Some J-Poles That I Have Known

Part 2: The Varieties of Twinlead J-Poles and Some Performance Standards

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One of the fascinating aspects of J-pole design is the number of slightly different designs that builders have constructed from common 300-Ohm parallel feedline, the most common form of which is TV twinlead. The question that occurred to me is whether there are any significant or at least detectable differences among these design variants. Modeling might shed some light on the question.

However, modeling is restricted to "proof-of-principle" models. Parallel feedline comes in a variety of physical forms, as illustrated incompletely in **Fig. 1**.

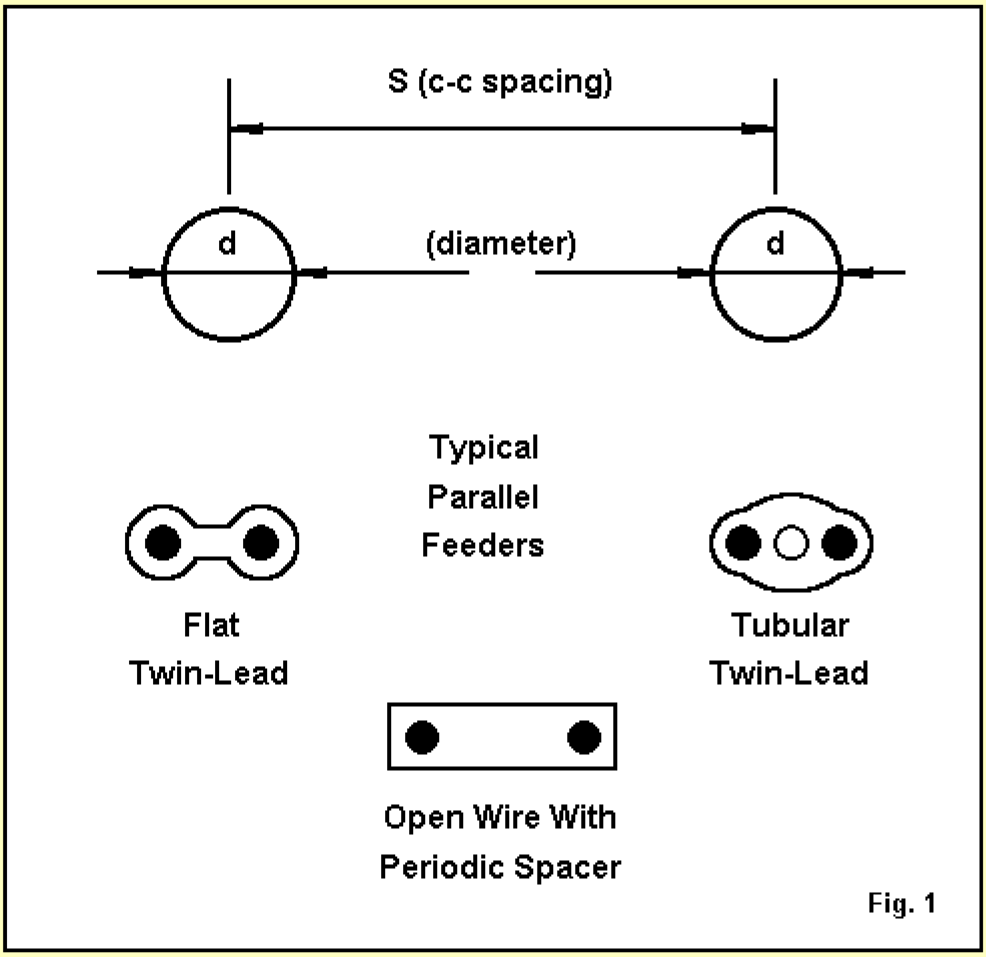


Fig. 1

The open wire feedline with periodic spacers generally presents no problems for antenna modeling. The wire is bare, and the spacers are usually widely enough spaced that a simple bare-wire model comes very close to a precise model of the physical antenna.

The vinyl-covers twinleads are another matter. NEC-4 has the ability to handle insulated wires, each wire having a larger radius than the conductor within. We may assign reasonable values to the permittivity and conductivity of the insulating sheath.

However, these insulations do not account for either of the two varieties of twinlead shown in the figure. Flat 300-Ohm TV twinlead has a continuous vinyl strip between insulated wires. The location is within the most intense portion of the field between wires when used as a transmission line. At present, there are no clear guidelines on how to estimate the thickness of the circular cross-section sheath in the model to approximate the effects of the strip. In contrast, the tubular twinlead version has an air pocket between wires to raise the velocity factor of the line. Nonetheless, the connecting vinyl still occurs where the field between wires is strong.

Therefore, models of twinlead must begin with bare-wire versions, with the caution that the dimensions that emerge may not be close to the dimensions demanded by vinyl-covered twinlead.

A second modeling caution involves the very close spacing of twinlead wires--usually AWG #20 wire (0.032" diameter) at a cent-to-center spacing of about 3/8". Then we add to the problem the fact that, for standard J-pole designs, the feed wire will be within 1.5" to 2.5" of bottom of the antenna. Obtaining in NEC-4 a model with a reasonable average gain test (AGT) value occupies as much of the design time as finding dimensions that yield a near-resonant 50-Ohm antenna.

One of the known work-arounds for excessively tight angles and close- spaced wires tends to fly against normal modeling procedures. Convergence tests tend to add segments until the antenna's gain and source impedance no longer change values between steps in the process. However, to arrive at an acceptable AGT value for models of twinlead J-poles often requires a reduction in segmentation density. Hence, the emergent dimensions become further suspect, since convergence testing and average gain testing are at odds. Nevertheless, we may derive some significant information from the exercise.

The Single-Wire Radiator Version of the J-Pole

The most straightforward way to obtain a J-pole from a length of TV twinlead is to retain the double line to serve as the matching section. Then, we strip away one wire from the upper portion, leaving a single radiator wire. The outline of a bare-wire version of this type of J-pole appears in **Fig. 2**.

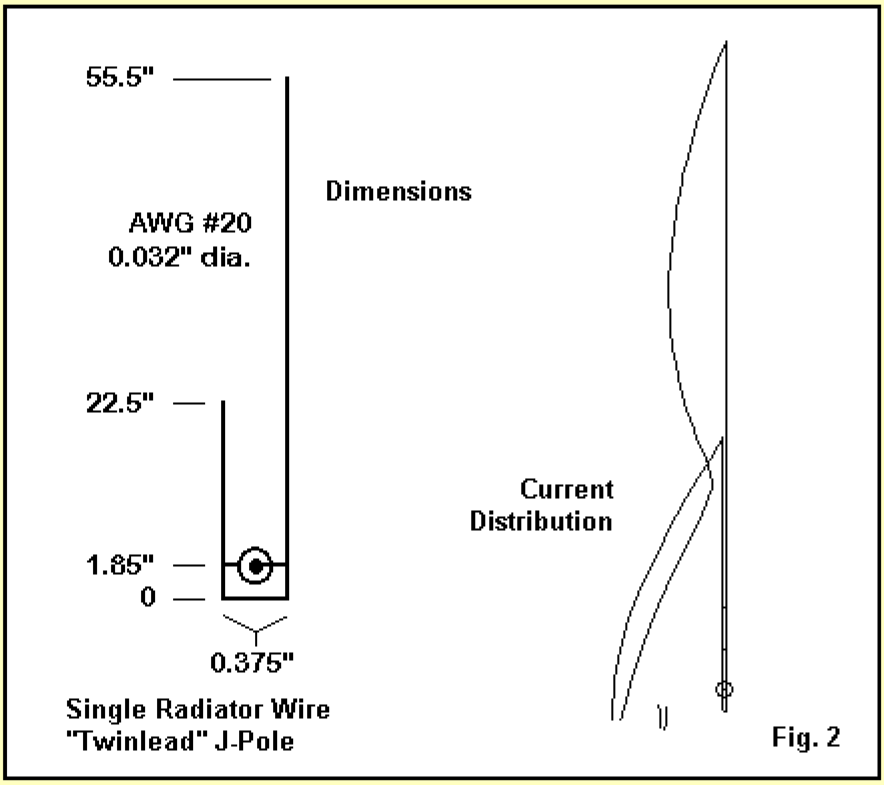


Fig. 2

As the dimensions on the sketch indicate, the radiator is 33" long and combines with a 22.5" matching section. The required distance above the bottom short in the section is 1.85". The right side of **Fig. 2** shows the current distribution along the antenna. Unlike the standard model of Part 1, the current minimum for the radiator does not align well with the top of the matching section. Instead, it occurs somewhat below the top of the open-end of the matching section.

The free-space model for this antenna yielded an AGT value of 1.008, indicating that gain reports would be about 0.04 dB too high. The maximum free-space gain of the antenna is about 2.45 dBi, when adjusted, with an average gain of about 2.38 dBi. The total pattern distortion created by the presence of the matching section is about 0.1 dB, as revealed by the top portion of **Fig. 3**. The narrow-spaced twinlead J-pole yields a very circular pattern.

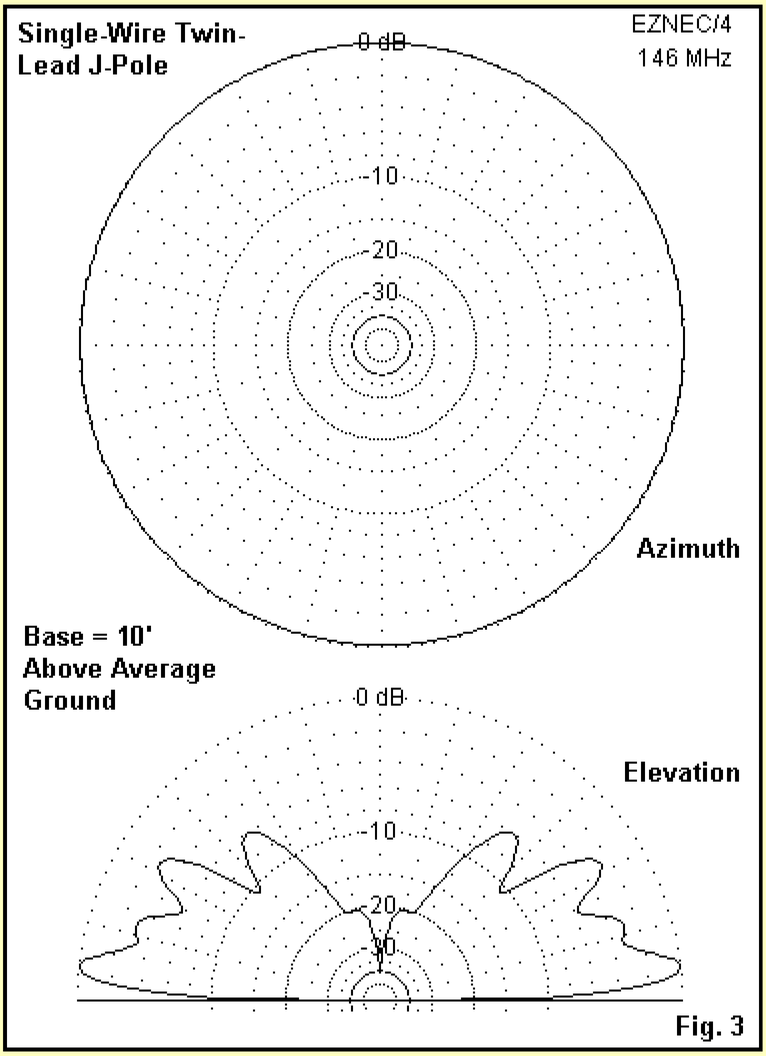


Fig. 3

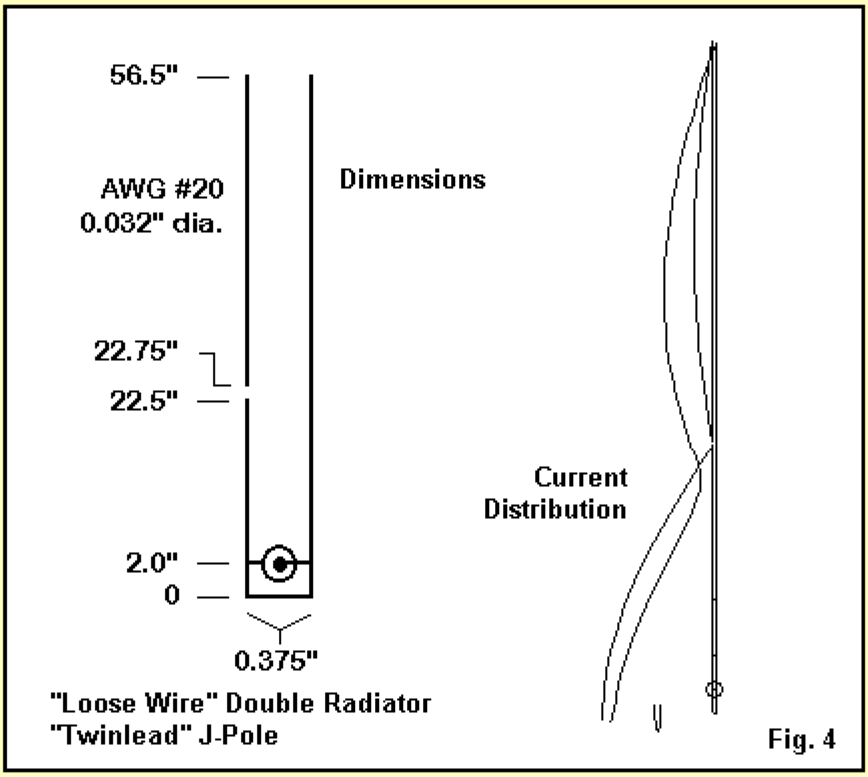
The patterns in **Fig. 3** emerge from a model whose bottom-most portion is at 10' or 120" above ground. Most commonly, we use 2-meter J-poles at heights ranging from 5' to 20 above ground, so the 10' position seems a fair sample. Remember that the high current portion of the radiator is another 40" above that base level.

The elevation pattern has a main lobe that is 6 degrees above the horizon. The maximum gain is about 5.1 dBi, subject to terrain features that clutter reality for most operations. While we examine the elevation plot, note the secondary or higher-angle lobes for comparison with other models that will appear in this part of our investigation.

The test model showed a source impedance at 146 MHz of 53.4 - j3.0 Ohms.

The Loose-Wire Radiator Version of the J-Pole

One natural variation on the single-wire radiator J-pole is the loose-wire radiator version. The sketch at the left of **Fig. 4** shows the general construction and the modeled dimensions.



The loose-wire J-pole emerges from the desire to use the twinlead intact for added strength. Therefore, instead of removing the wire that is parallel to the normal radiator, we leave it in place, cutting out only a small portion to allow one side of the matching section to be open. Interestingly, the total length of the matching section does not change. Instead, the tapping point for the source wire moves up a very small amount to arrive ar a near 50-Ohm feedpoint impedance. The test model showed a source impedance at 146 MHz of 47.4 + j2.9 Ohms.

The change of source wire position results from the slight lengthening required for the radiator--about 1" in the bare-wire proof-of-principle model. As the right side of Fig. 4 shows, the connected-radiator current minimum still occurs below the open end of the matching section. As we might expect, the closely-coupled loose wire show considerable current so that we should think of the two upper wires together as the radiating portion of the antenna. (We should, of course, never forget that the imbalance of current on the matching section wires results in some radiation from this portion of the antenna.)

The model yielded an AGT value of 1.002, indicating only a 0.01 excess in the gain reports. The adjusted maximum free-space gain was 2.45 dBi, with an average gain of 2.40 dBi. Once more, the distortion of circularity of the pattern amounted only to about 0.1 dB.

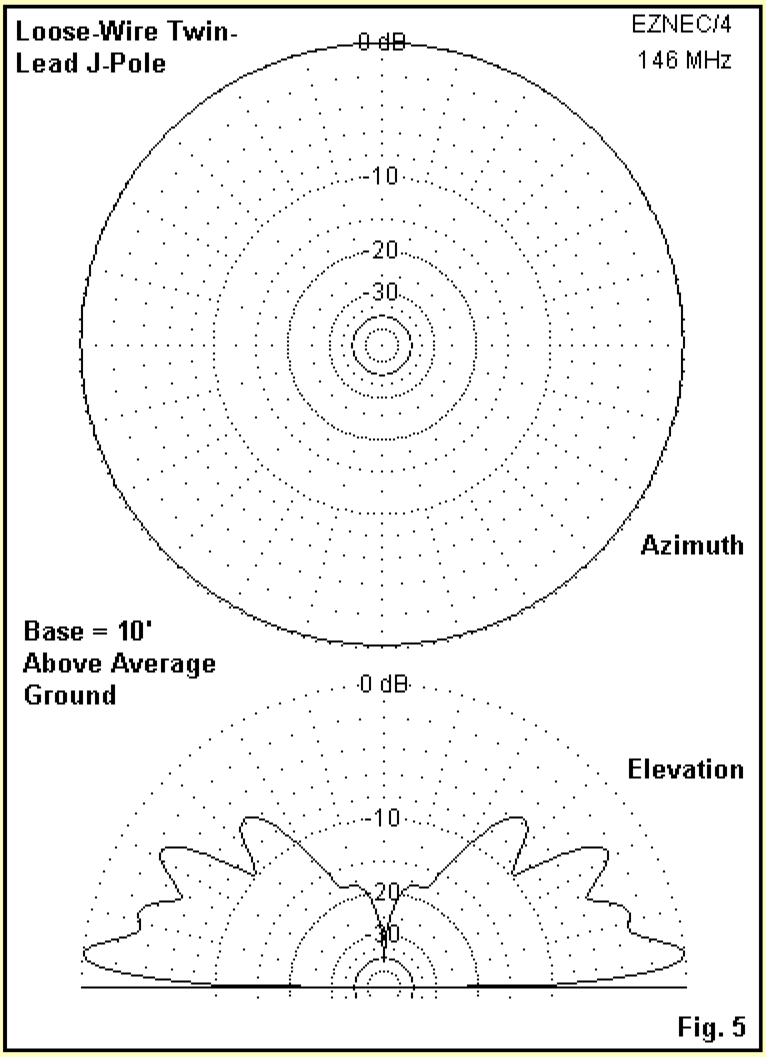


Fig. 5 shows azimuth and elevation patterns of the loose-wire twinlead J-pole with the base 10' above average ground. The upper pattern confirms the essential circularity of the pattern, while the lower elevation pattern seems initially indistinguishable from that of the single-wire twinlead J-pole. Indeed, the gain at a 6-degree elevation angle is about 5.1 dBi. The only difference between patterns that overlaying them can reveal is insignificant: the loose-wire version shows slightly larger lobes at the near-vertical angle just before the zenith null than the single-wire version. The difference of about 2 dB in lobes that are down in the -20 dB range could not be measured in any real situation.

The Top-Wire Radiator Version of the J-Pole

Twin-lead J-pole come in many physical varieties. Some builders design them to hang from the top, while other affix them to non-conductive supporting poles. One version has even been packed inside a length of Schedule 40 PVC. All seem to work quite acceptably so that the only choices facing the new builder is the preferred physical arrangement to suit operating needs.

From this array of variations has emerged one more variant of the twinlead J-pole. It creates a gap and retains the second wire in the radiator section. However, it folds over the two radiator wires at the top and joins them. Since the current goes to zero--in theory--at the top of the radiator, this arrangement should not disturb the current distribution on the radiator wires.

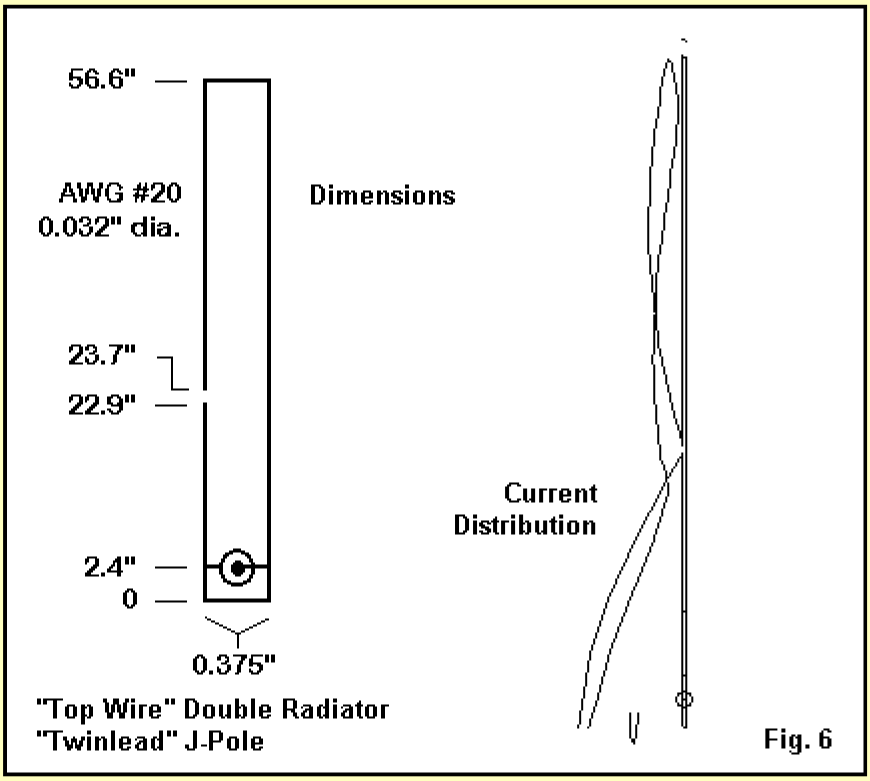


Fig. 6 shows the dimension of the proof-of-principle model needed to obtain a resonant feed point. The modeled impedance was 51.7 - j8.2 Ohms. Note that the overall height relative to the loose-wire version has grown only 0.1". However, the matching section is now 22.9" long, with the gap extending another 0.8". The feedpoint tap wire moved upward to 2.4" above the antenna bottom. Clearly, the top wire added some complexity to the operation of the J-pole without necessarily creating any significant construction problems.

The current distribution graphic on the right of **Fig. 6** shows what has happened. The gap that defined the end of the second radiator wire occurs above the current minimum for the connected wire. Therefore, two current excursions along the connected radiator wires must move the middle current minimum downward from the tip on the connected radiator wire. The tip region of the antenna shows a rising current magnitude.

The chief result of the current distribution is the alter the required dimensions of the J-pole relative to the other two versions. The difference does not show up in operation. The model showed an AGT value of 0.965, indicating that gain reports would be about 0.16 dB low. The adjusted maximum gain report is about 2.51 dBi, with an adjusted average gain report of 2.45 dBi. The minuscule difference between these values and those reported for the other two models results mostly from the fact that the AGT value is further from a perfect 1.0 value. The correction factor becomes less accurate as the AGT departs further from the ideal value.

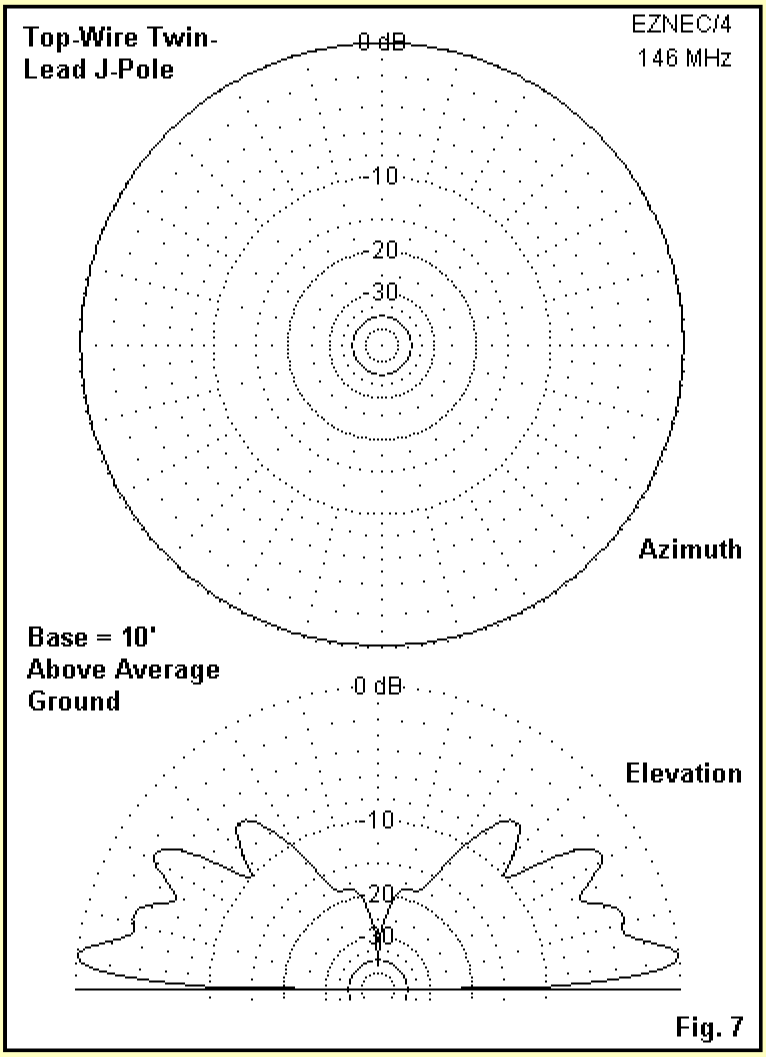


Fig. 7

Fig. 7 shows the azimuth and elevation patterns for the top-wire twinlead J-pole with a base height of 10'. The gain at an elevation angle of 6 degrees is once more about 5.1 dBi. The pattern is once more circular within about 0.1 dB. The elevation pattern is truly indistinguishable from that of the loose-wire version of the antenna.

Insulating the Wires

Nothing in the variant construction methods for the twinlead J-poles shows any sign of changing performance by even the most sensitive antenna range measurement, assuming that each antenna receives due care in the building and adjustment process. However, all of the models used to establish this fact used bare wire. The question remains as to the effects of insulation on the wires.

Some advanced NEC-4 programs provide an program control input labeled IS, for insulated sheath. The modeler can specify a second radius for each wire, one that is larger than the conductor radius itself. In addition, the modeler can specify values of conductivity and permittivity (relative dielectric constant) for the additional radius.

As a test, I began with the single-wire version of the twinlead J-pole. I added to every wire in the model an insulated sheath with a diameter of 0.047", about 1.5 times the diameter of the wire itself (0.032"). I assigned a conductivity of 1E-10 s/m to the sheath, on the assumption that the sheath is an excellent insulator. In fact, in other tests of the IS input, dipole performance did not show any noticeable change until the conductivity reach the 1E-6 s/m level. Hence, for most exploratory purposes, assigning a very low conductivity level will not affect the results. The selected permittivity value was 2.5, about in the middle of the range of most plastic materials used to insulate wires.

This model is only a first-order exploration into the performance of twinlead J-poles with insulated wires. The insulating sheaths do not touch--in fact, they leave a considerable air space between wires in the matching section. However, the model is sufficient to "see what happens" with insulated wires.

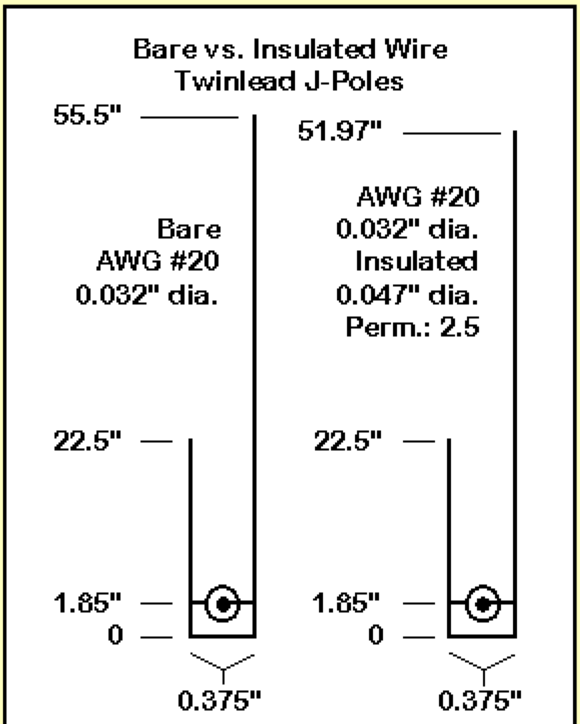


Fig. 8

Fig. 8 shows the dimensional differences between the bare and insulated single-wire radiator J-poles. The source impedance of the revised model was 50.6 + j9.7 Ohms with the feedpoint tap wire at just about the same height above the antenna base as for the bare-wire version. In fact, the only required change for this performance was to shorten the height by just over 3.5". The matching section legs remain the same in both models.

Although a fully developed model of the matching section might show some required changes in dimensions to account for the velocity factor of actual twinlead, the key result of using insulated wire on the assembly lies in the necessary shortening of the radiator section. To some degree, the matching section is self-compensating, since the current minimum of the radiator now occurs further down the connected leg of the matching section. Unfortunately, the software on which the insulated-sheath model was run does not permit a current distribution graph of the types shown for the other models.

Free-space performance of the antenna changes hardly at all. The pattern remains circular within the 0.1 dB level, and the average gain is about 2.4 dBi. In short, insulated-wire twinlead J-poles are every bit as good as bare wire versions and only require attention to the dimensions that result from the wire insulation.

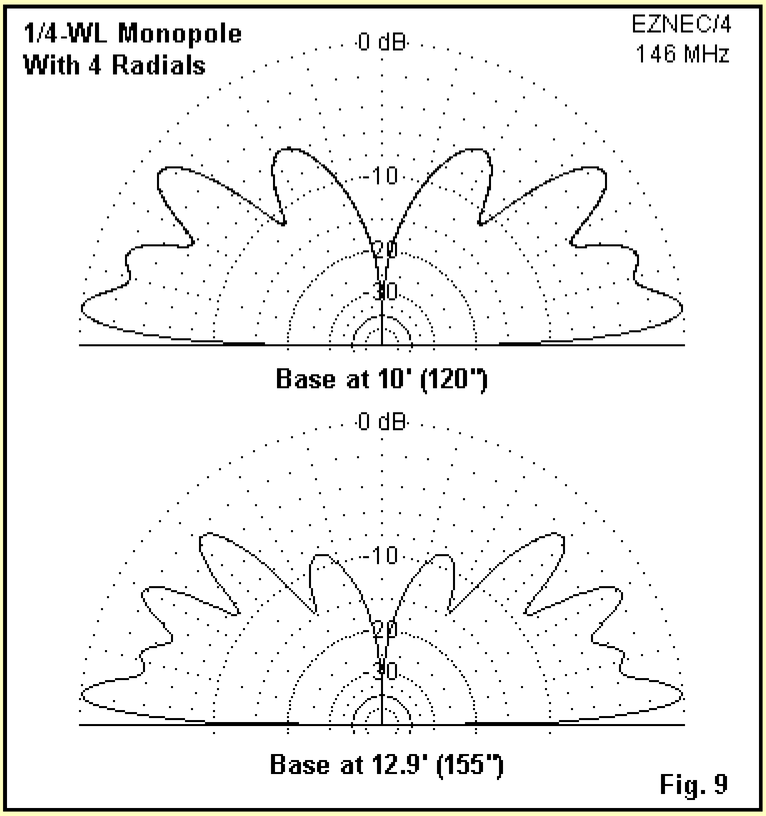
Some Standards of Comparison

Throughout this exploration of twinlead J-poles, we have placed the base of the antenna at 10' above average ground to find a sample of its performance potential. In all cases, a gain of 5.1 dBi at a 6-degree elevation angle emerged to make each version the equal of the others.

The question we might raise, since we have these figures at hand, is how the J-pole stacks up against other common antennas used in the same service. To answer this question, I looked at file models of both 1/4-wavelength monopoles with radials and 1/2-wavelength vertical dipoles. We use the former most commonly when we wish to place the feedline beneath the model. The latter serves well when side-mounting is required.

However, we have to examine a matter of test fairness. The J-pole is longer than either of the two comparison antennas, and its region of highest current is well above the antenna base. Simply placing the comparison antennas at a base height of 10' might not result in a fair comparison.

Therefore, I performed 2 tests. The first placed the comparison antenna base at 10' above ground. The second raised the antenna until it showed a take-off angle (or elevation angle of maximum radiation) of 6 degrees.



The 1/4-wavelength monopole with 4 radials yielded the elevation patterns shown in **Fig. 9**. (I have omitted azimuth patterns, since the comparison antennas have perfectly circular patterns in the absence of nearby objects.) The upper pattern--with a 10' base for the antenna--has a gain of about 3.4 dBi at 7.1 degrees above the horizon. We can obtain a 6-degree take-off angle by raising the antenna to a base level of 12.9'. The gain rises to just above 4.0 dBi. Clearly, the J-pole is superior by at least a full dB. Moreover, the near-3' increase in monopole height to achieve the 6-degree take-off angle places the monopole and J-pole high current regions at just about the same distance above ground.

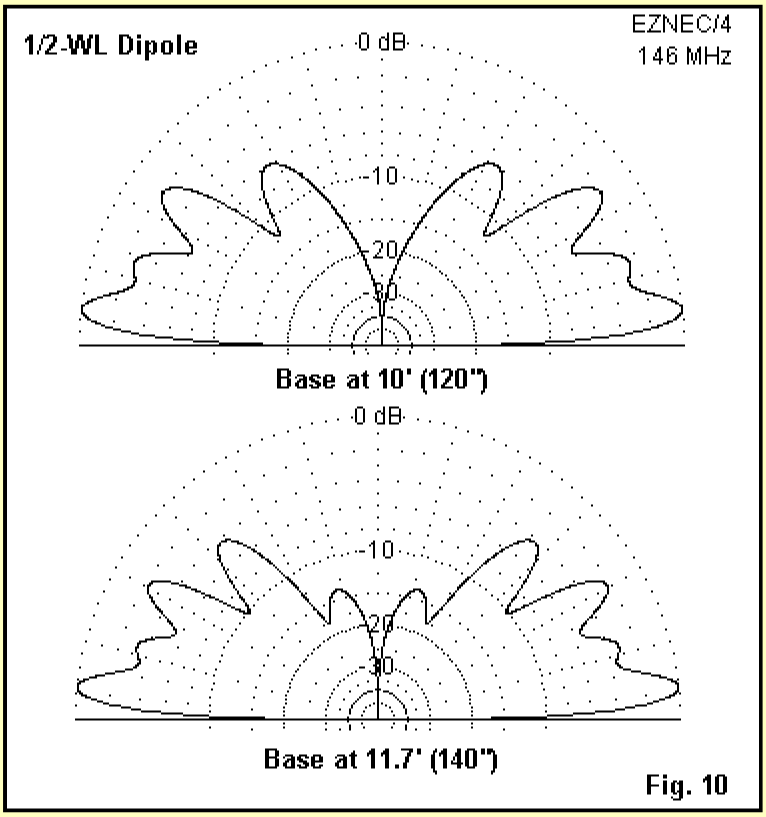


Fig. 10

Fig. 10 shows the comparable results for a vertical dipole. With the vertical base at the 10' level, the gain is just above 4.5 dBi with a 6.7-degree take-off angle. To achieve a 6-degree take-off angle, we must raise the antenna by about 1.7' or 20". It is not accident that this increase elevation corresponds roughly to the length of the matching section of our twinlead J-poles. The resulting gain is about 4.9 dBi, only about 0.2 dB lower than gain of the J-poles. Indeed, to ascribe the added J-pole gain to radiation from the matching section would likely not be wrong. However, to think that one could detect the 0.2 dB gain difference in operation would likely be very wrong indeed.

The J-pole, then, performs very much like a vertical dipole, with departures from its electrical mate's pattern that result from the presence of the matching section and its slight imbalance of currents. The departures are slight for very closely spaced thin wires, such as we find in a twinlead version of the antenna. However, the thin wires do not detract from the operating bandwidth of the antenna--one of its chief merits.

Fig. 11

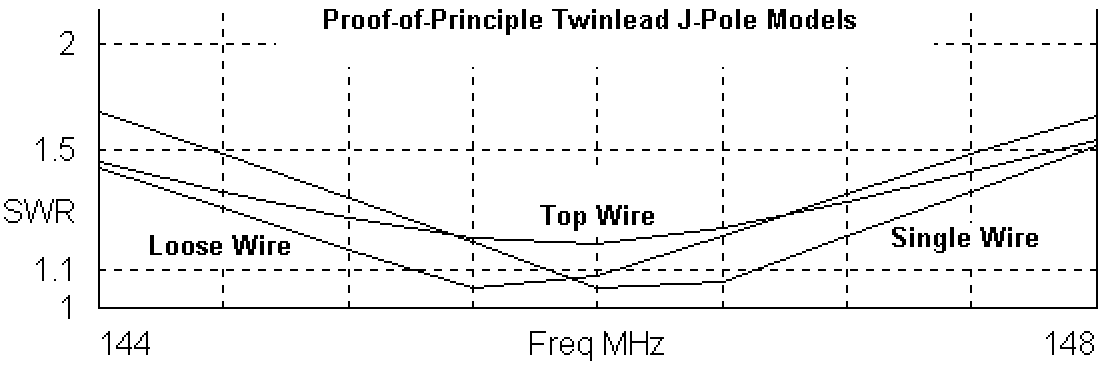


Fig. 11 shows the SWR curves for the 3 bare-wire models of J-poles that we explored. Conveniently, the curves are displaced sufficiently for ready examination. Clearly, the single-wire and loose-wire curves would overlap almost perfectly had we fussed the 146-MHz impedance to a perfect 50 Ohms. Both curves would show a 50-Ohm SWR of about 1.6:1 at the band edges had we done the additional work.

The top-wire curve is interesting, because its low point has a higher SWR value due to the high impedance of the antenna at 146 MHz and because its band-edge values are only about 1.5:1. The curve is shallower. At this point, it is unclear whether the top wire plays a significant role in this minor effect. Obviously, any significant length of 50-Ohm coaxial cable will wash out any differences among the curves.

The broadness of the SWR curves, despite the thinness of the radiator wire and despite construction changes that add virtual thickness to the wire for some of the models, raises some questions. The classic dipole model shows a rapid change of current and voltage at the ends as we change frequency. However, those changes do not show up at the feedpoint end of the matching section. We have noted the fact that for all of our models, the radiator current minimum occurs below the top of the matching section.

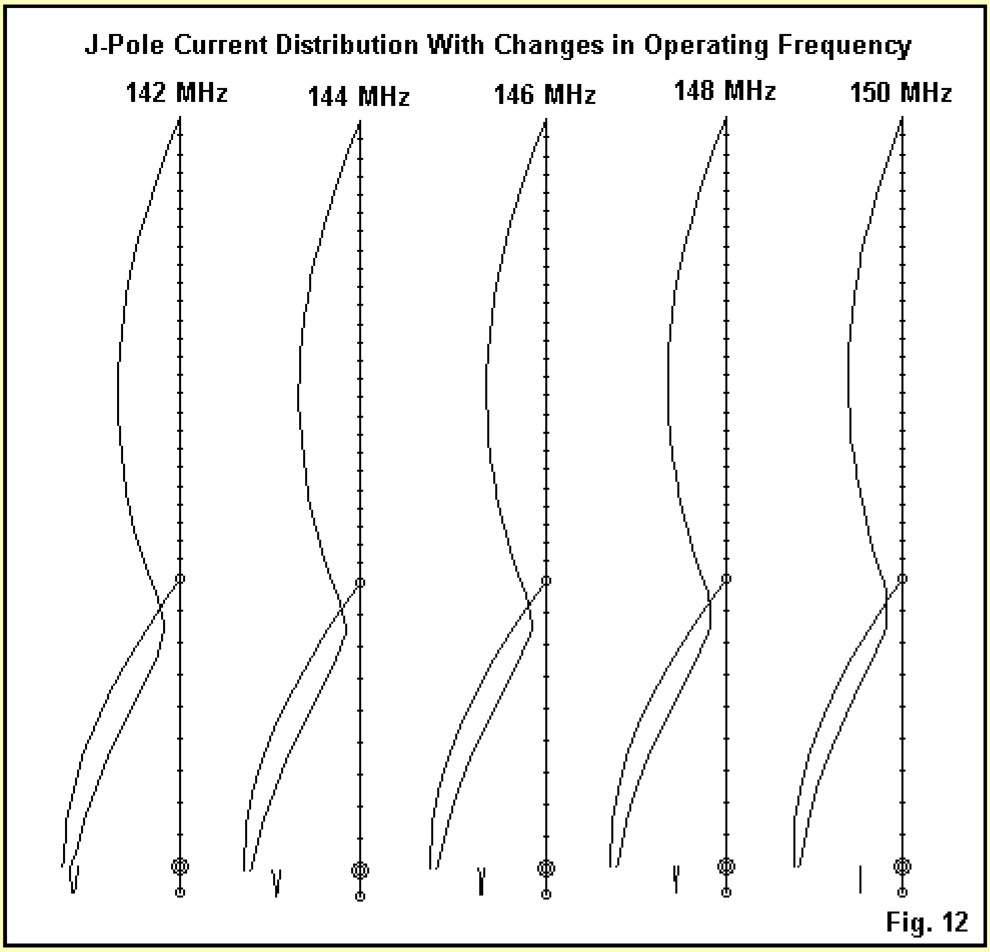


Fig. 12 shows the current distribution for the single-wire J-pole at 2-MHz intervals from 142-150 MHz. If you examine the curves carefully, you will see that the radiator current minimum point slowly climbs upward with frequency increases. The net effect is to change the combined lengths of the matching section legs, as well as the current magnitude in the small portion of the matching section below the feedpoint tap wire. Moreover, there is a changing current magnitude differential from one end of the feedpoint tap wire to the other as we increase frequency.

In effect, there is a degree of self-adjustment between the radiator and the matching section that increases the operating bandwidth beyond what we might expect from the wire size alone. The amount of self-adjustment is limited, as the 50-Ohm SWR is just above 2.5:1 at 142 and 150 MHz. Nonetheless, the degree to which the combined radiator and matching section exhibit a broad operating bandwidth in the J-pole adds one more dimension to our appreciation of this seemingly simple antenna.

More?

The SWR curve question that we have just begun to explore leaves us with another: what is the effect of element thickness (for both the radiator and the matching section) on the operation of a J-pole? Does the operating bandwidth change? Does the antenna gain change?

We have also alluded to another interesting aspect of J-poles. The narrow-space versions show a nearly perfectly circular pattern, which the wider-spaced version in Part 1 shows noticeable (but not harmful) distortions from circularity. We are left with the question of whether the degree of non-circularity of the pattern is directly related to the spacing of the legs in the matching section.

Each of these 2 questions calls for a bit of detailed modeling to see if the beginnings of a set of answers emerges. As I noted, once one gets hold of a J-pole, it does not let go. So a Part 3 seems inevitable.

Go to Part 3

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