

Notes on the Extended Aperture Log-Periodic Array Part 2: The Extended Aperture LPDA

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In Part 1 of this exploration, we examined the extended element, which lies at the heart of the extended aperture LPDA (EALPDA). A center-fed element about twice as long as a normal resonant dipole with a capacitance equi-spaced about 30% of the distance from the feedpoint outward along each half element will show about 1.1 dB additional gain and a narrower E-plane beamwidth than the dipole. The resonant impedance of the extended element is about 200Ω or roughly 3 times the impedance of a resonant dipole. We may construct such elements as monopoles or as extended dipoles. Longer elements with additional capacitances and higher gain values are possible, but the simplest extended element is all that we need for the basic EALPDA.

We also took a long look at optimized wide-band standard-design LPDAs for the 5-30 MHz range, the frequency span covered by the basic EALPDA shown in the Tanner 1973 patent submission. To replicate the somewhat vague reference to a long-boom LPDA, I modeled a 56-element LPDA using a τ of 0.96 and a σ of 0.18. Because LPDAs are subject to somewhat dated understandings based on literature from the 1960s and 1970s, we explored the antenna's performance in several modeling contexts. We looked at the antenna in free space and as a horizontal array 100' over perfect ground and over various grades of real ground. We rotated the antenna 90° to examine its properties in monopole form over perfect ground. Finally, we created a sloping LPDA with each element terminated 4' above perfect ground and above several qualities of real ground. The exercise familiarized us with the types of performance values that we see in each orientation so that we can apply the correct set for comparison with the EALPDA in its many possible configurations.

With these prerequisite, we are in a position to examine—within the limits of the available design information and the ability of modeling software to capture the design—the extended aperture log-periodic dipole array.

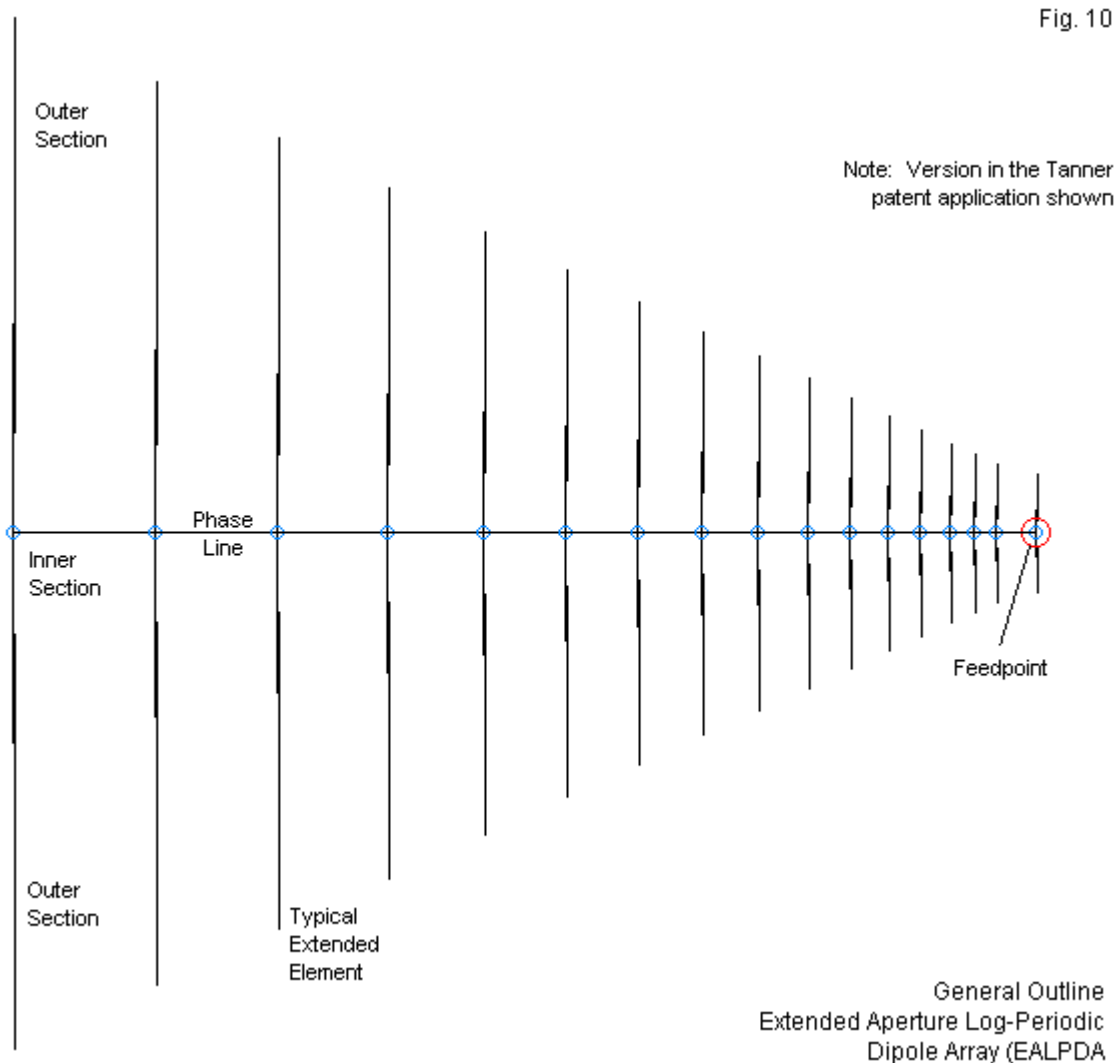
The Extended Aperture Log-Periodic Dipole Array (EALPDA)

A patent submission is not a technical document. Instead, it is a legal document and subject to numerous technical shortcomings. The Tanner patent for the EALPDA is also dated in its understanding of standard LPDA operation. For example, the document notes in column 1 that “in a prior art log-periodic antenna, the elements have high Q's so that few elements tend to be active at any frequency within the antenna's frequency range.” The author repeats this claim in other places (for example, column 6). As we have seen (in **Fig. 6**), this 1960s-1970s claim has given way in this decade to a better understanding of element activity.

The EALPDA rests on 2 general properties of the extended element: its higher gain and its broader bandwidth relative to a standard dipole element. On the basis of these properties, Tanner's EALPDA uses extended elements to arrive at an LPDA that requires perhaps $\frac{1}{4}$ the boom length of a standard LPDA for the same performance level. Since it requires extended elements, the total height of a vertical sloping version of the EALPDA is twice as high as the height of a standard vertical sloping LPDA. However, the array uses only about $\frac{1}{3}$ the number of elements ostensibly for the same performance. The lower Q or broader bandwidth of each extended element “causes more elements to be active at any one frequency, thereby lengthening the active region of the antenna” at any operating frequency (column 3). We may

pass over this problematical reference to active regions and simply note that the broader bandwidth of each element allows the inventor to use fewer elements, along with a much smaller value of τ in the design of an EALPDA.

The patent material provides the dimensions for a sample EALPDA in Table 1 in column 8. However, the text and the table are not in full agreement. For example, the text specifies 18 elements (items 51 to 68 in patent figure 3), but the table itself lists only 17 elements (51 to 67). 16 of the elements meet general requirements for τ -tapering of lengths and spacing between elements. However, the final element in the table has a specified position that is out of line. Therefore, it is initially unclear whether the table's information is technically correct for a viable design. The only way to find out is to model the array of wires specified in the patent and to see what we obtain. **Fig. 10** shows the array outline in an expanded sketch that shows the division of each element into 3 overlapping sections making up Charman-Cork extended elements.



The applicable value of τ for the EALPDA is 0.875, well below the 0.96 value of τ necessary to achieve the performance of the standard LPDA. For a τ of 0.875, the standard equation gives an optimal σ value of 0.161, but the patent design has a σ of about 0.170. In addition, the

patent design information does not specify a characteristic impedance for the phase line (or transposed transmission line). Hence, this parameter will be subject to trial and error. With these reservations, **Table 9** lists the dimensions of the modeled EALPDA. Each element entry has two components: a center section and an outer section. As a result, we also find an “overlap” entry for the distance occupied by both the center and the out sections. The space between the inner and the outer sections is a constant 4”, and the wire diameter is 0.16”. The center section lists its half-length, presuming a standard modeling practice of extending the element equally on each side of a selected axis line. The outer-1 and outer-2 entries indicate the coordinates for the start and end of each outer section relative to the selected axis.

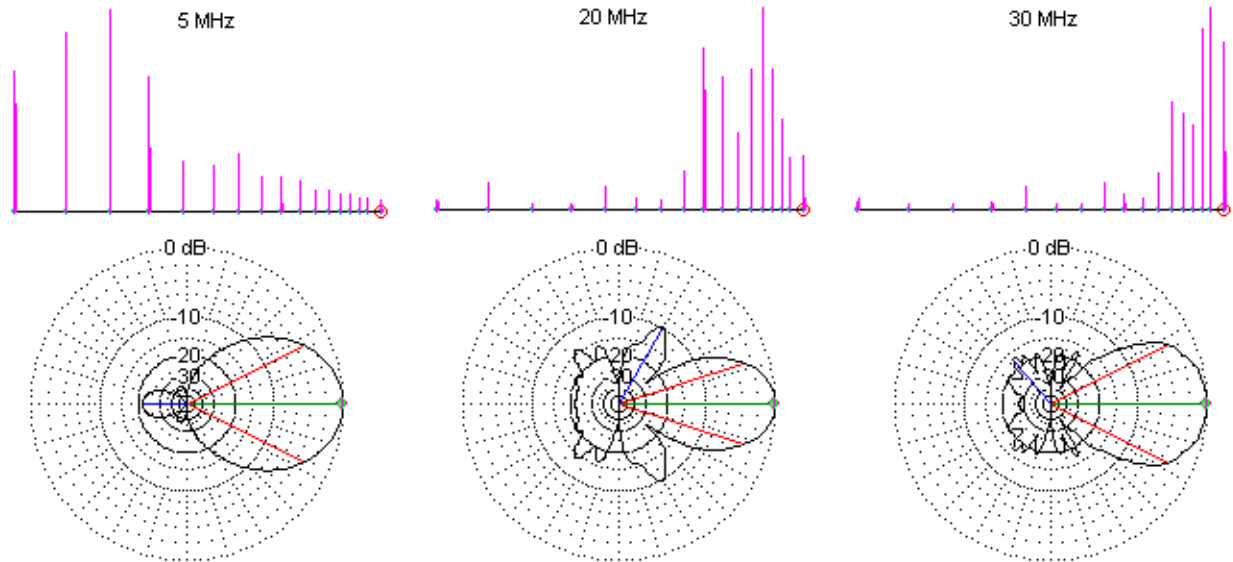
EALPDA Design		5-30 MHz				Table 9
Tau = 0.875, Sigma = 0.17						
Element	Space	1/2 Ctr	Outer-1	Outer-2	Overlap	Ttl Len
1	0.0	40.5	19.5	100.0	21.0	200.0
2	27.5	35.5	17.1	87.5	18.4	175.0
3	51.5	31.1	15.0	76.6	16.1	153.2
4	72.5	27.2	13.1	67.0	14.1	134.0
5	91.0	23.8	11.5	58.6	12.3	117.2
6	107.0	20.8	10.0	51.3	10.8	102.6
7	121.0	18.2	8.8	44.9	9.4	89.8
8	133.4	15.9	7.7	39.3	8.2	78.6
9	144.2	14.0	6.8	34.4	7.2	68.8
10	153.7	12.2	5.9	30.1	6.3	60.2
11	162.0	10.7	5.2	26.3	5.5	52.6
12	169.2	9.4	4.5	23.0	4.9	46.0
13	175.6	8.3	4.0	20.2	4.3	40.4
14	181.2	7.2	3.5	17.6	3.7	35.2
15	186.0	6.3	3.1	15.4	3.2	30.8
16	190.2	5.6	2.7	13.5	2.9	27.0
17	198.0	4.8	2.3	11.8	2.5	23.6

Note the position in the Spacing column of element 17. A perfect progression of τ would place it at about 194' from the rear element. For the initial model, the longest element used 99 segments per section (297 segments overall for the element). The segmentation decreases by the antennas τ factor as the elements grow shorter. Both of these factors—the departure from the τ -progression relative to spacing and the level of segmentation—will become model and modeling issues shortly. However, to gain some insight into the potential performance of the array in free space, we may examine the spot data in **Table 10** and the sampling of patterns and current distribution in **Fig. 11**. (Compare **Table 10** with the free-space values for the standard array in **Table 5**.)

Several trials yielded a 250- Ω phase line as the best fit for a 200- Ω target feedpoint impedance, corresponding with the same impedance target for the standard array. Indeed, although the impedance of an individual element is about 3 times higher than for a standard dipole element (200 Ω vs. 70 Ω), the use of extended elements in an EALPDA does not appear to change the relationship between the phase-line characteristic impedance and the array feedpoint impedance.

Table 10. Horizontally oriented 17-element EALPDA with a constant element diameter in free space.

Frequency MHz	5	10	15	20	25	30
Max. gain dBi	8.82	9.52	9.40	9.58	10.35	8.46
Front-back dB	21.53	20.02	22.74	21.41	28.05	26.62
Beamwidth degrees	52.4	39.4	38.6	36.0	39.8	53.6
Z (R +/- jX) Ω	214 + j22	185 + j16	216 + j20	207 + j2	253 - j95	267 - j86
SWR 200 Ω	1.13	1.13	1.13	1.03	1.62	1.60



Sample E-Plane Patterns and Current Distributions: Tanner Patent EALPDA

Fig. 11

Compared to the free-space values of the 56-element standard LPDA, the gain of the initial EALPDA model is about a full dB low. As well, the front-to-back values are modest. More striking are the E-plane patterns in **Fig. 11**, which shows various levels of less than ideal shapes above the lowest operating frequency. The current distribution curves show one reason why: the rearward elements show selective activity of significant proportions for all but the lowest frequency of operation.

The initial design, taken directly from the patent document raises two questions. The absence of an 18th element in the table along with the odd placement of the most forward element suggests that the design may not be as complete an array as it seems. The sudden drop in gain along with the rising SWR values at 25 and 30 MHz abet the doubt about the design. In addition, the pattern shapes suggest the possibility that the segmentation—adequate by reference to the standard LPDA design—may not be able to allow accurate calculations of the capacitance in the element-wire overlap regions, especially with shorter elements. Therefore, I reset element 17, added a new 18th element, and increased the element segmentation. The rearmost element now uses 137 segments per section, with the number of segment tapered by the τ -factor as the elements grow shorter. The revised version of the array approaches 3000 segments. However, average gain test (AGT) values for the array range from 0.993 to 1.005, suggesting a maximum gain error of only 0.03 dB. **Table 11** provides the dimensions of the modified EALPDA model using overlapping wires.

The overlapping-wire model is subject to the precision of the wire overlaps in establishing the correct capacitance between element sections. As shown in the first portion of these notes, it is possible to construct the elements from a single wire, placing a capacitor (or a modeled capacitive load) 30% of the distance from the center of the element outward. Therefore, I constructed a second model using this technique. I used sufficient segments in each element to place the required capacitive loads within 0.5% of the ideal position. The right 2 columns of **Table 11** provide the total element length and the values of each of the two required capacitors. The element spacing and the total element length are identical for the two models.

Modified 18-Element EALPDA Design		5-30 MHz			Tau = 0.875, Sigma = 0.17		
Element	Space	Overlapping-Wire Model			Cap-Loaded Model		
		1/2 Ctr	Outer-1	Outer-2	Overlap	Ttl Len	Cap pF
1	0.0	40.5	19.5	100.0	21.0	200.0	35.5
2	27.5	35.5	17.1	87.5	18.4	175.0	31.1
3	51.5	31.1	15.0	76.6	16.1	153.2	27.2
4	72.5	27.2	13.1	67.0	14.1	134.0	23.8
5	91.0	23.8	11.5	58.6	12.3	117.2	20.8
6	107.0	20.8	10.0	51.3	10.8	102.6	18.2
7	121.0	18.2	8.8	44.9	9.4	89.8	15.9
8	133.4	15.9	7.7	39.3	8.2	78.6	13.9
9	144.2	14.0	6.8	34.4	7.2	68.8	12.2
10	153.7	12.2	5.9	30.1	6.3	60.2	10.7
11	162.0	10.7	5.2	26.3	5.5	52.6	9.3
12	169.2	9.4	4.5	23.0	4.9	46.0	8.2
13	175.6	8.3	4.0	20.2	4.3	40.4	7.2
14	181.2	7.2	3.5	17.6	3.7	35.2	6.3
15	186.0	6.3	3.1	15.4	3.2	30.8	5.5
16	190.2	5.6	2.7	13.5	2.9	27.0	4.8
17	193.9	4.8	2.3	11.8	2.5	23.6	4.2
18	197.1	4.2	2.0	10.3	2.2	20.6	3.7

Note: Spacing and total length are the same for both models.

Table 11

Table 12. Horizontally oriented 18-element modified EALPDA with a constant element diameter in free space.

Overlapping-Wire Model

Frequency MHz	5	10	15	20	25	30
Max. gain dBi	8.63	9.74	9.93	9.82	9.98	9.52
Front-back dB	20.46	19.82	22.57	22.25	25.90	24.09
Beamwidth degrees	52.2	38.8	38.6	37.8	41.0	42.0
Z (R +/- jX) Ω	176 + j8	170 + j5	179 - j28	178 - j31	166 - j4	230 - j26
SWR 200 Ω	1.14	1.19	1.20	1.22	1.21	1.21

Capacitor-Loaded Model

Frequency MHz	5	10	15	20	25	30
Max. gain dBi	8.56	9.71	9.97	9.95	9.99	9.68
Front-back dB	18.82	24.81	24.81	34.58	27.87	33.77
Beamwidth degrees	51.8	38.2	36.2	38.2	39.0	41.0
Z (R +/- jX) Ω	170 + j3	191 - j23	218 - j26	225 - j6	188 - j52	163 - j27
SWR 200 Ω	1.18	1.13	1.16	1.13	1.32	1.29

Reference data for a 56-element standard design LPDA in free space						
Frequency MHz	5	10	15	20	25	30
Max. gain dBi	10.71	10.89	10.96	11.08	11.02	10.96
Front-back dB	50.48	54.05	46.53	44.64	41.72	34.23
Beamwidth degrees	53.2	52.8	52.6	52.2	52.0	53.2
Z (R +/- jX) Ω	196 - j5	193 - j8	191 - j12	191 - j23	192 - j24	193 - j48
SWR 200 Ω	1.03	1.06	1.08	1.13	1.14	1.28

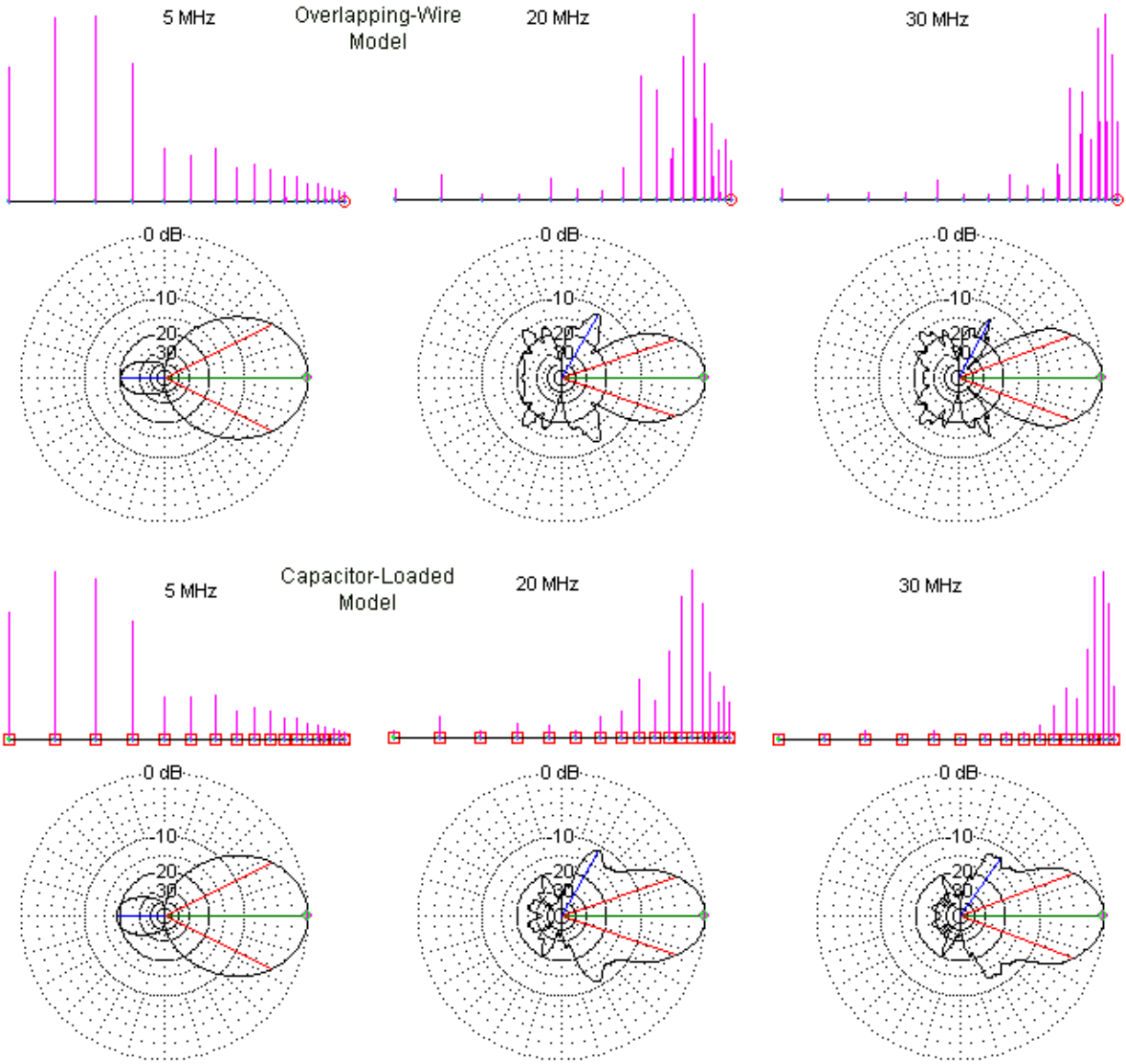
The sample data in **Table 12** show no major changes in either the gain or the beamwidth number between the two versions of the 18-element modified EALPDA. However, the capacitor-loaded version shows significantly higher 180° front-to-back ratios above the lowest operating frequency. In addition, we find significant differences in the feedpoint resistance and reactance values between the models, although neither set results in an unacceptable 200- Ω SWR value.

Fig. 12 compares the current distribution along each version of the array and E-plane patterns at 5, 20, and 30 MHz. Above 5 MHz, the capacitor-loaded model results in cleaner pattern shapes as well as somewhat lower levels of rear-element activity. It is quite likely that the capacitor-loaded model comes closer to the theoretically possible performance of the EALPDA, while the overlapping-wire model might show what the user can expect in practice from the subject array.

The performance improvement that emerges from moving to 18-elements is apparent at the upper end of the operating spectrum. The gain at 30 MHz is on a par with other values within the spectrum. The high-end SWR values are also down. Perhaps more significant than individual values is the shift in the reactive feedpoint components from inductive to capacitive, generally a sign of reasonably good array control. It is likely that the addition of further elements might lead to additional impedance control, since the τ of the array is low at 0.875.

In one arena, the modifications appear not to have effected improvements. The patterns in **Fig. 12** show similar shapes to those in **Fig. 11**. Moreover, we continue to find activity on rearward elements as we increase the operating frequency. The presence of significant forward and rearward sidelobes also raises the possibility of anomalous frequencies at which the pattern shows serious degradation or even reversal. The only sure way to determine—prior to construction and field testing—whether anomalous frequencies do exist is to subject the models to a series of frequency sweeps in which each sweep covers a relatively small range and uses sampling increments as small as 0.1 MHz. Although we shall perform some frequency sweeps for our models, we shall limit the increments to 0.5 MHz. Our goal is to obtain an overview of the potential performance, not to perform engineering design analysis.

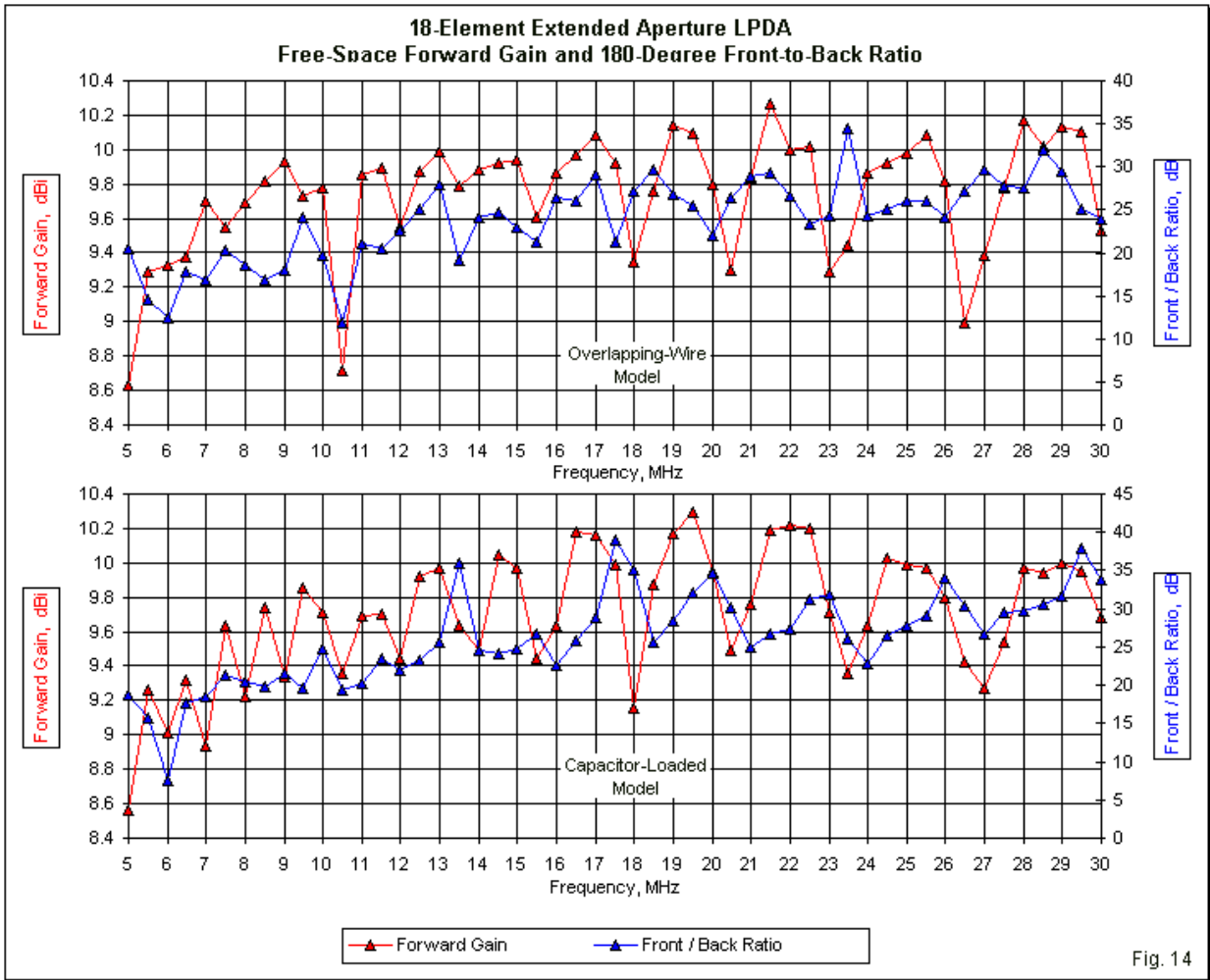
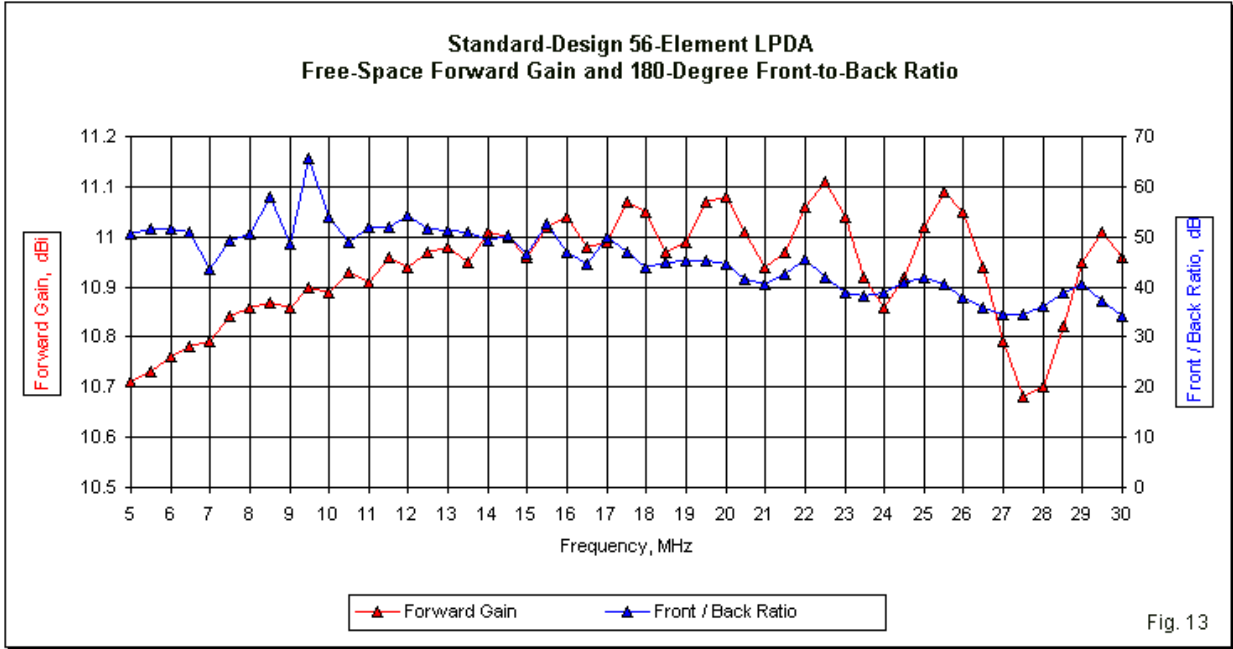
(A further intriguing but unexplored question involves the assigned length of the array in the patent. It records a boom length from rear element to vertex of 220', resulting in a 200' length between the longest and shortest elements. One might add within the assigned value of τ one or more additional forward elements to determine the effects on the 30 MHz performance. Alternatively, one might re-design the array for τ values that increase the array length to perhaps 250' or even 300'. As well, one might experiment with slightly lower values of σ . Such experimental designs might not prove to be suitable for physical implementation, since longer booms involve increased catenary effects on the element support lines. However, the performance trends, including the current distribution on the elements sections, would prove quite interesting.)



Sample E-Plane Patterns and Current Distributions: Modified 18-Element EALPDA

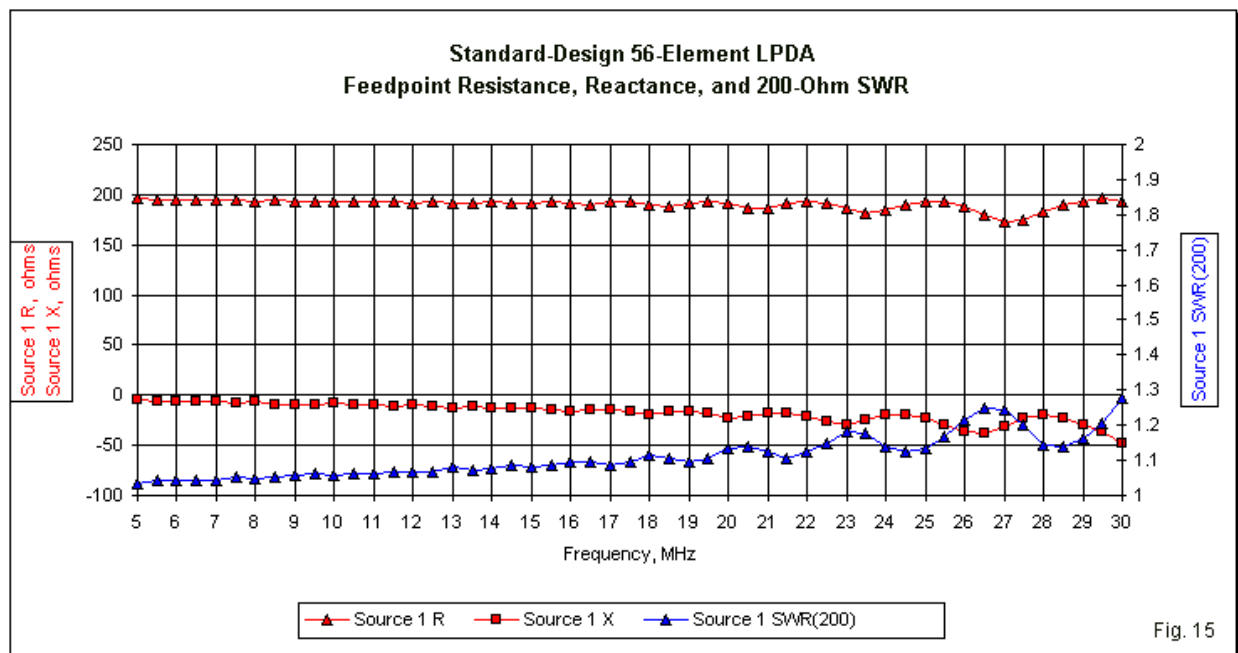
Fig. 12

To test this possibility, I ran frequency sweeps of two free-space LPDAs in 0.5-MHz increments from 5 to 30 MHz. One subject was the free-space version of the 56-element standard LPDA. The other was the modified 18-element EALPDA. We may compare the performance patterns of the two arrays while checking for the possibility of anomalous frequencies. Both models use constant-diameter elements with a 0.16" diameter. **Fig. 13** sweeps the free-space forward gain and the 180° front-to-back ratio of the standard LPDA. Both curves show that performance undulates with changing frequency, although over a very small region for both parameters. Typically, the performance peaks for no two parameters exactly coincide in frequency, since element activity is a joint function of the energy from the phase line and mutual coupling among elements.



The comparable sweep curves for the modified EALPDA design appear in **Fig. 14**. The apparently natural variation in performance levels for both the gain and the front-to-back ratio are much higher, partly as a function of the low value of τ used in the design. However, one goal of the EALPDA was to obtain high performance with a much shorter boom length, a goal that necessitated the use of a lower value for τ . Perhaps the most striking fact to emerge from the sweep is that fact that none of the excursions in gain or front-to-back ratio indicate the presence of an anomalous frequency, although the front-to-back ratio at 6 MHz in the capacitor-loaded model is suspiciously low.

The general notes on **Fig. 14** apply to both models of the array. Between the two versions of the EALPDA, we find some minor and some major differences. The gain curve for the overlapping-wire version shows larger gain excursions in the natural undulation of the forward gain value across the spectrum. Nevertheless, the overall maximum and minimum gain values are very similar. Averaging over the complete sweep spectrum, the capacitor-loaded model exhibits a higher front-to-back value. The table lists the 180° value, but the sample patterns also suggest less overall rearward radiation from the model that uses capacitor loading instead of overlapping wires. The one suspect frequency in the sweep occurs only on this model and appears as a very low front-to-back value at 6 MHz. However, before we register the frequency as anomalous (in this particular model), we must examine some other performance data.



The standard 56-element LPDA shows equal control of the feedpoint properties across the operating range in **Fig. 15**. As the frequency increases and the number of forward elements become less numerous, the curves show an increasing level of undulation. However, the 200- Ω SWR does not reach 1.3:1 by 30 MHz.

In contrast, we find much less smoothness in the resistance, reactance, and 200- Ω SWR curves for the modified EALPDA, as revealed in **Fig. 16**. However, the SWR value for the overlapping-wire model only exceeds 1.5:1 in the vicinity of 6 MHz and remains below 1.35:1 across the remainder of the operating spectrum. In the capacitor-loaded model, we find an SWR value that exceeds 2:1 by a wide margin, owing mostly to sudden spike in the feedpoint

resistance relative to the desired 200-Ω value. The anomaly occurs therefore in both versions of the array, offset by a small frequency difference that makes it apparent on one graph but easy to miss on the other. The existence of the anomaly points to the importance of sweeping designs of wide-band LPDAs using very small frequency increments. However, for the terms of this exercise, we shall simply presume that good engineering can easily smooth out the graphs.

The general absence of sudden changes in the feedpoint resistance and reactance are further good indications that the EALPDA is not subject to any further anomalies. Indeed, the EALPDA has achieved one of its goals, namely, relatively high performance with no significant anomalous frequencies from 5 to 30 MHz with a value of τ that allows a short boom length for the array compared to standard designs. Whether the 20-dB front-to-back ratios in the overlapping-wire version, the 1-dB gain deficit shown by the models relative to the 56-element standard design, and the side-lobe structures are hindrances to the array's use falls outside the realm of this exploration.

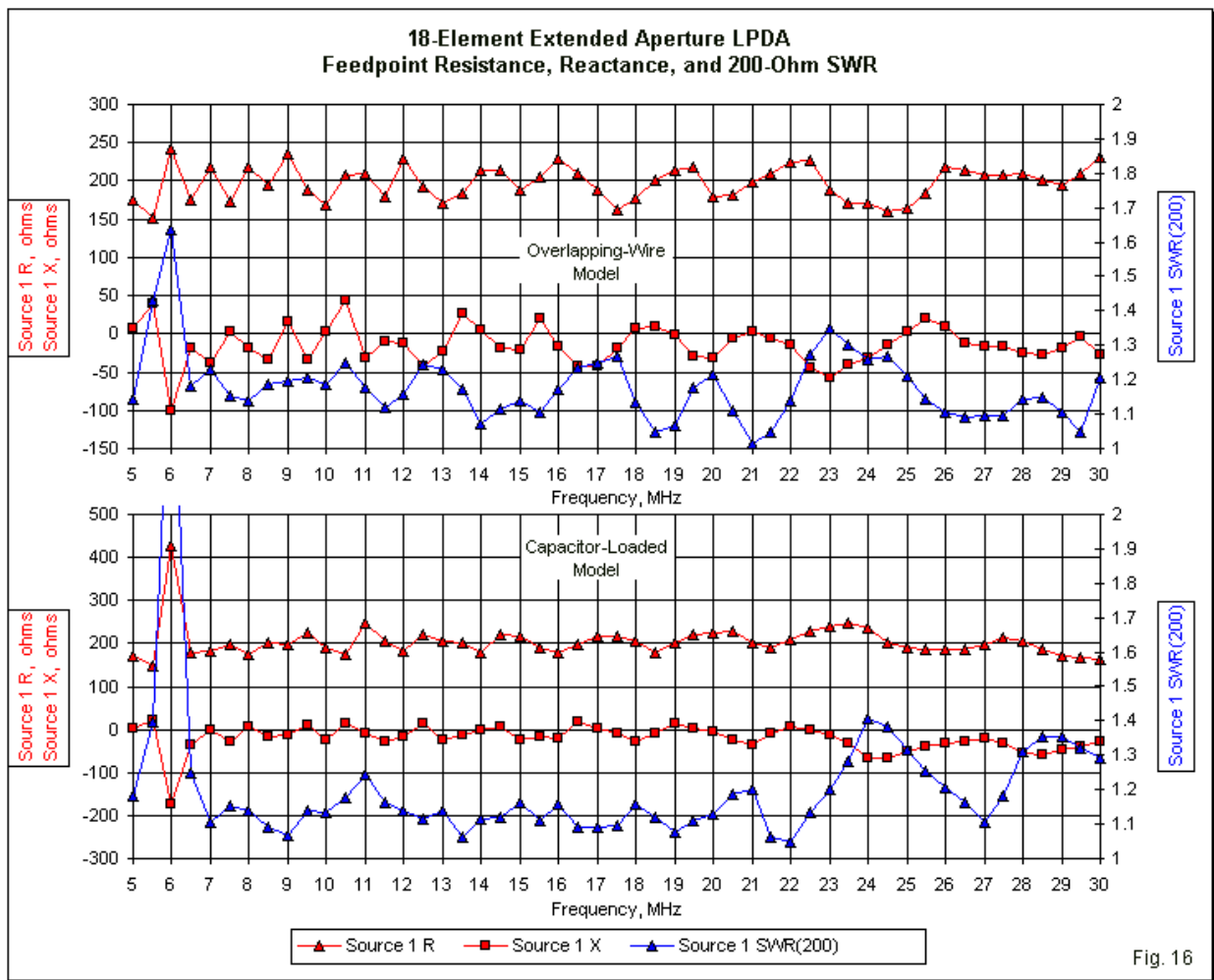


Fig. 16

One further patent claim is worth our immediate attention, namely that the EALPDA design results in narrower pattern beamwidth values than we may obtain from standard LPDA designs. **Fig. 17** combines sweeps from both arrays to provide a fulsome sampling. The 56-element standard design produces a very smooth beamwidth curve, with undulations only appearing in

the upper third of the spectrum (counting linearly). The average value is about 53° . Over the sampling, the beamwidth varies by no more than 3.2° .

The modified EALPDA overlapping-wire model shows a range of beamwidth values from 35.2° to 52.2° for an average value of 41.4° . However, the range would be considerably reduced without the presence of the values for 5.0 and 5.5 MHz. Above these frequencies, the capacitor-loaded model tends to show a narrower range of variation than the overlapping-wire model. (The initial EALPDA design using the listings in the patent also showed a 50° beamwidth at 30 MHz, providing a further justification for the modifications.) If we use a figure of about 40° as the average beamwidth, the EALPDA—as modeled in these notes—shows a full 25% reduction in the beamwidth. This reduction does not quite meet the claims in the patent, but the reduction is real and may be of interest to numerous LPDA applications. The primary application envisioned by the patent for the basic EALPDA involves the use of the array in a vertical orientation. Therefore, we shall have to examine the H-plane beamwidths over ground before we can reach any conclusions.

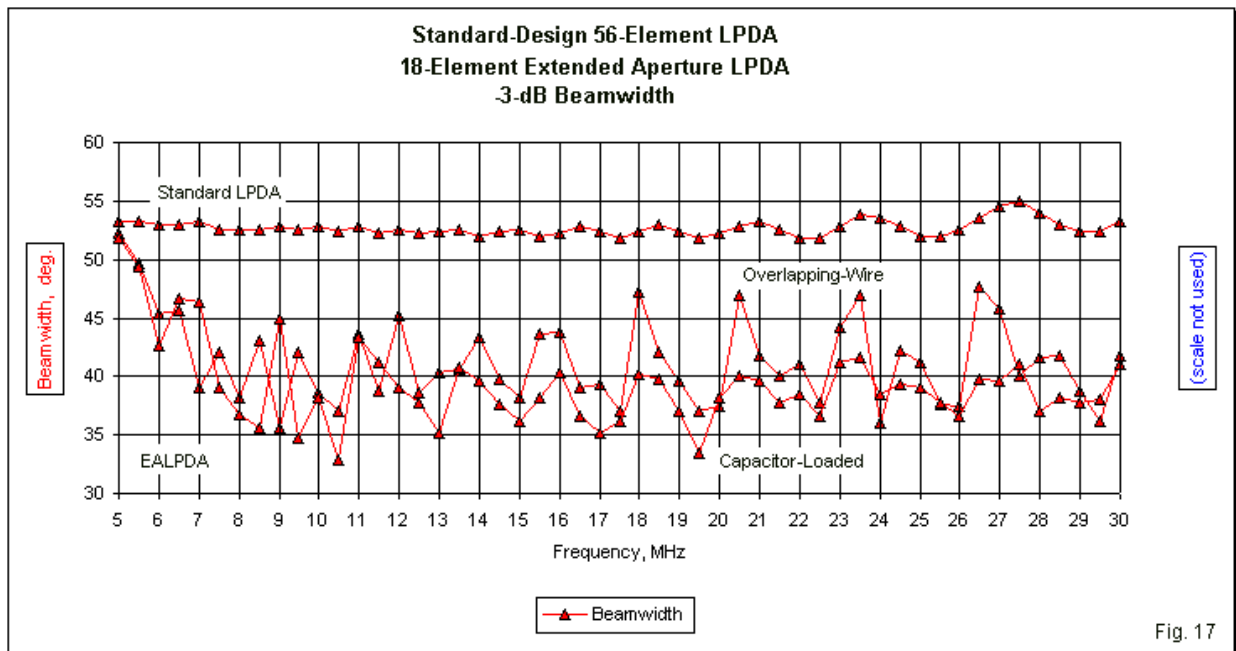
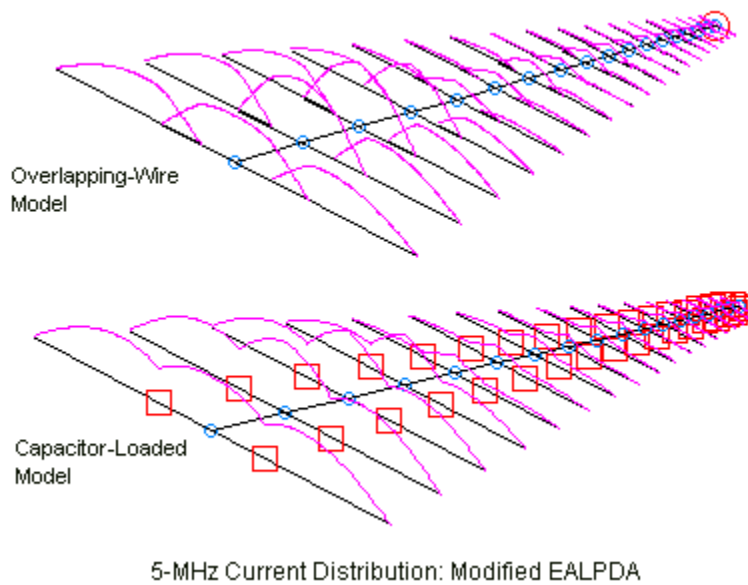


Fig. 17

Before we turn to vertical versions of the EALPDA, let's consider the undulations in the sweeps of the array a bit further. We have noted that the antenna design under examination meets the basic claims of the patent, even if it does not reflect the smooth performance of a standard very long LPDA using a 0.96 value for τ . We have attributed part of the undulation to the low EALPDA τ (0.875) and part to the activity of rearward elements. Still another part emerges from the unequal illumination of forward elements (relative to the most active array region). **Fig. 18** shows the current distribution along the elements at 5 MHz. Note that the center section of the forward elements remains significantly active, while the outer sections become relatively inert as we move forward of the first few elements. The pattern is quite similar whether we separate the inner and outer sections with overlapping wires (and overlapping current distribution curves) or whether we use a capacitor to divide the inner and outer sections. The pattern of activity varies with the operating frequency. However, the net result is that the outer element sections of the very forward elements do not contribute to stability of the curves as much as do the inner sections. Whether this phenomenon is endemic

to the general design direction or is peculiar to the present embodiment lies outside the sphere of these notes.

Fig. 18

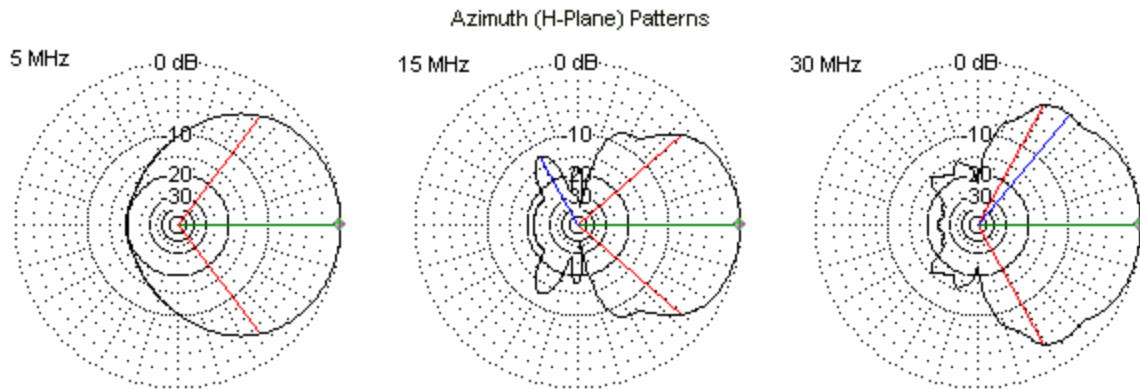
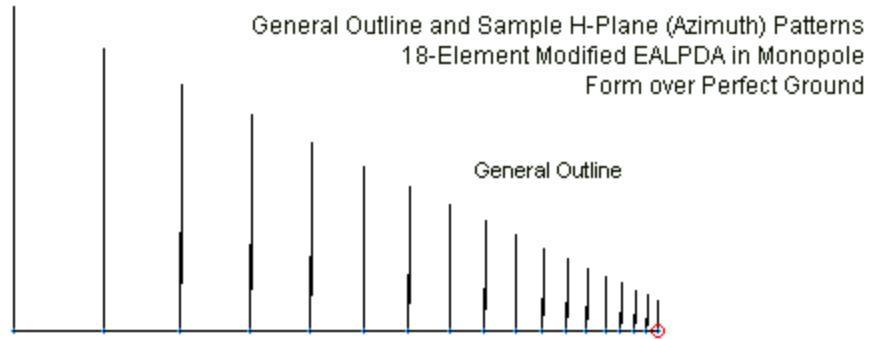


When we examined the standard 56-element LPDA, we created a monopole version for two purposes: the see what sorts of performance numbers emerged for comparison to the free-space performance data and to take an initial look at the H-plane beamwidth values. The resulting values for the standard LPDA appear in **Table 6**. We may perform a similar task for the EALPDA, although we must examine 2 models. Like the free-space models, we may create extended element monopoles over perfect ground using either overlapping wires of capacitive loads to separate inner from outer section. The dimensions shown in **Table 11** provide adequate guidance, since the models simply rotate the free-space models along the boom, prune $\frac{1}{2}$ of each total element, and then set the array on perfect ground. In NEC models, we must review the transmission lines and the source positions. In addition, we reduce the characteristic impedance of the phase line by half, and reference the resulting source impedance values to 100Ω (instead of the $200\text{-}\Omega$ value used with the free-space or other full-element models).

Fig. 19 and **Fig. 20** supply general outlines of the two new monopole EALPDA models and provide sample H-plane patterns. We shall need to comment on both the common features and the unique properties that emerge from the models, following the data in **Table 13**. In view of patent claims for a narrower beamwidth for the EALPDA, the general appearance of the patterns (especially when compared to those in **Fig. 8**) immediately raises questions. The 56-element long-boom standard LPDA showed no H-plane sidelobes to either the forward or the rearward main lobe until we reached the very high end of the operating spectrum. At 30 MHz, the H-plane pattern for both the monopole and the sloping, full-element versions of the array showed relatively small forward and rearward sidelobe structures. We attributed those structures to the electrical shortening of the total boom length at the highest frequencies of operation, even in view of the fact that the standard array contained elements up through 50 MHz.

Fig. 19

Note: Detail of multiple element sections missing due to reduction in size of sketch.



General Outline and Sample H-Plane (Azimuth) Patterns
18-Element Modified EALPDA in Monopole Form over Perfect Ground

Fig. 20

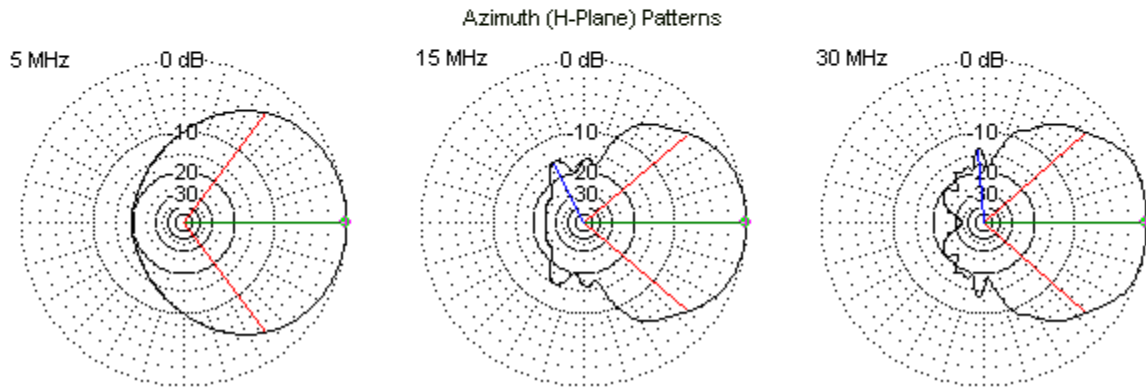
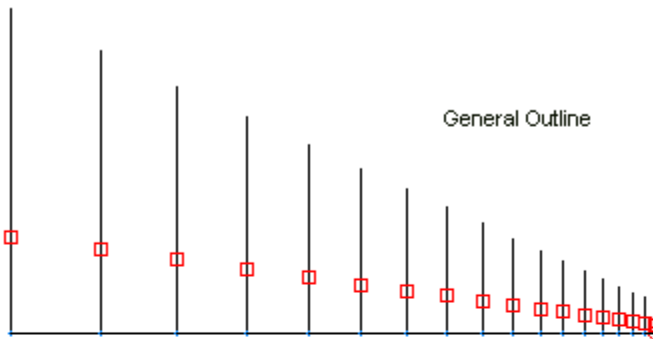


Table 13. Performance of overlapping-wire and capacitor-loaded monopole EALPDAs over perfect ground

Overlapping-Wire Model						
Frequency MHz	5	10	15	20	25	30
Max. gain dBi	11.65	12.71	12.92	12.88	13.03	12.59
Front-back dB	19.63	19.26	22.65	22.17	25.91	23.76
Beamwidth degrees	105.6	85.2	82.0	107.2	92.2	122.6
Z (R +/- jX) Ω	88 + j4	85 + j1	90 - j15	91 - j17	83 + j1	118 - j11
SWR 100 Ω	1.15	1.18	1.21	1.22	1.20	1.21
Capacitor-Loaded Model						
Frequency MHz	5	10	15	20	25	30
Max. gain dBi	11.59	12.67	12.91	12.96	13.01	12.81
Front-back dB	19.41	25.35	24.95	36.07	26.16	33.95
Beamwidth degrees	106.8	86.2	80.8	76.4	89.2	82.4
Z (R +/- jX) Ω	87 + j2	96 - j10	108 - j14	110 - j6	86 - j16	91 - j16
SWR 100 Ω	1.16	1.12	1.17	1.12	1.26	1.21
Reference values for the 56-element standard LPDA						
Frequency MHz	5	10	15	20	25	30
Max. gain dBi	13.71	13.90	13.97	14.10	14.02	13.99
Front-back dB	49.98	53.33	46.43	44.79	41.65	34.61
Beamwidth degrees	66.4	65.2	65.0	63.8	64.6	66.0
Z (R +/- jX) Ω	99 - j2	98 - j4	98 - j6	98 - j11	97 - j11	99 - j21
SWR 100 Ω	1.02	1.04	1.07	1.12	1.12	1.25

Between the two EALPDA models, we do not find significant differences in the forward gain. However, both models—like the free-space model—show values about 1-dB less than the 56-element standard LPDA model. The capacitor-loaded EALPDA shows systematically higher 180° front-to-back values than the overlapping-wire version above 5 MHz, although neither version reaches the values displayed by the standard long-boom LPDA. Moreover, the rear lobe structure above 5 MHz is considerably more complex in the EALPDAs, largely due to the use of the low value of τ (0.875). Still, the capacitor-loaded model shows a slightly cleaner rear-lobe structure than the overlapping-wire model, although the general shapes of the samples shown have a clear kinship.

Perhaps the most striking set of numbers involve the H-plane beamwidth of the EALPDA models. The overlapping-wire model shows two higher-frequency patterns with beamwidth values in excess of 100°. This phenomenon first called my attention to the need for capacitor-loaded models. In those models, the upper frequency patterns show consistent beamwidth values between 76° and 90°. In both models, the 5-MHz pattern shows a 106° beamwidth.

Apart from internal differences between EALPDA models, the relationship between the H-plane and the E-plane beamwidths stands in stark contrast to the comparable relationship in standard LPDA design. The 56-element LPDA shows a 1.2:1 ratio between the H-plane and the E-plane beamwidth values (65° vs. 53°, to use relatively average figures). Above 5 MHz, the capacitively loaded EALPDAs show an average E-plane beamwidth of about 38°. The average H-plane value is about 85°, a 2.2:1 ratio. At 5 MHz, the EALPDA H-plane beamwidth exceeds 100°, while the E-plane value is similar to the value for the standard LDA, about 52°. It is not clear why the lowest operating frequency exhibits this uncharacteristic behavior, but the activity of the forward elements—as shown in **Fig. 18**—may well play a role.

The differences in the modeled performance of the two versions of the EALPDA are not so different as to void the general beamwidth behavior of the Tanner design. The claim for a narrower beamwidth applies only to the E-plane patterns and not to the H-plane patterns. We shall encounter this situation again as we examine the sloping version of the array with a base height of 4' above perfect ground. The data for the comparable standard LPDA appear in **Table 7**, although I have included some of the information in **Table 13** for ready reference.

The sloping versions of the two models of the EALPDA both place the element 4' above perfect ground, with full elements extending upward. *Radio Communications*, the RSGB publication for October, 1981, on p. 926, portrays a single bay sloping TCI EALPDA with 18 elements (labeled as Model 510). The later 1987 issue of TCI's Technical Notes (#1) shows a double version of the array forming a horizontal V, ostensibly for slewing the array's primary direction. The V-angle is not determinate from the sketch, so we shall restrict ourselves to the 18-element modification of the version of the EALPDA in the patent application. However, we shall examine both overlapping-wire and capacitor-loaded versions of the single bay. The modeled data appear in **Table 14**.

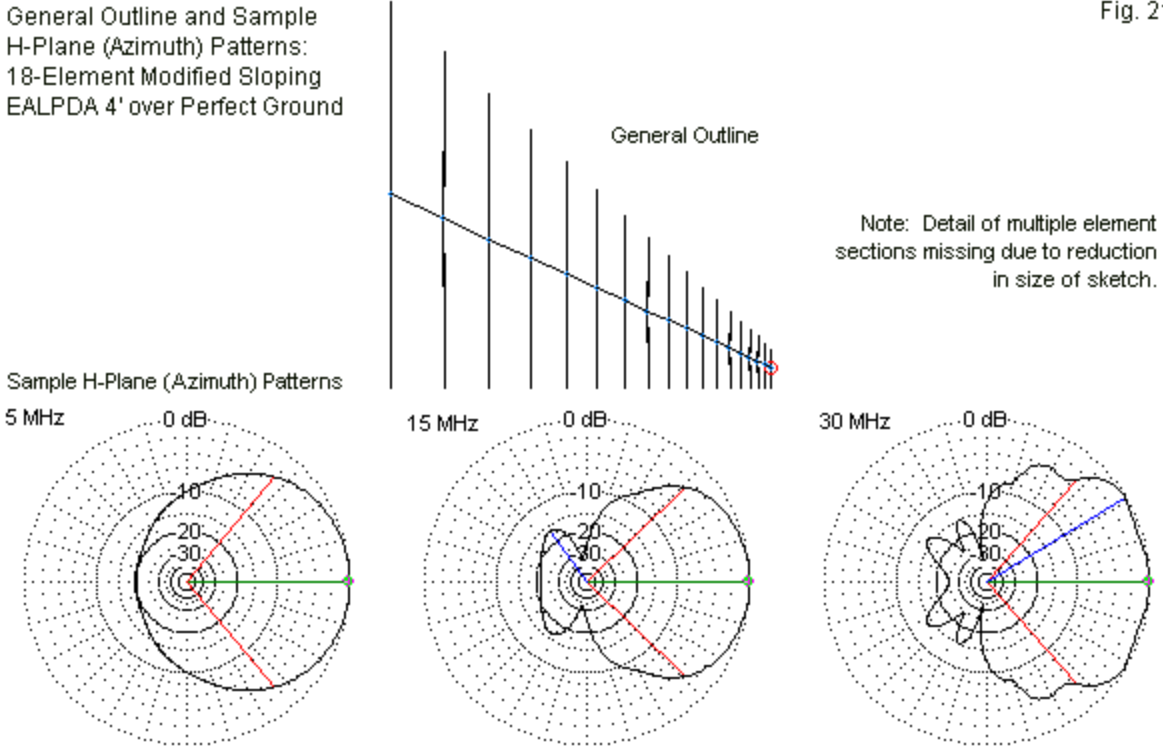
Table 14. Vertically oriented 18-element modified EALPDA with a constant element diameter in 4' above perfect ground.

Overlapping-Wire Model						
Frequency MHz	5	10	15	20	25	30
Max. gain dBi	14.14	15.06	15.58	14.74	15.62	14.74
Front-back dB	19.54	18.12	21.74	24.22	23.51	24.89
Beamwidth degrees	100.8	88.2	87.4	91.0	84.6	97.2
Z (R +/- jX) Ω	207 + j25	221 + j29	205 - j5	192 - j9	198 + j7	232 - j43
SWR 200 Ω	1.14	1.19	1.04	1.06	1.04	1.28
Capacitor-Loaded Model						
Frequency MHz	5	10	15	20	25	30
Max. gain dBi	14.09	15.19	15.37	15.41	15.54	15.55
Front-back dB	18.10	26.92	25.89	25.59	26.10	25.94
Beamwidth degrees	102.2	81.4	81.8	81.8	88.6	84.8
Z (R +/- jX) Ω	198 + j3	197 + j8	205 - j30	220 - j34	183 - j16	185 - j16
SWR 200 Ω	1.17	1.04	1.16	1.20	1.13	1.12
Reference data for 56-element standard LPDA						
Frequency MHz	5	10	15	20	25	30
Max. gain dBi	15.91	16.11	16.19	16.27	16.28	16.05
Front-back dB	44.89	61.32	50.36	43.00	46.29	35.91
Beamwidth degrees	54.8	54.2	54.5	55.0	56.0	60.4
Z (R +/- jX) Ω	195 - j5	194 - j9	193 - j11	190 - j26	196 - j26	190 - j59
SWR 200 Ω	1.04	1.06	1.07	1.15	1.14	1.36

The table includes reference data on the 56-element 775' long standard LPDA. Clearly, the EALPDA in this form shows the same 1-dB deficit in forward gain shown by the free-space and the monopole versions. As well, we find the same differentials among the values for the 180° front-to-back ratio that we saw in the monopole comparisons. Perhaps more interesting is the fact that the cases in which the overlapping-wire version of the array drop below a 15-dBi forward gain are also cases in which the H-plane beamwidth exceeds 90°. Compare these values with the corresponding values for the capacitor-loaded model. Equally interesting are the sample patterns for 5, 15, and 30 MHz, shown in **Fig. 21** and in **Fig. 22**.

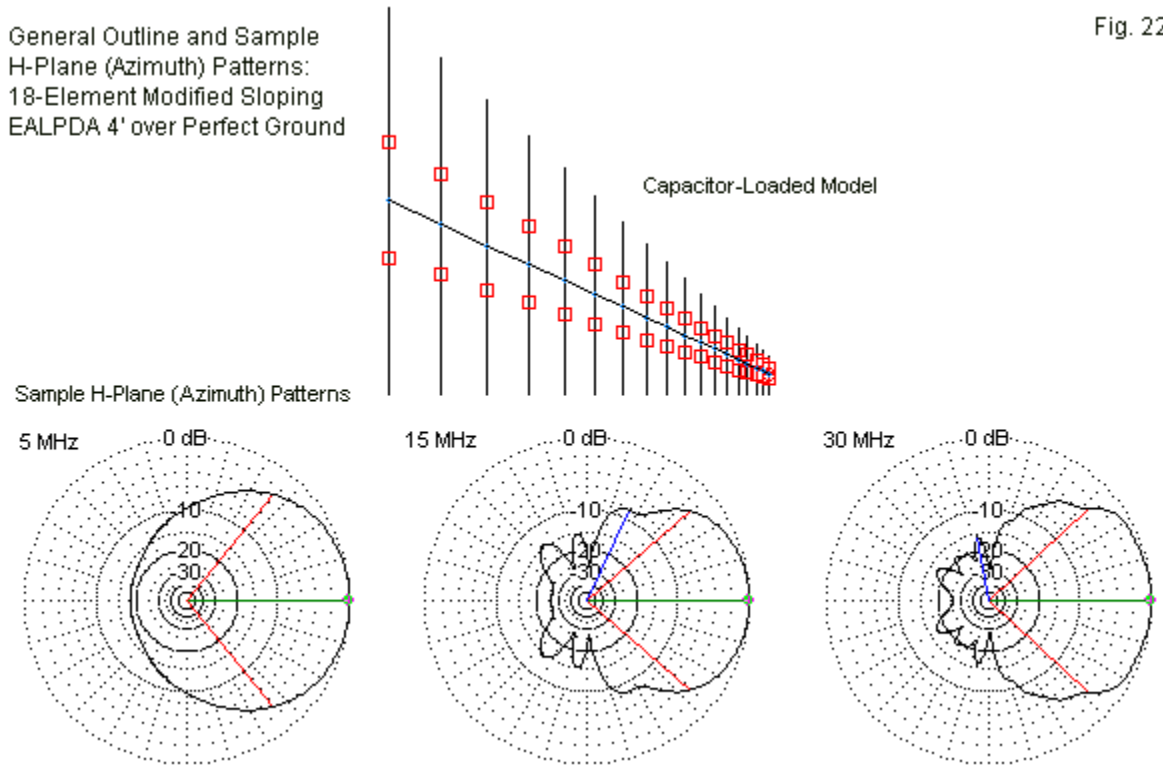
General Outline and Sample H-Plane (Azimuth) Patterns:
18-Element Modified Sloping
EALPDA 4' over Perfect Ground

Fig. 21



General Outline and Sample H-Plane (Azimuth) Patterns:
18-Element Modified Sloping
EALPDA 4' over Perfect Ground

Fig. 22



The 15-MHz patterns differ both in beamwidth and in the rearward lobe structure. The 30-MHz pattern for the capacitor-loaded model shows signs of approaching the wider pattern of the overlapping-wire version, but the main forward lobe reveals only minor indents in regions where the overlapping-wire version shows almost enough reduction to classify the side bulges as distinct lobes. Even though the modeled data for the two versions of the single-bay EALPDA show a very clear kinship, the results differ enough to set limits on the level of confidence that one may have in either model.

Conclusion

We have explored the basic parameters of EALPDA design and modeling. Although multiple design and modeling issues preclude hard and fast conclusions, we may at least note that the Tanner patent makes a very reasonable case for a long-element, short-boom LPDA design that is able to cover 5 through 30 MHz with high performance—even if that performance does not quite meet the standards established by the very long-boom 56-element LPDA shown in Part 1. In all configurations, we find a gain deficit of about 1 dB, with further deficits in the category of front-to-back ratio. These deficits result largely from the use of a lower value of τ (0.875) so that the boom length is less than 200' (compared to 775' for the 56-element sample standard LPDA). A standard LPDA using the same lower value for τ would not be able to cover the frequency span without much greater fluctuations in performance, along with anomalous frequencies at multiple points in the operating spectrum. The use of the extended element and its wider operating bandwidth allow fewer long elements to do the work of a greater number of shorter elements in terms of providing full frequency coverage without objectionable swings in performance.

Perhaps the major surprise in our survey has been the relatively wide H-plane beamwidth of the monopole and sloping vertical versions of the EALPDA design. The standard LPDA showed a reasonable coincidence between E-plane and H-plane beamwidth values—about the difference that we might expect of a Yagi beam with the same forward gain level. In contrast, the EALPDA shows a ratio of H-plane to E-plane beamwidth of over 2:1. The culprit is most likely the short boom length relative to the operating frequency, a direct function of the selected value of τ . The use of long or extended elements may confine the E-plane beamwidth, but such elements are no better than $\frac{1}{2}\lambda$ elements in terms of confining the H-plane beamwidth. H-plane beamwidth values appear to be largely a function of boom length. (Note: the term “boom length” refers to the active boom length at any given operating frequency within the operating range of the antenna.)

Despite the one surprise, not hinted at in any of the literature on extended elements of extended aperture LPDAs, the overall EALPDA design is capable of wide-band LPDA performance on its 200' boom length.