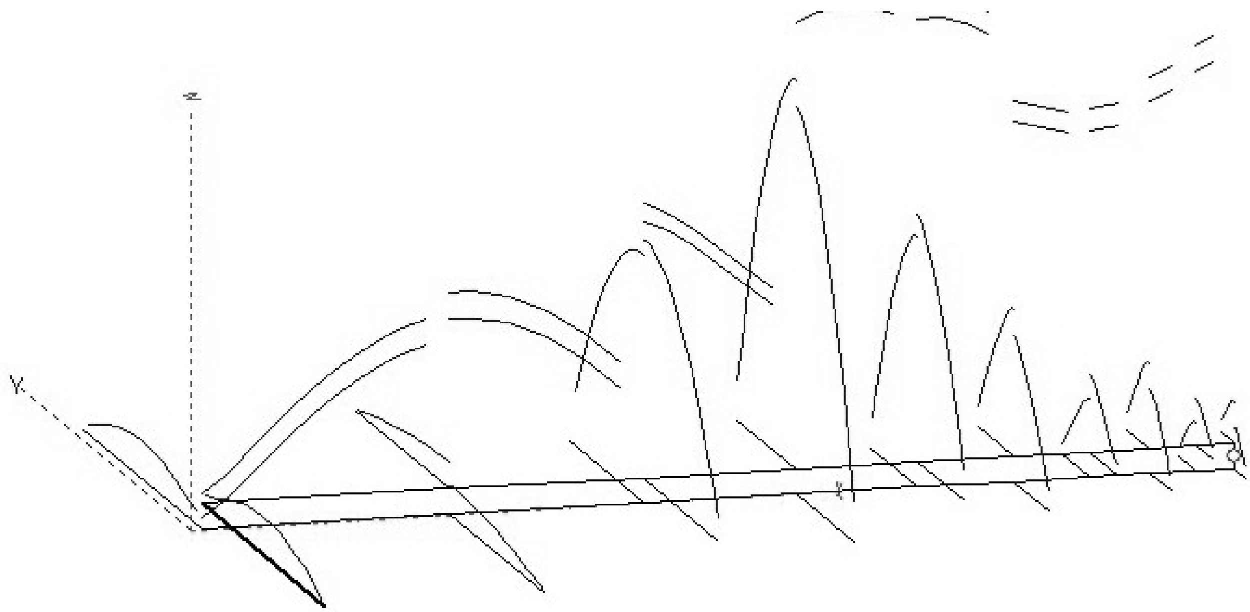
[illegible]

Ben's formula for the feed line impedance is not correct for this close spacing. The correct formula is Z = 120 * arccosh D/d where D is the center to center spacing and d is the conductor diameter. His Z is 65Ω. I had an article in VHFer in 1966 and CSVHF proceedings in 2010 on that topic that includes a graph. For 100 ohms the center to center spacing should be 1.35x d = 0.253” or a gap of 0.065” instead of 1/32”. The one I took to CSVHF with the 1/32” spacing had a poor impedance match and was down a little on gain from the model. My spacers may have been lossy too.

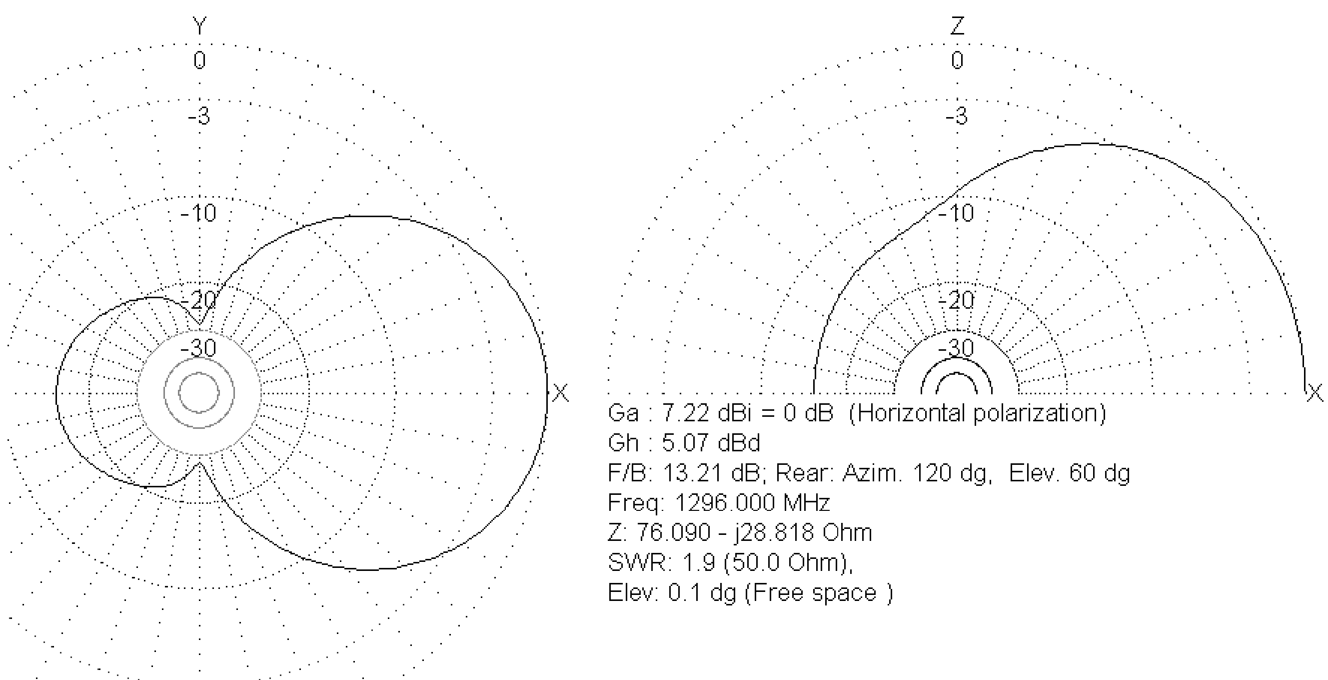


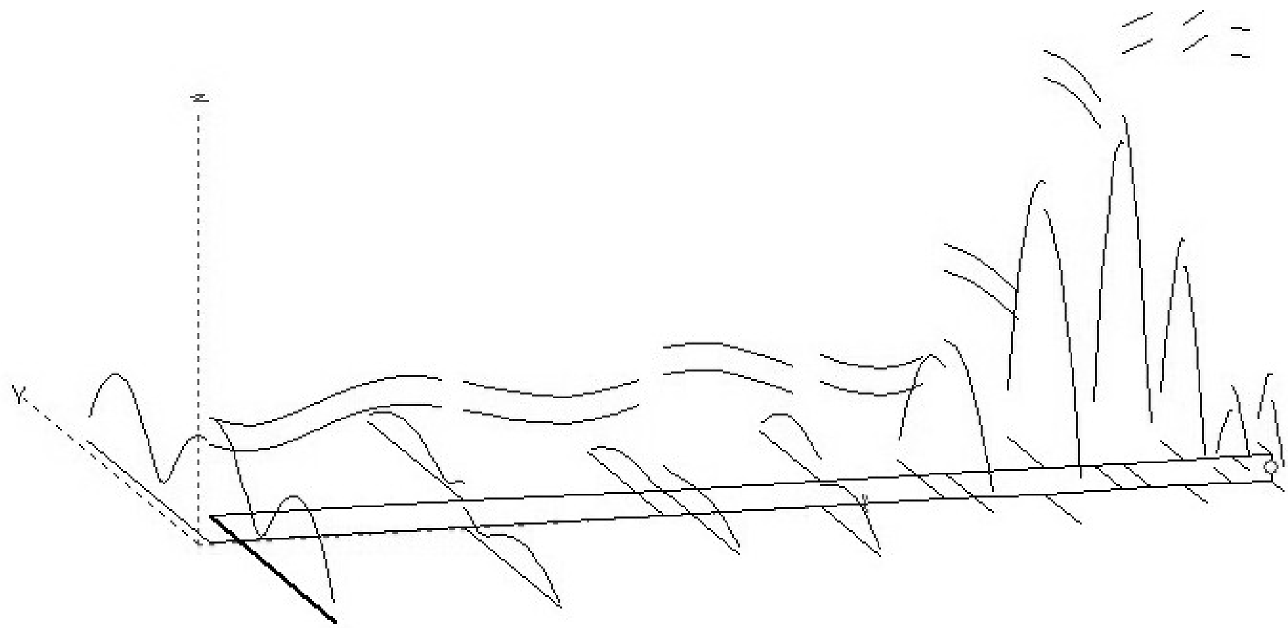
This is the Mmana-Gal current display of Ben's feed at 902 MHz. And it gives a computed radiation pattern next.



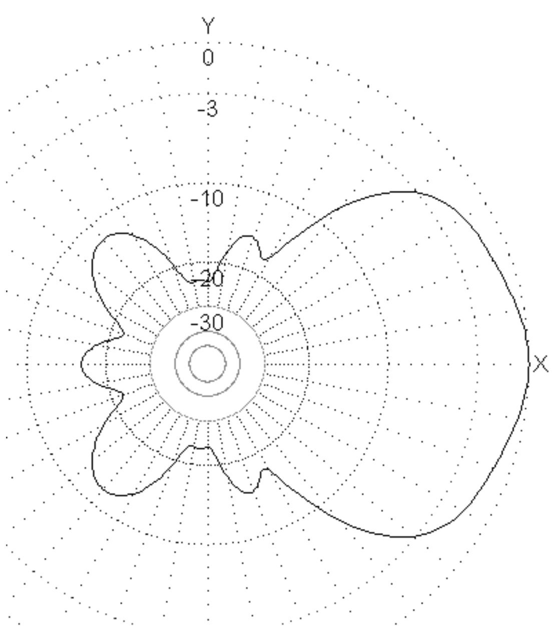


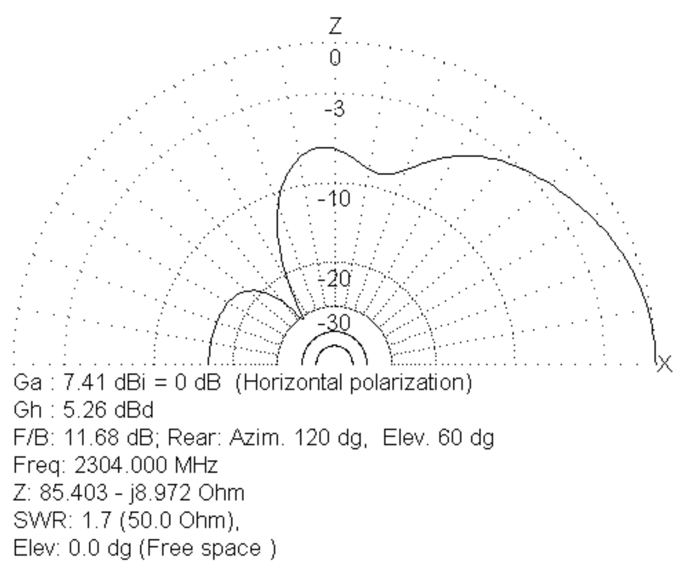
This is the current plot for 1296. Notice the feed current between elements 4 and 5 is greater than the element currents. A sign of W8JK mode of close spaced elements fed out of phase where the coupling raises the currents in the elements and so give some gain.





The currents at 2304, some W8JK mode showing and every element no matter how long or short had some current and the longer elements add to the 45 degree lobes from being 1.5 wave long or longer. But it is still a workable feed. I also ran the model at 3456, 5760, and 10368. Going higher in frequency the multiple lobes increase, but up to 5760 the patterns are still useful. Front to back at 10368 is too poor for a good feed, but then the shortest element is ½ wave resonant about 6770 MHz.





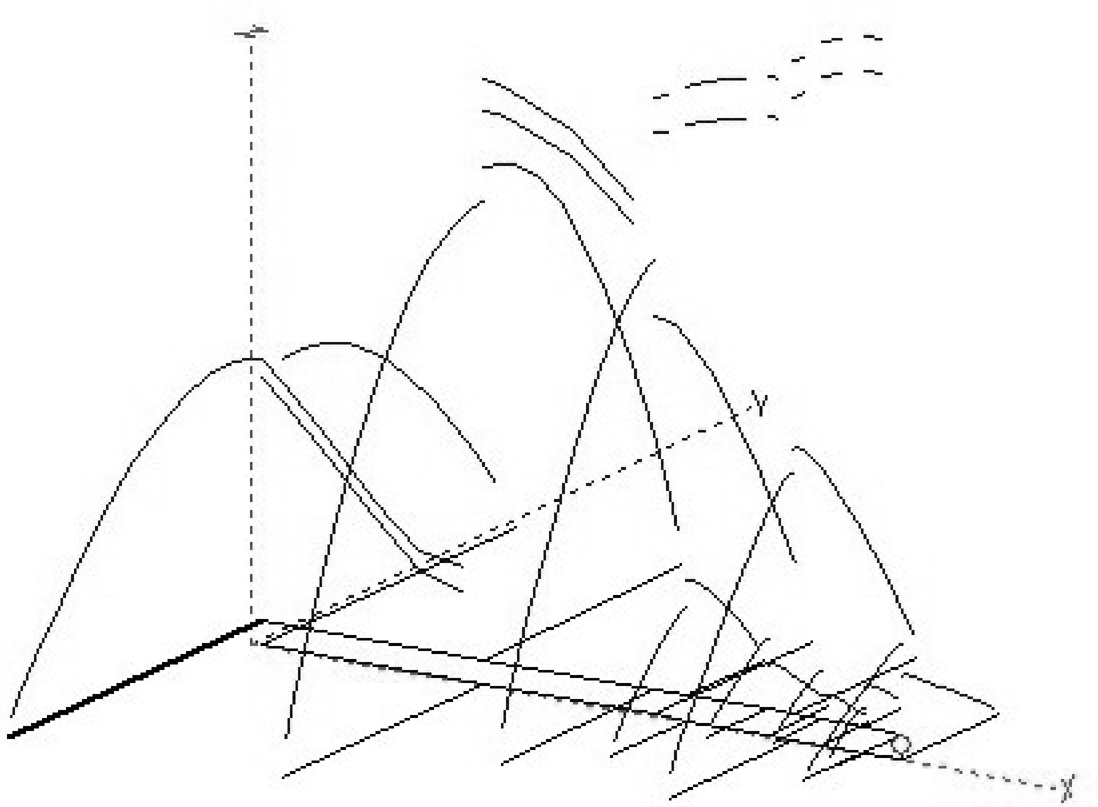
If the answer I received in 1962 was really true, the shorter elements do very little to add the gain or directivity of the multi band LP and there is no real reason the elements need to be in length order, especially when we want feeds for two or three band and don't care about antenna performance between those bands.

So I propose that the dual band LP can be built with the resonant elements for two bands sharing the same position on the LP feed line with the other active elements spread by the usual design formulae for length and location. That should put the phase centers much closer to the same position and with the same element and spacing tapers the antenna patterns should be similar. There will have to be some compromise for more than two bands, though by not having resonant elements on those bands their phase centers can be made to match those of the first set of resonant elements by adjusting the phase angles of two almost resonant driven elements to be equally leading and lagging phase angle and equally spaced from the resonant elements. This is not a good idea when continuous coverage is needed.

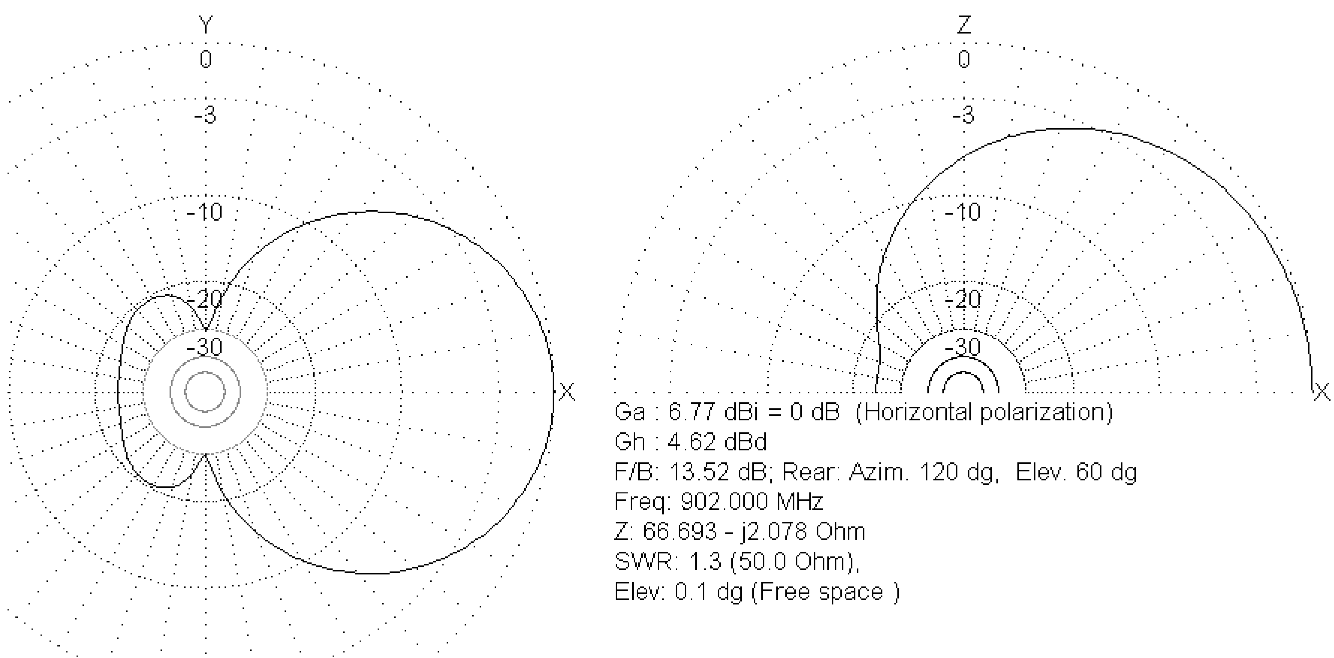
I started the modeling looking just at the resonant element with the two halves offset like in a LP and adding the high band elements in various schemes. What I found is that after adjusting the low frequency element alone for resonance indicated by zero reactance at the design frequency, that adding the high band elements, in the various schemes in the figure that the capacitive reactance of the short elements always moved the feet point well away from the zero reactance resonance. And on the high band frequency the close positioning of the two band elements coupled to the low band elements even if they were nearly ½ wave on each side and so very high impedance.

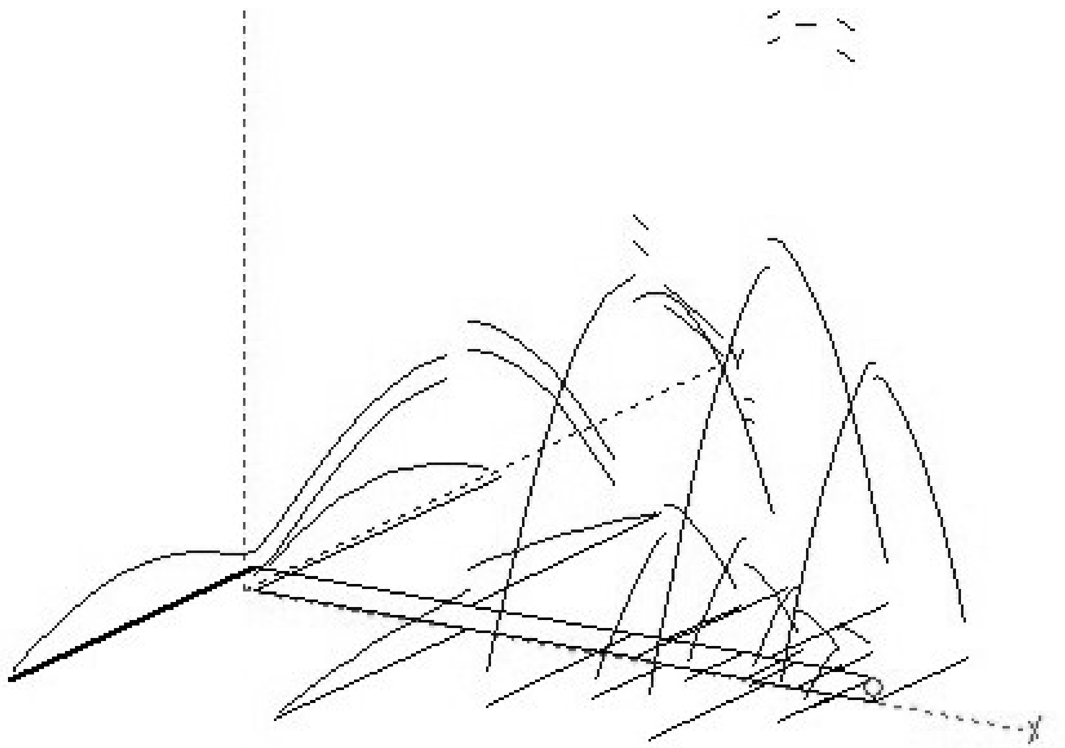
As I tried to model variations on the original LP, I ran into an oddity with Mmana-Gal data entry. The radiation patterns and current distributions indicated some of the elements were not connected to the feed line. What I found is that if giving input in inches using the *i or in feet using the *f operators the resultant metric number displayed didn't always include all the metric digits, so when I used the displayed metric number for the feed end of an element sometimes even though the difference in end coordinates might have been only a few micrometers, Mmana-Gal didn't make the connections. I didn't find a way to tell it “connect this to W3E” which is a feature of EZNEC. So it is necessary to use the same *i or *f data input to make sure wires get connected.

I concluded that putting high band elements in line with low band elements was not a great idea, so I shuffled the high band elements to fit between the low band elements. Numbering Ben's original elements 1 to 10 from the longest to the shortest, my modified and shortened LP assembled them in the order 1, 2, 3, old 6, old 7, old 4, old 8, old 9, old 5. I left out the old 10 because it would have been against the old 5. Also by putting two short elements in the gap between long elements the alternating element pattern characteristic of the LP is maintained. I spaced elements 7 and 8 equal distances from the old 4. After I solved the Mmana-Gal connection problems it works as planned. The elements with the peak current are practically the same place on the feed, requiring a great deal less compromise for fitting the focus of the dish.

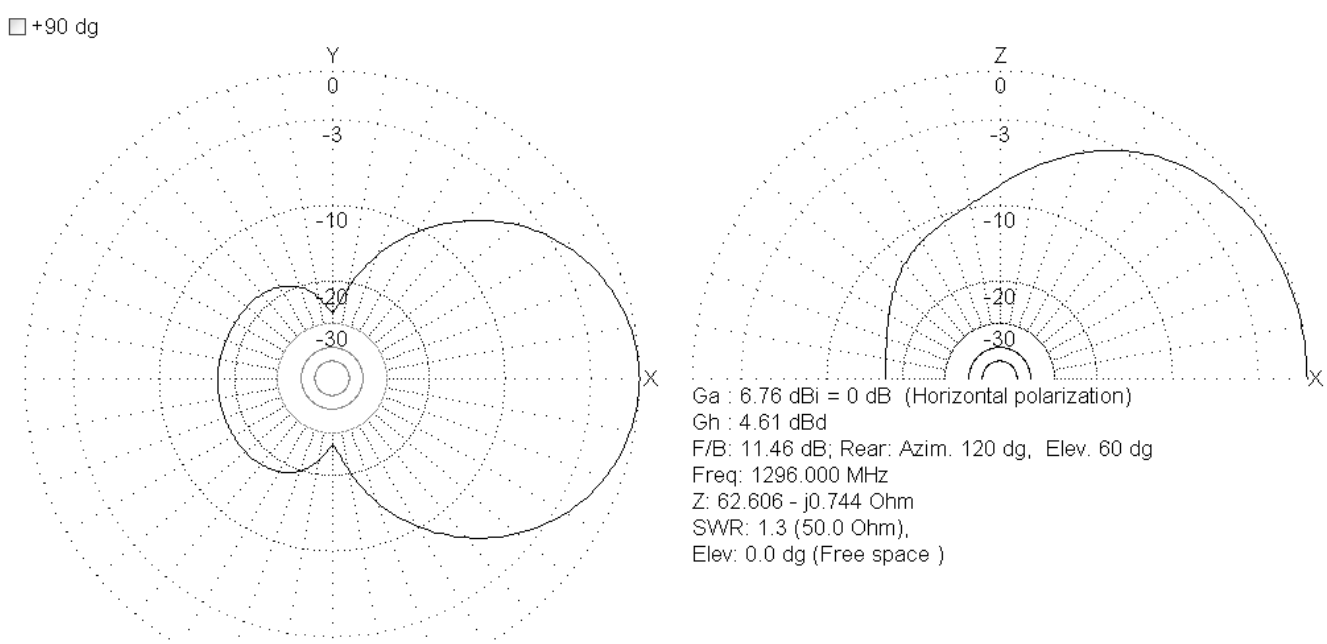


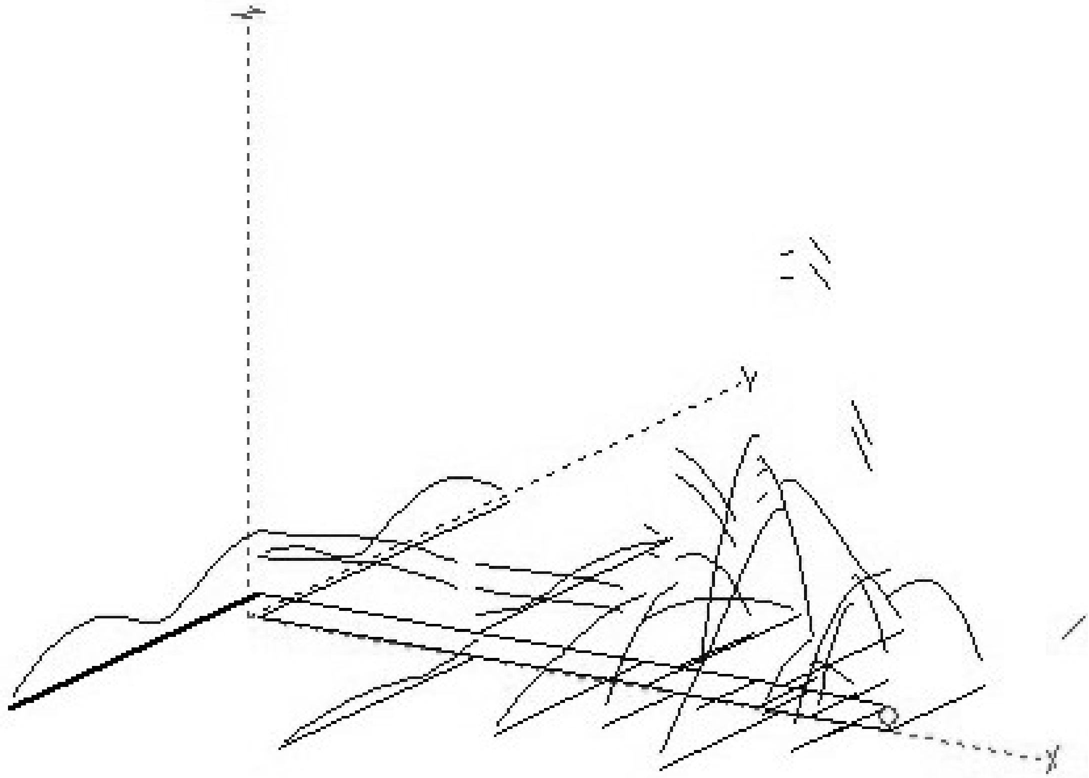
902 MHz currents in the KØCQ shortened LP feed. And the radiation pattern is decently clean.



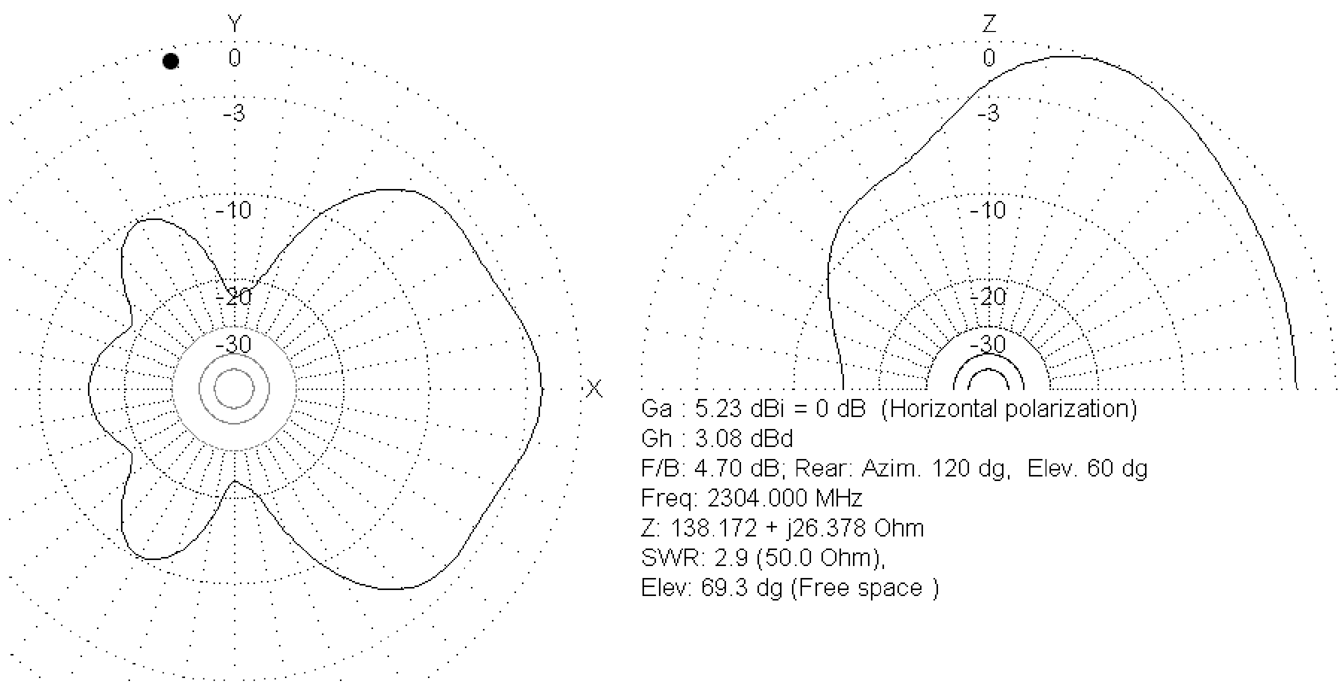


Element currents of the KØCQ short feet at 1296, and the radiation patterns.





Element currents of the KØCQ short LP feed at 2304, notice every element has some 2304 MHz current, and that affects the pattern to follow.



The gain is down a little but I think still a decent feed for a networking reflector.

The element plan.

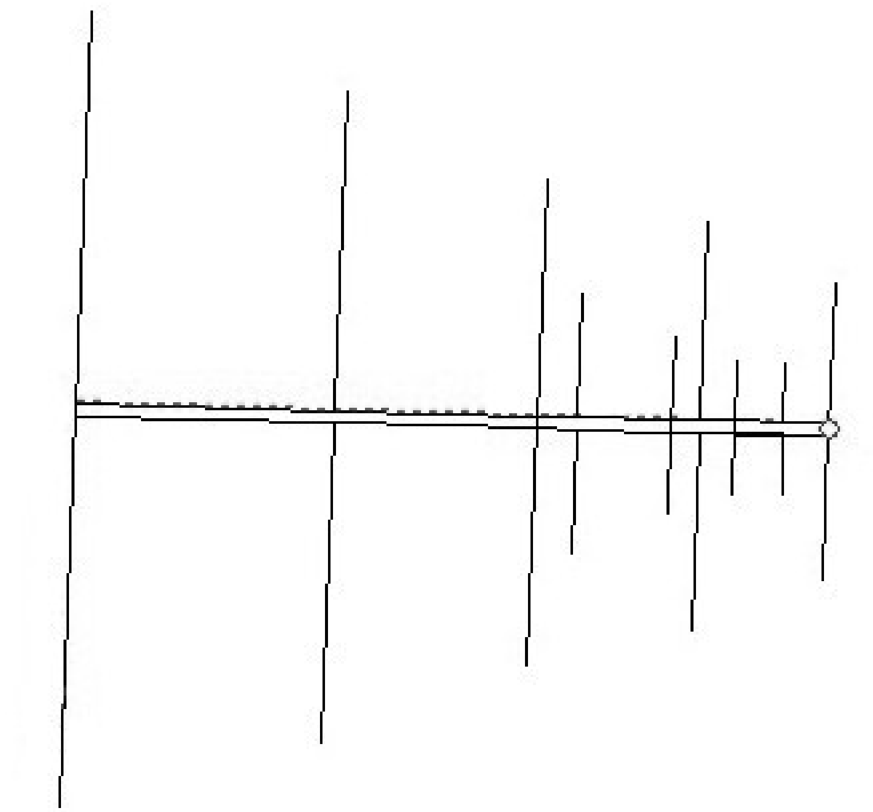


Table of elements starting with the longest element. Feed 3/16” diameter space 7/32” center to center, elements 1/16” diameter.

Element, F, full length, half length, distance from back end

Element	F	full length	half length	distance from back end
1	762 MHz	19.67 cm	9.835 cm	0.254 cm
2	964 MHz	15.54 cm	7.77 cm	5.565 cm
3	1222 MHz	12.27 cm	6.135 cm	9.959 cm
Old 6	2497 MHz	6.05 cm	3.025 cm	10.539 cm
Old 7	3136 MHz	4.78 cm	2.39 cm	12.473 cm
Old 4	1545 MHz	9.7 cm	4.85 cm	13.073 cm
Old 8	3566 MHz	3.78 cm	1.89 cm	13.764 cm
Old 9	5070 MHz	2.98 cm	1.49 cm	14.784 cm
Old 5	1957 MHz	7.66 cm	3.83 cm	15.692 cm

Its sure that the taper of the short elements can be slowed to achieve more gain at 2304 if needed.. After I solved the missing connections problem, I did try with and without old elements 5 and 10. This set worked adequately in the model.

The half length in the table is from the center of the feeder, so the half length elements need to be cut 3/32” or 0.238 cm longer to go through the 3/16” feeder, especially if it is made of hobby shop tubing which is what I plan to use. Despite the high frequency the basic operation of the LP allows for elements not being cut to the nearest 0.1mm without seriously affecting its operation.

The original W8JK two element antenna uses two half wave elements fed out of phase, By my analysis and Dr. Kraus's publications its very important that the feeds be connected together with low loss short (and crossed) feed line because the opposite phases and the close coupling (gain increases the closer the two dipoles are spaced) causes circulating currents in the elements larger than the feed current and the standard feed is to the center of the feed line between the dipoles. Several published authors have not noticed that detail and have suggested the two dipoles can have separate feed lines and be cross connected at any distance from the dipoles. Then one of them grumbles in his book about the 8JK concept not working. That was G6XN in his book “HF antennas for all locations” and the ARRL's W1ZR in the recent “Basic Antennas” that is otherwise a good beginning antenna book.

The way I see it, the LP starts with the W8JK and extends it by adding more elements then shifting the element relative phase by the feed position and the element lengths to achieve nearly a single direction radiation pattern, but the effects of the circulating current between adjacent and nearly resonant elements is important to the performance of the log periodic.

N0NAS told me he has seen a commercial EMF antenna built this way. So there might be some patent or antenna journal information to be found. I haven't looked yet.

WA5VJB told me this scheme of interlaced elements has been used for TV antennas.

Measuring a LP with two antenna ranges active gets difficult without a bandpass filter between the antenna and the detector and because of that at CSVHF in Rocheesr MN, the gain was not proovable on 2304 because changing the boom direction didn't necessarily peak the signal. I'll see if I can come up with better spacers of the right distance for future tests and maybe a band pass filter too.

There clearly is room for further refinement.

73, Jerry, KØCQ