Some J-Poles That I Have Known

Part 3: The Effects of Element Diameter and Match-Section Leg Spacing on Standard and Non-Standard J-Poles

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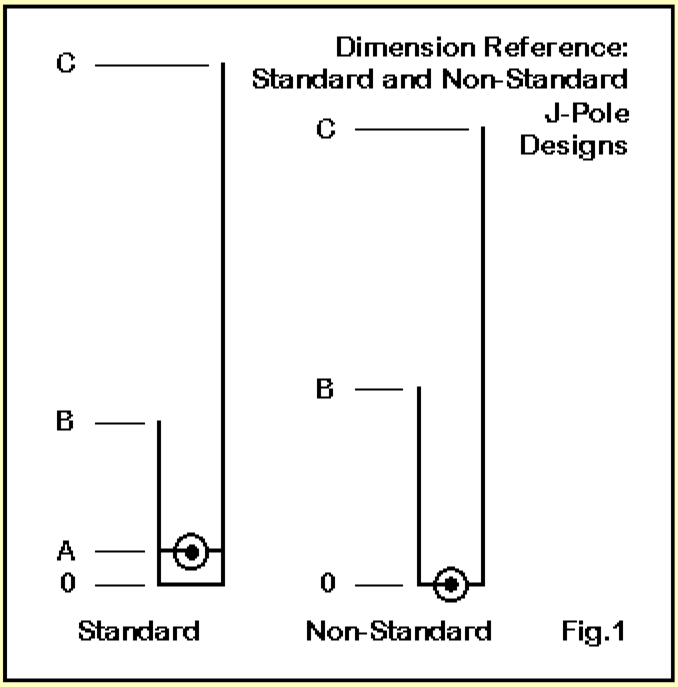
Our examination of twinlead J-pole design variations restricted us to thin-wire, close-spaced J-poles. However, an alternative design direction makes use of tubular elements--sometimes copper water pipe. The larger diameter of the elements naturally leads to wider spacing between the legs of the matching section. The general question we might want to ask is whether there are any significant performance differences that result from either enlarging the element diameter or widening the spacing. Even f we do not find operationally significant differences, the trends that we might find in systematically looking at these two variables can give us some proper expectations when building and adjusting a J-pole.

To sample the arena--still using 146 MHz as a design frequency--I looked at the performance of both standard and non-standard J-poles--as specified in Part 1 of this exploration. I modeled a number of J-poles using a standard spacing of 1" between match-section legs in diameters from 0.125" to 0.5" in 1/8" increments. Then I did the same for a J-pole using 0.375" diameter elements, increasing the spacing from 1" to 4" in 1" increments. The material throughout was aluminum, although the results would have been virtually identical for copper.

Changing any of the design variables results in an overall change in J-pole dimensions. Therefore, the sketches in **Fig. 1** can be a guide to dimensional references from this point forward.



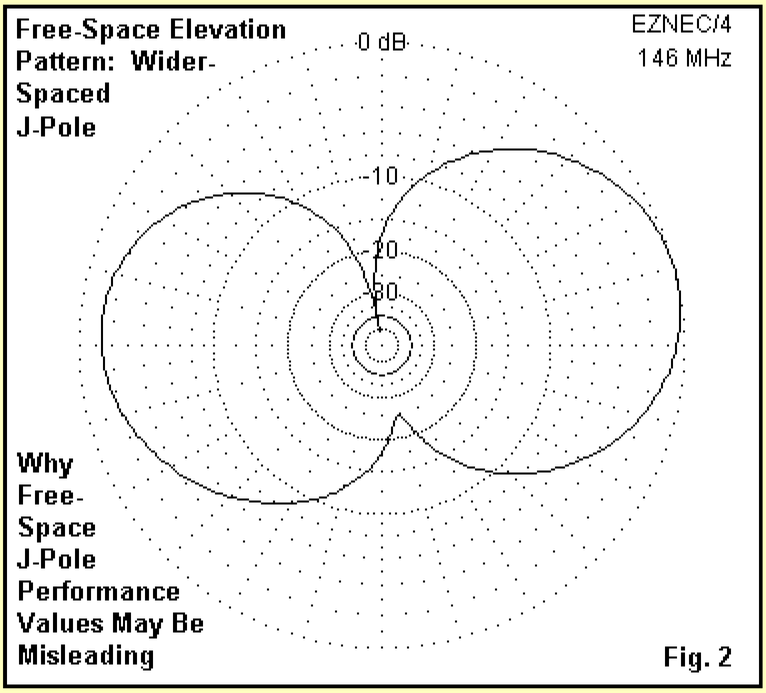
A applies only to standard dipoles and is the distance from the base of the antenna to the feed-wire. **B** is the distance from the antenna base to the open end of the short match leg, while **C** is the distance from the antenna base to the top of the radiator. All dimensions will be in inches. As we saw in Part 2, the difference between **C** and **B** does not necessarily define a full half-wavelength, even for a standard J-pole, since the current minimum marking the bottom of the radiator may occur below the top of the shorter match section leg of the antenna.

As the figure indicates, non-standard designs will always be shorter than standard designs. One consequence of this fact is that with a constant base height for the antenna over ground--say, 10' (120")--the take-off angle or elevation angle of maximum radiation will be slightly higher for the non-standard design than for a standard J-pole. The higher angle results from a slightly lower height for the region of maximum current on the radiator.

Non-standard designs have another requirement that does not apply to standard J-poles: the mount should be insulated. Most builders presume that in a standard J-pole, the lower cross piece is at zero impedance. Technically, this is true of only a point along the cross wire. However, the differences in impedance--and hence current--on the wire will be small and likely only to require a very small adjustment of the source wire to re-establish a 50-Ohm resonant feedpoint impedance. Therefore, extending the long leg of the standard J-pole downward to form a mounting extension for a metal mast generally creates no operational problems.

With a non-standard J-pole design, the connection of the base of either leg of the matching section to a mounting extension of mast would most likely upset the current distribution along the matching section, resulting in unpredictable results--with the exception of the prediction that the antenna mostly likely would no longer operate in accord with models. constructing a mounting from PVC or similar non-conductive materials is quite simple and expedient for most J-pole element diameters and spacings. If one wishes to make a connection to discharge static build-up on the antenna, then one should apply standard static discharge methods to the design.

In the notes that follow, all performance figures will employ models with the antenna base placed 10' above average ground. Although free space is a very usual environment for comparing design variations in antenna work, it will not be useful for J-poles with matching legs separated by an inch or more. **Fig. 2** shows us why.



The presence of inevitably unbalanced currents on the legs of the matching section does more than create some radiation from the lowest portion of the antenna. The current imbalance also changes the free-space angles of maximum radiation, as exemplified by the free-space elevation (E-plane) pattern in the figure. In the direction of the short leg, the pattern angle is above the hypothetical horizon, while in the direction of the longer element, the pattern angle is below that same horizon. The difficulty arises from the fact that the maximum strength bearings for the two lobes are not 180 degrees apart. The greater the spacing between the legs, the more divergent the angles. Hence, for antennas fatter than or more widely spaced than the twinlead designs we examined in Part 2, the free-space patterns do not give results that we can compare from one design variation to the next.

Providing a ground and a constant antenna-base height resolves the problem, especially since virtually all J-poles are used over real ground (although a few aeronautical and aerospace versions might exist). We have already alerted you to the differential that will exist between standard and non-standard designs due to differences in the effective height of the radiator section. However, we can still examine general performance trends that emerge by varying either the element diameter or the matching-leg spacing.

These trends are subject to limitations in modeling J-poles. Although the trends that we shall see in the dimensions will be correct, the exact dimensions will not be directly transferable without further adjustment to a physical antenna. Close spacing of wires having different length tends to provide offset results in NEC. As well, the feedpoint regions of both types of J-poles sets certain limits to segmentation. The result will be a requirement that all reported gain figures be adjusted by reference to the average gain test (AGT) value as recorded in dB. The tables that supply the data for each systematic run of models also include the AGT value. A positive value indicates that the NEC reported gain is too high by about the AGT figure. Hence, a truer gain value results from adjusting the reported gain by subtracting the AGT value from the report. The reverse applies to AGT values less than 0.0 dB. The tables provide adjusted rather than raw gain reports.

Theoretically, the AGT value expressed as a simple average gain value--with values either higher or lower than the ideal of 1.0--may also be used to correct source impedance reports. We simply multiply the resistive portion of the source impedance by the AGT value to obtain a truer impedance. This technique applies to resistive impedances rather than to complex impedances. For simplicity in determining operating bandwidth for the antennas, the NEC reported impedance figures have been used. Hence, the impedance of a physical antenna answering to the modeled dimensions may by somewhat off for a true 50-Ohm impedance. Adjustments may be small in most cases, but they will be necessary. However, the use of NEC-reported impedances is sufficient to show with good accuracy the most important trends.

And trends are the key to this exploration. Our goal is to understand better J-pole behavior, not to provide blueprints for building one. The literature and the web are full of J-pole plans, most of which have stood the test of repeated replication. These notes have a different goal altogether.

Varying the Element Diameter of J-Poles

To see what trends might accompany variations in the diameter of the material from which we construct J-poles, I set up basic designs of both standard and non-standard J-poles using a fixed center-to-center spacing of 1" between the matching section legs. Then I varied the diameter of the aluminum elements from 1/8" to 1/2" in 1/8" increments.

The results appear in both tabular and graphical form in the following notes. The following table provides a reference to the lines labels for the tables in this section and the next. The table also indicates the performance areas in which I took the keenest interest.

Label Reference Table

A	**Dimension A: bottom to feedpoint in inches (standard J-pole)**
B	**Dimension B: bottom to open end of match section in inches**
C	**Dimension C: bottom to open end of radiator**
Zo	**Calculated matching section characteristic impedance in Ohms**
AGT	**Average Gain Test value in dB**
M-Gain	**Maximum adjusted gain in dBi at take-off angle**
A-Gain	**Average adjusted gain in dBi at take-off angle**
TO /_	**Take-off or elevation angle of maximum gain in degrees**
F-B	**Front-to-back ratio in dB in plane of J-Pole**
Dia.	**Element diameter in inches**
Space	**Element spacing in inches**

The dimensions are of great interest, since they indicate trends in relative lengths as we change element diameter (or, later, spacing). The calculated characteristic impedance (Zo) of the matching section may be mostly of archival interest. The maximum gain value, as adjusted by the AGT, is always in the direction of the short leg of the antenna. The average gain values are simply the gain of the antenna at 90 degrees to the bearing for the maximum gain. Further averaging might be applied, but was unnecessary in this first order exploration. The TO angle applies to the antenna when its base is 10' above average ground. finally, the front-to-back ratio indicates the degree of distortion of the azimuth pattern from a perfect circle--as one might obtain from a ground-plane monopole or a vertical dipole.

The following tables provides the results for both standard and non-standard J-poles in the diameter-variation test.

Constant 1" Element Spacing, Increasing Element Diameter

Standard J-Pole

Dia.	**0.125"**	**0.25"**	**0.375"**	**0.5"**
A	**1.25**	**1.20**	**1.20**	**1.30**
B	**19.75**	**19.75**	**19.60**	**19.65**
C	**59.50**	**57.90**	**57.60**	**57.50**
Zo	**332**	**249**	**200**	**166**
AGT	**-0.28**	**-0.53**	**-0.89**	**-1.52**
M-Gain	**5.12**	**5.28**	**5.35**	**5.41**
A-Gain	**4.95**	**5.07**	**5.08**	**5.08**
TO /_	**6.1**	**6.1**	**6.1**	**6.1**
F-B	**0.43**	**0.55**	**0.68**	**0.81**

Non-Standard J-Pole

Dia.	**0.125"**	**0.25"**	**0.375"**	**0.5"**
B	**22.50**	**22.50**	**22.50**	**21.60**
C	**48.30**	**45.50**	**42.50**	**39.40**
Zo	**332**	**249**	**200**	**166**
AGT	**-0.05**	**+0.04**	**+0.89**	**+1.66**
M-Gain	**5.07**	**5.04**	**4.97**	**4.92**
A-Gain	**4.86**	**4.77**	**4.64**	**4.57**
TO /_	**6.6**	**6.6**	**6.6**	**6.6**
F-B	**0.46**	**0.60**	**0.70**	**0.76**

The standard J-pole shows very little variation in the required height of dimension B, the length of the short matching leg. As well, there are only small variations in the distance from the antenna base to the source wire, dimension A. The major changes relate to the overall length of the radiator section, which shows modest decreases with each increase in element diameter. For the entire 4:1 increase in element diameter, the overall antenna height decrease is only 2".

In contrast, for the same change in element diameter, the non-standard J-pole requires a height reduction of nearly 9". Interestingly, the short leg requires no change until we reach the 0.5" diameter material. However, in physical antennas, we should expect some changes to sustain a 50-Ohm feedpoint impedance, since the AGT value differs for each model.

Throughout, each model was set for a feedpoint impedance of 50 Ohms as determined by an SWR of less than 1.01:1 at 146 MHz. We shall examine SWR curves for both types of J-poles near the end of this section of the notes.

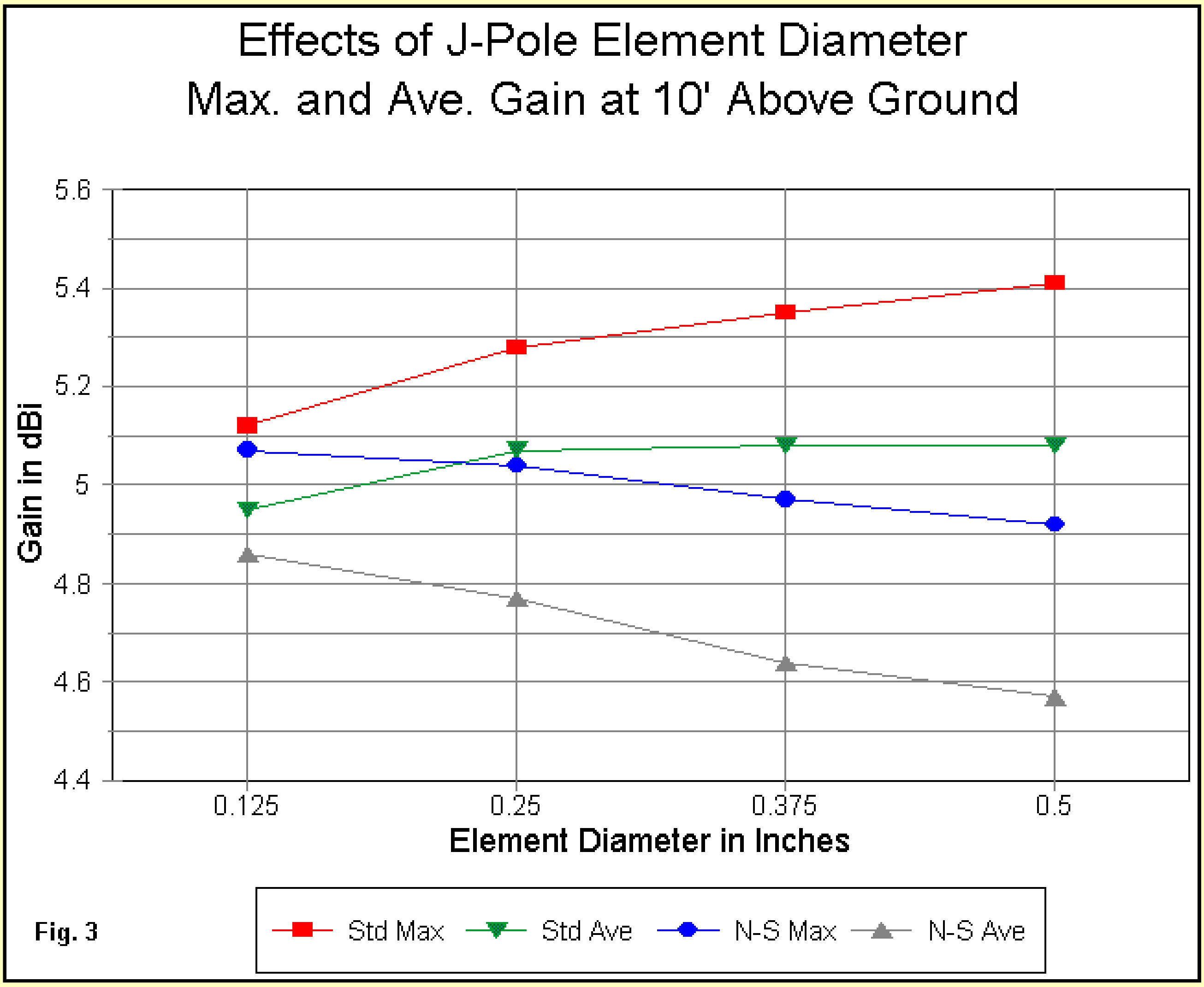


Fig. 3

Fig. 3 plots the maximum and average gain values for both antenna types throughout the range of element diameters. In general, the corresponding values for the standard J-pole are slightly higher than those of the non-standard model due to the differences in the height of the maximum radiation region of the antennas. The differences would make no operating difference at all, although the trends are interesting in and of themselves.

The standard design tends to show a rising gain curve with increases in element diameter--although the rise is too modest to alone be a reason for changing a planned material. The increase in diameter raises the region of maximum radiator current faster than the height reduction lowers it. The opposite is true for the non-standard J-pole: the reduction in overall height is more extreme with each increment of increase in element diameter, resulting in a marginally lower overall gain for the same 10' base height of the antenna. In short, the differences in the gain values are almost completely the result of changes (or lack of changes) in the height of the maximum current region of the radiator.

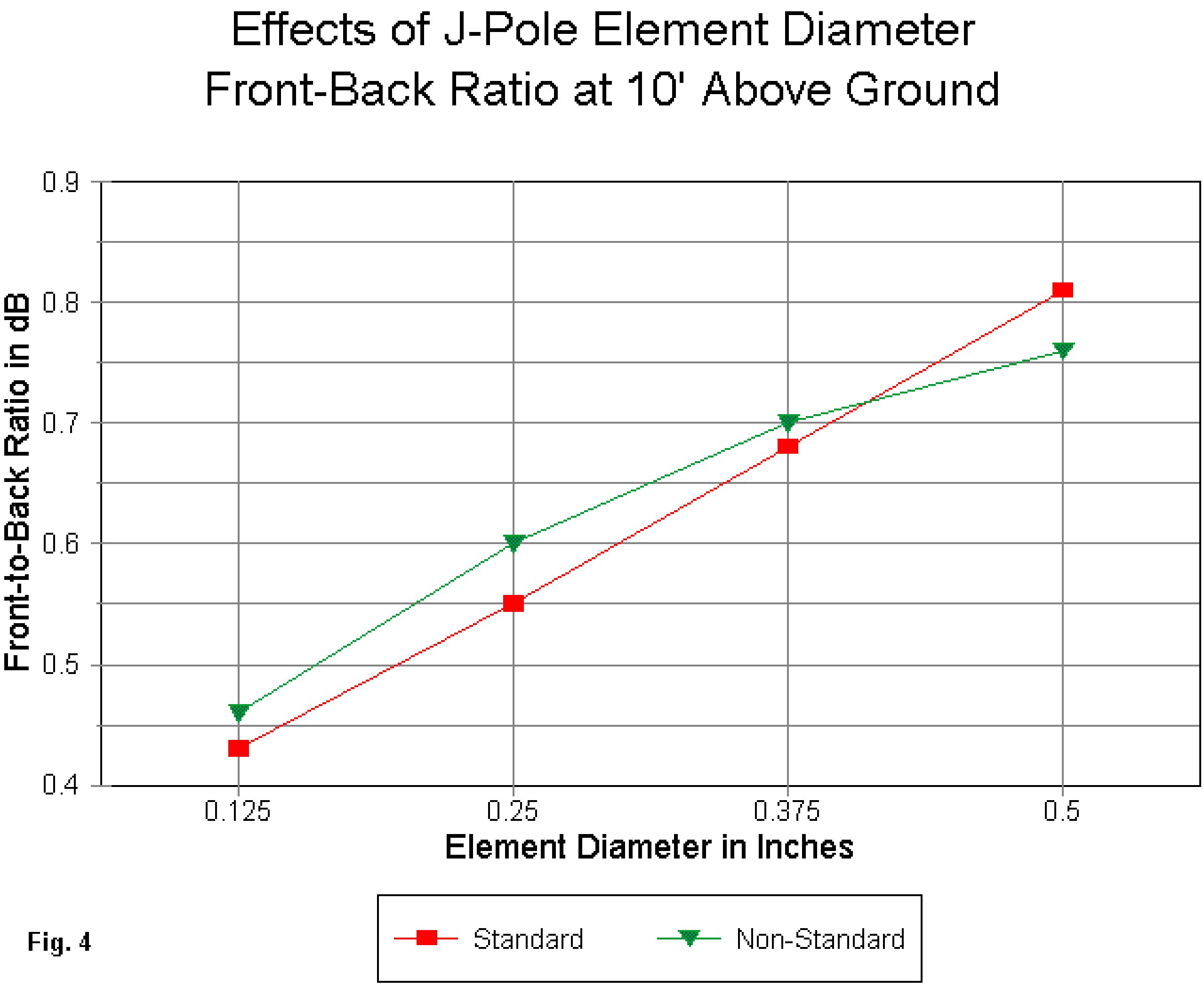
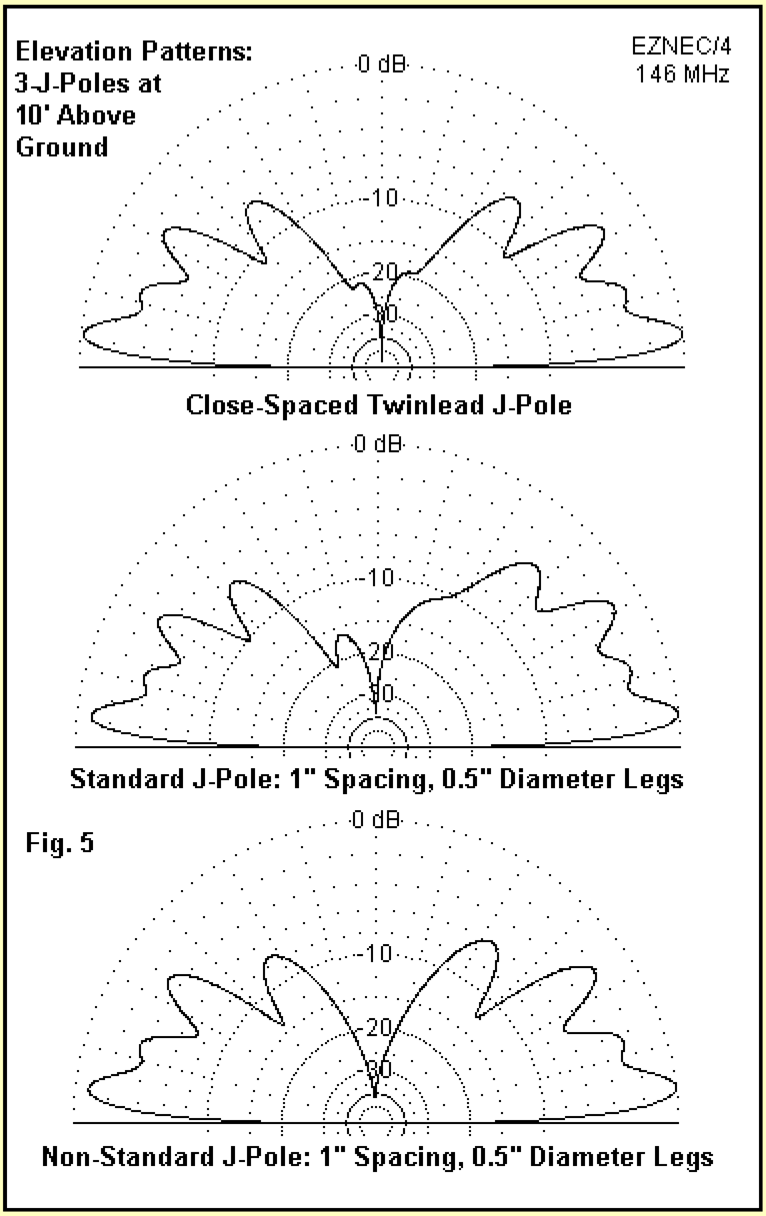


Fig. 4

More interesting is **Fig. 4**, which plots the front-to-back ratio for the antenna types through the increases in element diameter. Both types of J-pole show an increasing difference between the gain in the direction of the open matching leg and the direction of the long radiator. Although the amount of differential is not very significant, the curve shapes are. The standard J-pole shows a virtually linear track of the increase in front-to-back ratio, while the curve for the non-standard design tapers the rate of increase with each increase in element diameter. By a diameter of 1", the non-standard design would almost cease to show further increases in the front-to-back ratio.

Examining elevation patterns for the antenna types along the axis in plane with the two elements provides some further insights into differences in the behavior of the two types of J-poles. **Fig. 5** tells the story.



Elevation Patterns: 3-J-Poles at 10' Above Ground

Fig. 5

Close-Spaced Twinlead J-Pole

Standard J-Pole: 1" Spacing, 0.5" Diameter Legs

Non-Standard J-Pole: 1" Spacing, 0.5" Diameter Legs

At the top is the elevation pattern for the single-wire twinlead J-pole from the preceding episode. There is for the thin-wire, closely-spaced design only a hint of a difference between the forward lobe structure and the rearward lobe structure. As well, the front-to-back ratio measure a minuscule 0.1 dB. The standard J-pole shows a much more radical difference between forward and rearward lobes structure--much larger a difference than we find for the non-standard design despite the similarity in the front-to-back ratios for the two antennas. At the take-off angles recorded in the table, the azimuth pattern does not suffer as a result of these variations, and the azimuth pattern shown in **Fig. 6** suffices as a representation for all of the antenna models in the tables.

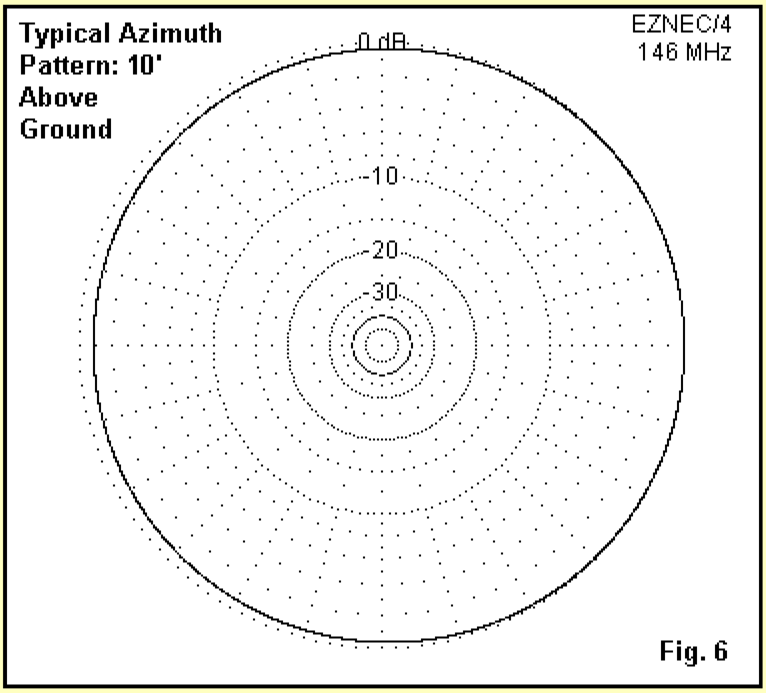


Fig. 6

The feedpoint impedance behavior of the different types of J-poles does show some semi-significant variations and interesting trends. In **Fig. 7**, we find at the top the 50-Ohm SWR curve for the standard J-poles having the largest and smallest diameter elements. There is virtually no difference in these curves despite the 4:1 difference in element diameter.

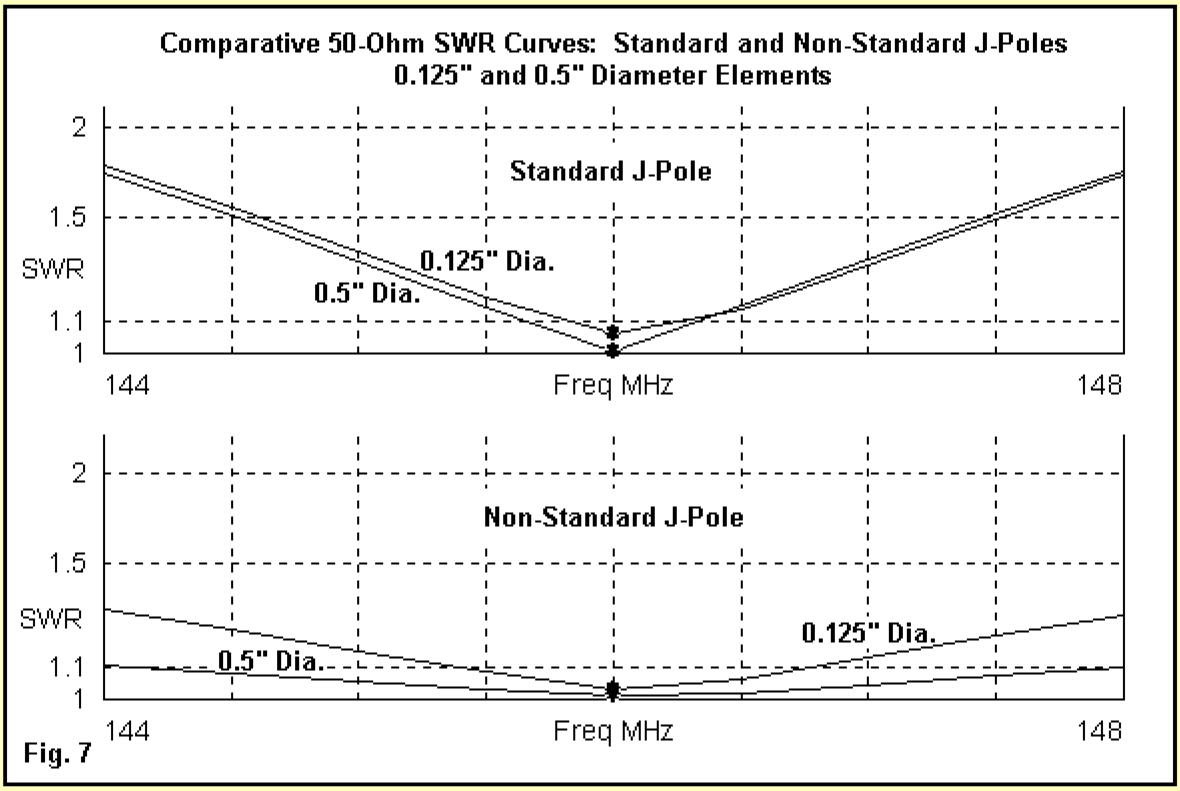


Fig. 7

In contrast, the lower section of **Fig. 7** shows the 50-Ohm SWR curves for the largest and smallest diameter elements as used in the non-standard J-pole. Overall, we can see that the smallest diameter element has a wider operating bandwidth than the largest diameter element version of a standard J-pole. At the same time, increasing the diameter of the non-standard design results in further widening of the operating bandwidth.

The operating bandwidth, as registered in 50-Ohm SWR curves, is not an isolated fact, but relates closely to the dimensional changes we examined as the first item of interest. The standard J-pole dimensions changed very little over the range of element diameter increases, and the similarity of

SWR curves reflects that fact. In contrast, the overall height of the non-standard design changed by a much greater amount, indicating that element diameter would have a much more marked effect on other operating characteristics. Of all the performance parameters checked, operating bandwidth was the one most closely related to the dimensional changes in the designs.

Varying the Element Spacing of J-Poles

It is likely somewhat inaccurate to refer to the two legs of a J-pole as elements, since the short leg is part of a matching section and not intended as a radiator. However, the short leg does radiate--as evidence by the free-space elevation pattern in **Fig. 3**--and it is usually more compact to refer to the two legs of the J-pole as elements.

The systematic examination of the spacing between J-pole legs or elements used constant diameter 0.375" aluminum elements throughout and varied the spacing in 1" increments from 1" to 4". Using the same labels as in the preceding section, the following table presents the recorded data.

Constant 0.375" Element Diameter, Increasing Element Spacing

Standard J-Pole

Space	**1.0"**	**2.0"**	**3.0"**	**4.0"**
A	**1.20**	**1.50**	**1.95**	**2.80**
B	**19.60**	**19.60**	**19.60**	**19.60**
C	**57.60**	**57.60**	**58.60**	**60.30**
Zo	**200**	**284**	**332**	**367**
AGT	**-0.89**	**-0.06**	**+0.26**	**+0.47**
M-Gain	**5.35**	**5.45**	**5.43**	**5.25**
A-Gain	**5.08**	**5.14**	**5.14**	**5.05**
TO /_	**6.1**	**6.3**	**6.3**	**6.3**
F-B	**0.68**	**0.94**	**1.17**	**1.35**

Non-Standard J-Pole

Space	**1.0"**	**2.0"**	**3.0"**	**4.0"**
B	**22.50**	**21.80**	**20.70**	**19.80**
C	**42.50**	**47.50**	**50.60**	**52.10**
Zo	**200**	**284**	**332**	**367**
AGT	**+0.89**	**+0.29**	**+0.06**	**+0.13**
M-Gain	**4.97**	**5.32**	**5.52**	**5.61**
A-Gain	**4.64**	**4.88**	**5.06**	**5.17**
TO /_	**6.6**	**6.6**	**6.5**	**6.4**
F-B	**0.70**	**1.07**	**1.35**	**1.60**

Regardless of the J-pole type, the overall length of the radiator side increases with increases in spacing between the match-section legs. The standard design increase is modest: under 3" for a 3" increase is spacing. The non-standard design radiator side length increases nearly 10" for the same increase in leg spacing. The large increase is matched by a gradual shortening of the short-leg side--a little over 2.5" for the spans tested. The short leg on the standard design remains constant. However, the distance between the antenna base and the feed-wire increases from 1.2" to 2.8" as the space between legs goes from 1" to 4".

Note that the overall radiator-side length follows an opposing curves with respect to increasing element diameter and increasing the spacing between elements.

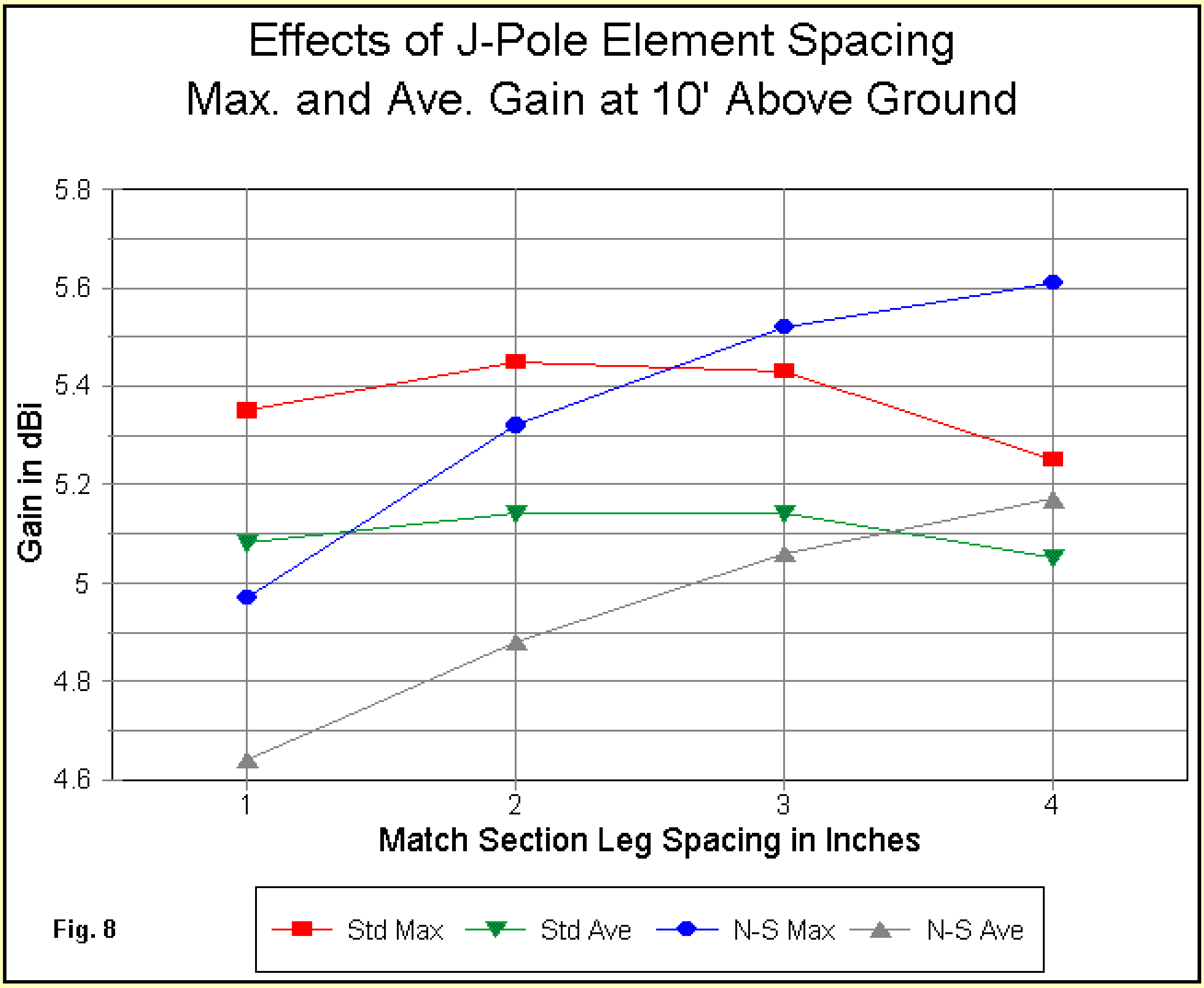


Fig. 8

The maximum gain and average gain curves follow the changes in the overall length of the radiator-side in both designs, as shown in **Fig. 8**. The standard design shows a decrease in gain at the upper end of the spacing range, although operationally insignificant. The gain does increases very slightly as we move from a 1" spacing to a 2" spacing, although the overall length does not change in that span. However, to suggest that a 2" spacing might be optimal would be to ignore the many construction variables that would modify the nearly flat curve.

The non-standard design shows a rising gain curve, but one that is consistent with the increase in length of the radiator with increasing distance between match-section legs. More significant is the fact that the non-standard J-pole shows a faster rise in the front-to-back ratio than does the standard design, for the same range of match-leg spacings. See **Fig. 9**.

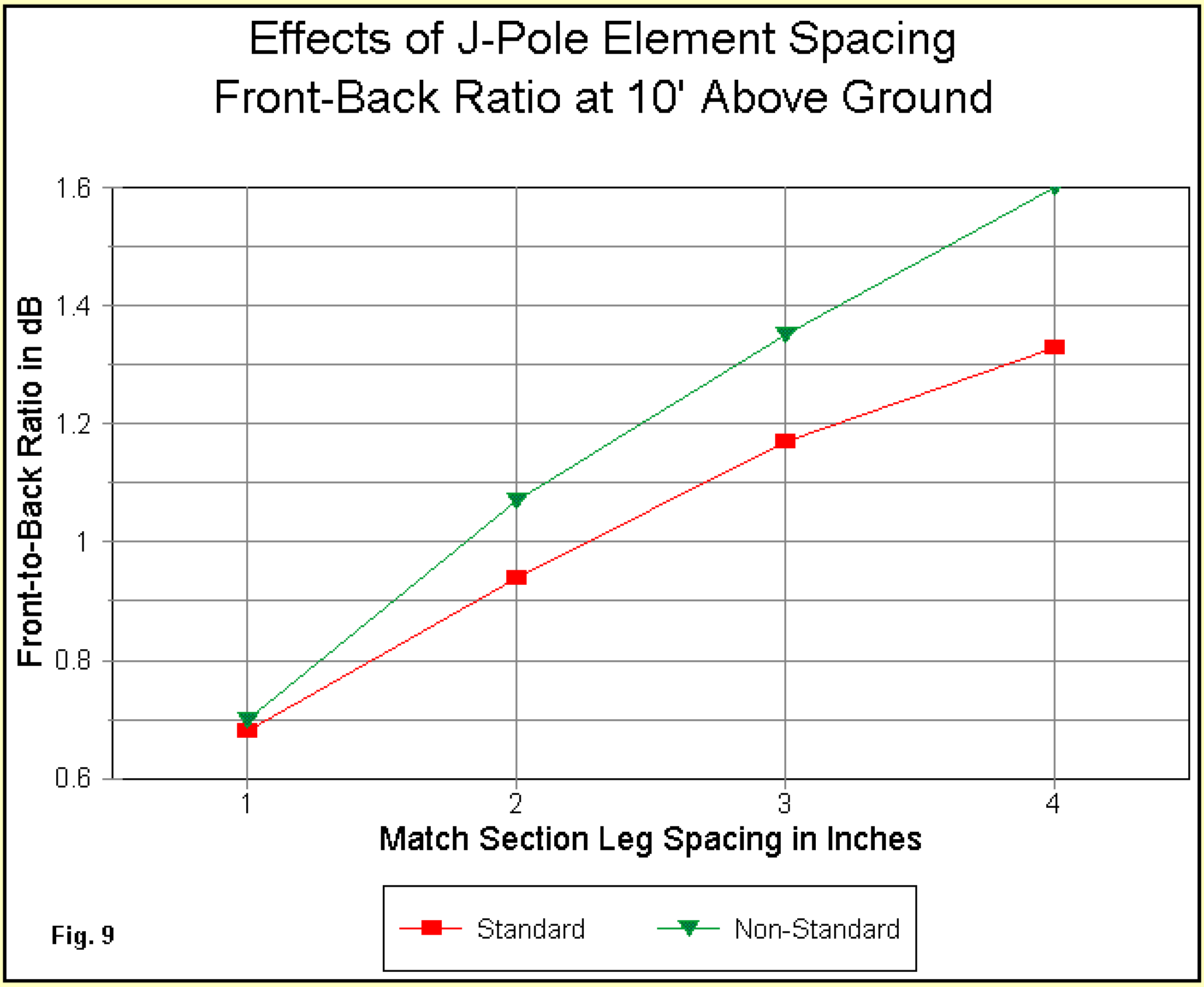
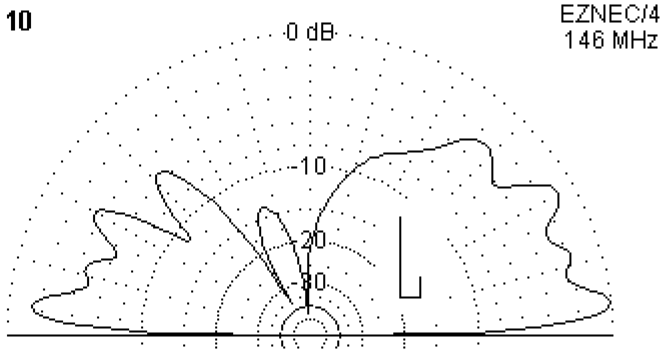


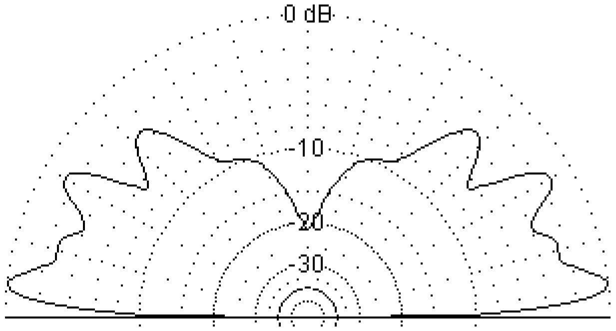
Fig. 9

The patterns for the J-poles become increasingly interesting as we increase the spacing between the match-section legs. **Fig. 10** compares the elevation patterns with the antenna at a 10' height, using the standard J-pole with a 4" spacing--the most dramatic example. In the plane of the 2 elements, with the short leg being the forward direction, the elevation pattern shows marked differences between the forward and rearward set of lobes. When we take an elevation pattern at 90 degrees to the front-back line, we obtain the symmetrical pattern in the lower half of the figure.

Fig. 10



0-180-Degree Elevation Pattern

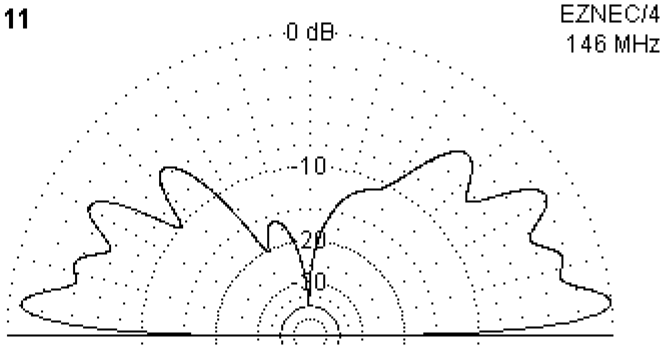


90-270-Degree Elevation Pattern

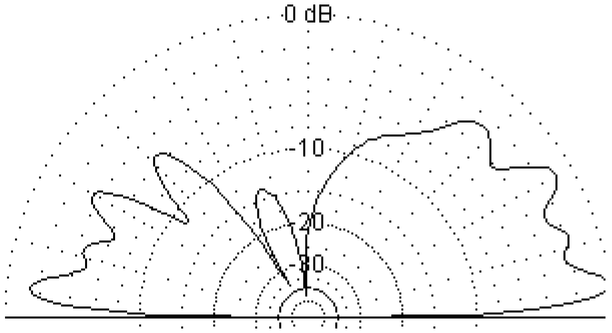
Elevation Patterns of a Standard J-Pole with 4"-Element Spacing Showing Pattern Changes With Changes in Pattern Axis

As we increase the spacing between match-section legs, we find a growth in the disparity between the forward and rearward lobe sets. **Fig. 11** compares the elevation patterns of the standard J-pole with element spacings of 1" and 4".

Fig. 11



1" Spacing

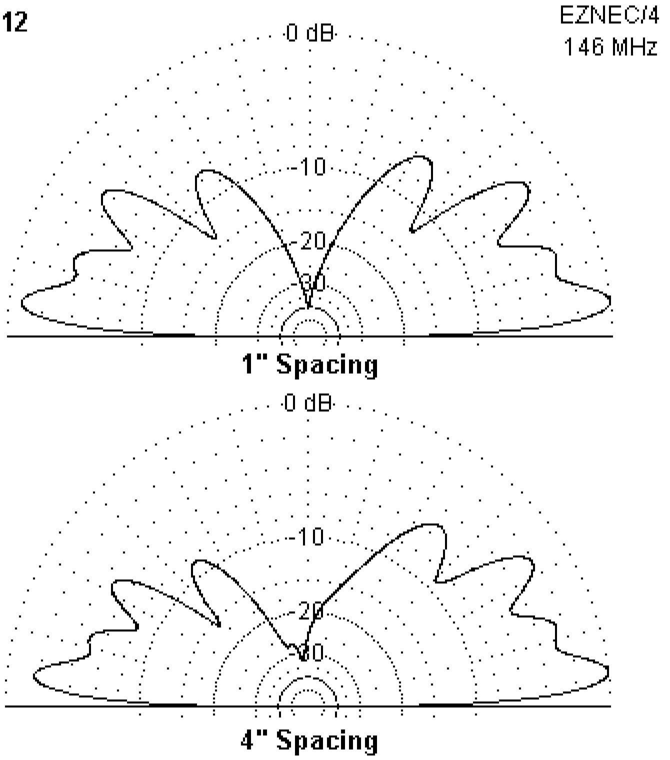


4" Spacing

Comparison of Elevation Patterns of Standard J-Poles with 1" and 4" Element Spacing

The non-standard design shows a comparable but less radical growth in elevation lobes sets with increases in element spacing. **Fig. 12** compares the patterns for 1" and 4" match-leg spacing.

Fig. 12



Comparison of Elevation Patterns of Non-Standard J-Poles with 1" and 4" Element Spacing

If we remember the free-space elevation pattern in **Fig. 2**, we can understand the lobe-set disparity. The forward lobe of the free-space pattern for the standard J-pole showed a distinct upward tilt. Consequently, over ground, the standard J-pole tends to show relatively high energy at higher elevation angles. In contrast, the non-standard free-space pattern shows less tilt and the elevation patterns over ground show somewhat less total high-angle energy.

However, there may be a limit as to the maximum advisable spacing between the legs of a J-pole. Almost all of the azimuth patterns for the J-poles in the spacing series shows the same characteristics as the one in **Fig. 6**. The maximum gain lies on a heading that exactly follows the plane of the elements, with minimum gain in the reverse direction.

Azimuth Pattern: Standard J-Pole with 4" Element Spacing at 10' Above Average Ground

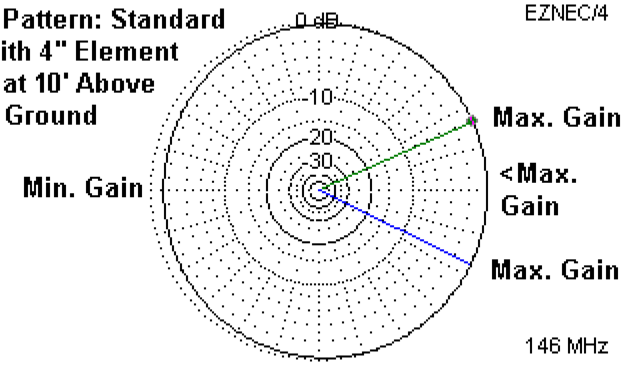


Fig. 13

However, as we set the spacing of the standard J-pole at 4", the pattern begins to change, as shown in **Fig. 13**. Maximum gain appears at two points in the relative forward direction, each separated from the in-plane direction. It is likely that as we would further increase element spacing, the points of maximum gain would more widely diverge from the presumed forward direction, eventually resulting in an oval pattern with the strongest points almost broadside to the plane of the

J-pole. Just how much pattern distortion one can tolerate is a user judgment based upon the operational goals for the antenna.

With the standard J-pole, the operating bandwidth, as reflected in 50-Ohm SWR curves, did not change as we increased the diameter of the element material. However, as we increase the spacing between the legs of the J-pole, the operating bandwidth does increase, as shown in the top half of **Fig. 14**. With a leg spacing of 4", the 50-Ohm SWR remains below 1/5:1 across the entire 2-meter band. At the 1" minimum spacing used in the survey, the maximum SWR is just above 1.7:1 at the band edges.

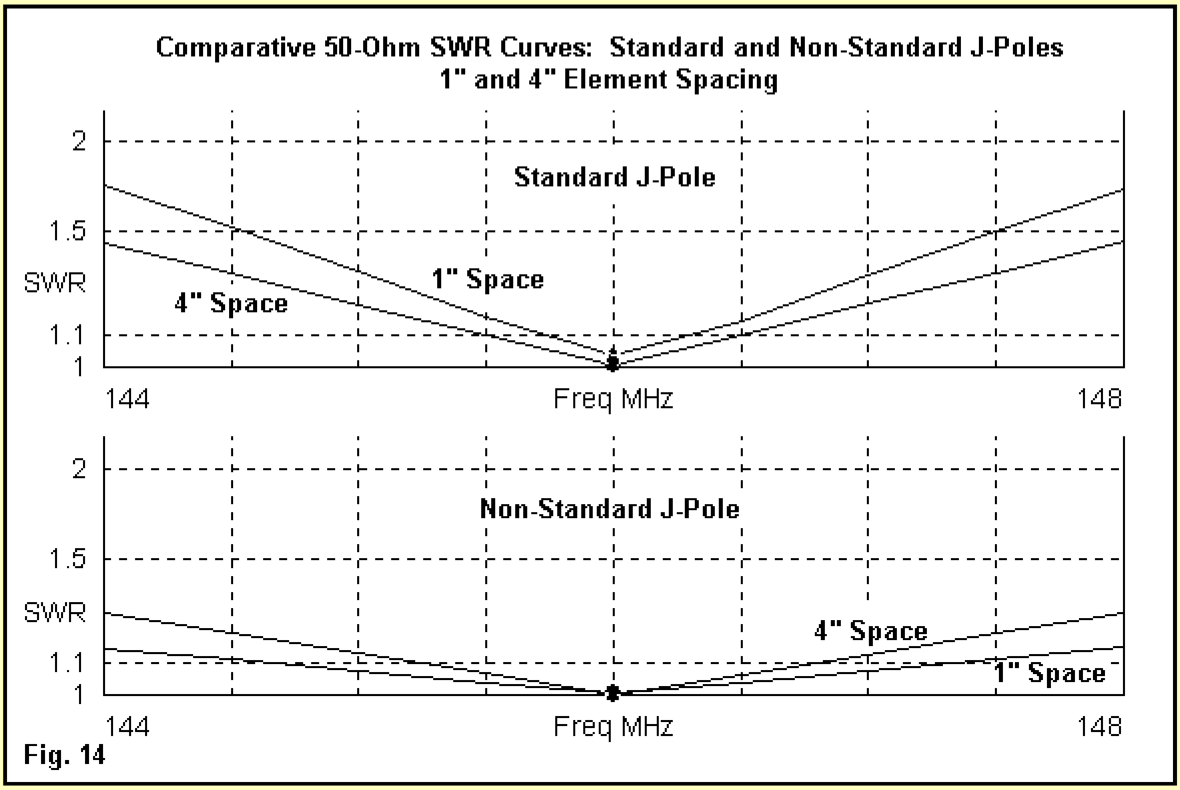


Fig. 14

The non-standard J-pole design once more shows an inherently wider operating bandwidth than the standard design. The worst-case SWR shown in **Fig. 14** for the non-standard design is under 1.3:1. However, the bandwidth actually decreases as we increase the spacing between the match-section legs. This result seems contrary to the result for increasing the element diameter. However, the bandwidth does correlate quite well with the changes in the overall length of the radiator. The bandwidth increases with decreases in radiator-leg length and decreases with increases in the radiator-leg length.

Conclusions, But Not THE Conclusion

The trends that this small survey has uncovered may be useful to the J-pole designer, but they do not approach the level of making a significant difference in the operational use of a J-pole. Over the range of element diameters and match-section leg spacings modeled, a user would be very hard pressed to detect any difference in performance between J-pole types or between designs taken from the most extreme cases.

Perhaps the most significant conclusion to reach from the data is the need to have some degree of adjustability built into a J-pole that departs from one of the cookie-cutter sets of plans for them. If you change the material diameter or the leg spacing from one of those plans, you likely will have to adjust at least the length of the radiator side. In addition, for standard designs, placing the taps for the feedpoint remains a field exercise--meaning that the taps should be adjustable and tried until one obtains a satisfactory result. For the non-standard design on its insulated base, being able to adjust the length of both sides of the assembly will facilitate the discovery of dimensions that yield a 50-Ohm resistive feedpoint impedance.

We have examined standard and non-standard J-pole designs with respect to element diameter and leg spacing. Only one other dimension remains to be explored: the overall length of the radiator. Indeed, since the lower portion of a J-pole is mainly a means of providing power to the radiator section, the J-pole is as much a candidate for lengthening into various collinear vertical arrays. As well, it may be useful as the driven element for modest--or even immodest--Yagis. Therefore, one more episode seems in order to explore these potentials--and possibly compare the results to more standard designs for collinear and parasitic arrays.

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