Some Notes on Linear Resonators
Part 3: Wire Linear-Resonator Dipoles

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In Parts 1 and 2, we looked at dual-band linear-resonator dipoles for the upper HF region that used elements having a substantial diameter. 20-meter main elements used 7/8" tubing, while 15-meter main elements used 3/4" tubing. One major consequence of the material selection was our ability to use a fairly wide separation between the main element and the 1/4"-diameter linear-resonator rod. We centered our focus on 6", but explored some narrower and wider spacing values between 4" and 8".

In this final excursion into the land of linear resonators, we shall reduce the main element diameter to wire size. One consequence of the reduction is that we shall be able to use the same diameter material for both the main element and the linear resonator. Since all wires in the NEC-4 models will have the same diameter, the modeling accuracy, as indicated by the average gain test (AGT) scores, should improve. However, there will be a second consequence for the models (and for any physical implementation of a wire-based linear-resonator dipole). The ability to find acceptable dimensions to achieve a set of resonant points on 2 band with a 50-Ohm SWR of less than 2:1 depends in large measure on the mutual coupling between the parallel wires within the linear-resonator section of the antenna. Since we are wholly dependent on the wires as linear inductors for the mutual coupling, the degree of coupling depends upon the wire diameters and the spacing between them. As we reduce the diameter of the wires, we must bring them closer together to achieve the same level of coupling.

Suppose that we reduce the wire size by a factor of 7:1. That is, suppose that we reduce the diameter from 7/8" to about 1/8". The required spacing between the wires is roughly proportional to the element diameter. Hence, the spacing between the main element and the linear-resonator rod will decrease from about 6" to the vicinity of 1". As we shall see, the narrow spacing will be quite critical in dual-band dipoles with small ratios between the upper and lower frequencies, but will be less critical with higher frequency ratios.

To sample both possibilities, let's explore two different wire-based linear-resonator dipoles. The first will cover 20 and 15 meters. The 3:2 frequency ratio falls at the lower end of the scale. As well, the combination allows us to compare the results with the model used in Part 1 of this series. Later, we shall examine a 20-10-meter combination. The larger 2:1 frequency ratio will show us both the advantages and the disadvantages of the alternate design.

A 20-15-Meter Wire Linear-Resonator Dipole

The 20-15-meter combination dipole that we explored in Part 1 proved that the linear-resonator technique can be successful if we observe its limitations. The large-diameter (0.875" diameter) model allowed us a wide SWR bandwidth on 15 meters. However, the 20-meter impedance dropped to the vicinity of about 35 Ohms. Obtaining coverage of 20 meters required careful attention to the overall length of the antenna. The 1/4"-diameter linear-resonator rod--spaced 6" from the main element--was a little under 100" long and required a capacitor value of about 16 pF for 15-meter resonance.

Translating that "fat-element" model to wire size requires that we reduce both the element diameter and the rod-to-element spacing. For reasons that will become evident a little later, I did not start with the usual amateur AWG #12 wire 0.0808" or 2.05 mm diameter). Instead, I used the less common AWG #8 wire (0.1285" or 3.26 mm diameter). As well, I reduce the rod-to-element spacing down to 1". Since the end wires of the resonator section are so short, I had to increase the overall segmentation density of the model to preserve some semblance of segment-length equality. **Fig. 1** shows both an overall outline of the model and an expanded view of the linear-resonator section.

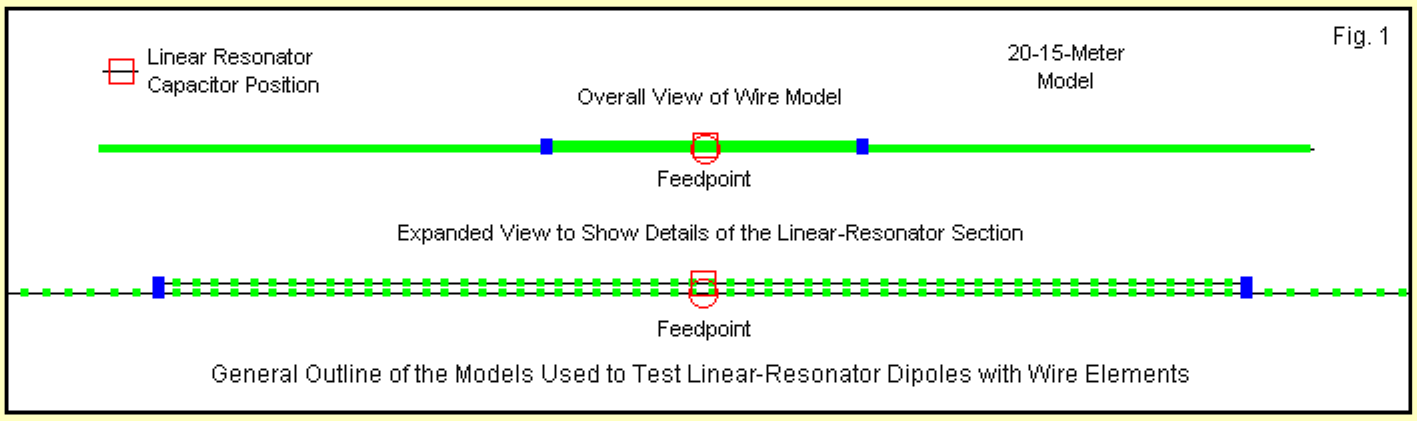


Fig. 1

General Outline of the Models Used to Test Linear-Resonator Dipoles with Wire Elements

Quite likely, any implementation of a wire-based linear-resonator dipole will require the use of parallel sections of rod to effect the resonating capacitance. The development of a homemade concentric capacitor that is thin enough to avoid touching the main element is difficult at best. For our initial model, all wires are AWG #8. The proximity of the wires does not yield perfect AGT scores. However, the values (0.985-0.988) are significantly improved relative to earlier models that had junctions of wires with different diameters.

The close spacing between the wires does not affect the general radiation pattern of the dipole. As shown in **Fig. 2**, the 15-meter performance includes slightly high gain and a slightly narrower beamwidth than we obtain on 20 meters. The free-space patterns show a 0.5-dB difference in gain. In the plane formed by the main element and the resonator rod, the close spacing does make a difference. In this plane, the front-to-back ratio is down to 0.1 dB, a reduction from the 0.5-dB value we obtained from the fatter model. As a consequence, the 15-meter pattern shows deeper side nulls than we obtained using fatter elements: about 25 dB below the level of maximum gain.

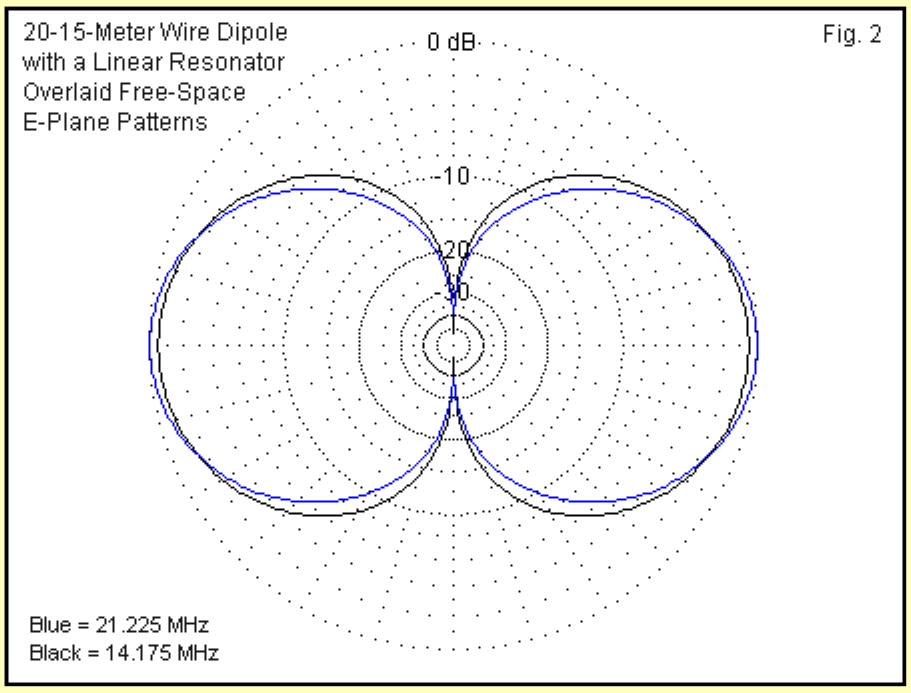


Fig. 2

20-15-Meter Wire Dipole
with a Linear Resonator
Overlaid Free-Space
E-Plane Patterns

Smaller diameter elements do produce other effects that are noteworthy. For a linear element, a smaller diameter element generally produces an antenna with a narrower SWR bandwidth. We can observe this effect in a general way by looking at a typical wide-band SWR sweep. **Fig. 3** shows a 50-Ohm sweep from 13 to 22 MHz to include the bands of interest.

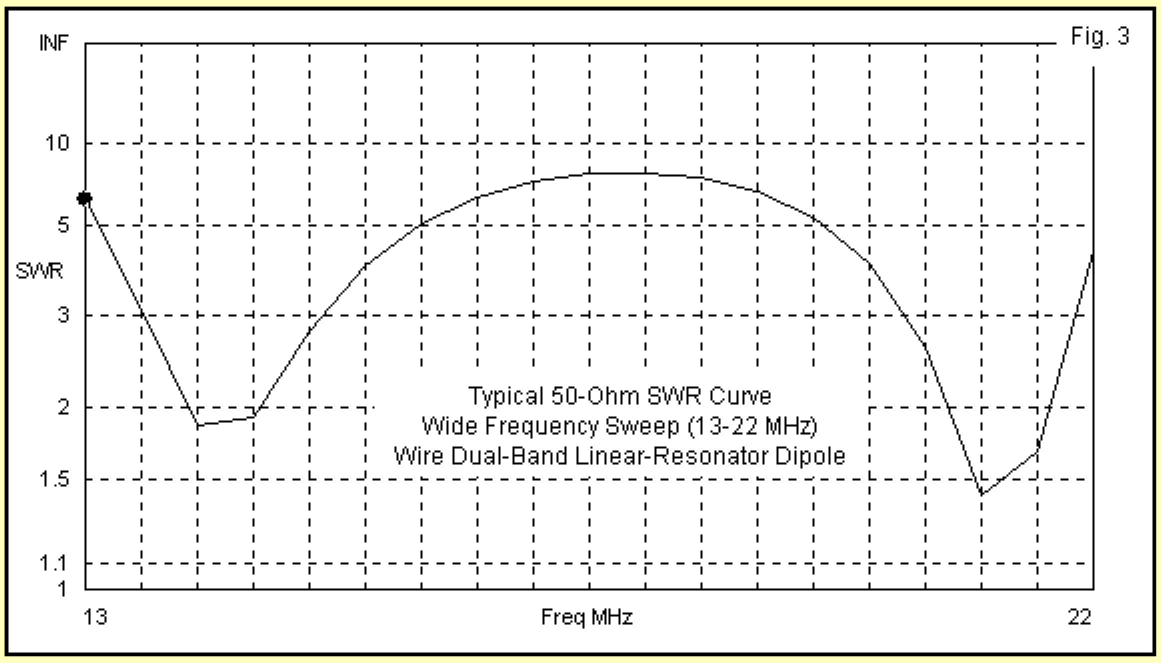


Fig. 3

Typical 50-Ohm SWR Curve
Wide Frequency Sweep (13-22 MHz)
Wire Dual-Band Linear-Resonator Dipole

The peak 50-Ohm SWR value between bands was between 5:1 and 6:1 for the fatter models of Part 1. For our wire versions, the peak value will climb to the 8:1 or higher region. The actual value is not important in operation, but it does provide a caution to experimenters. Finding the precise values for all dimensions, including the capacitor setting, will likely be somewhat more finicky for a wire-base dipole than for a tube-based dipole.

By the terms of our project, we are looking for dimensions that will produce 50-Ohm coverage on both 20 and 15 meters with less than a 2:1 SWR. (Indeed, if we forget this project specification, we might as well use a simple wire with a parallel feedline and an antenna tuner.) As we did for the fat-element models, we shall freeze some dimensions and vary others to obtain a sense of the trends at work.

Varying the Resonator Rod Length

The first set of tests will use AWG #8 wire throughout. A simple dipole for 14.175 MHz would normally require a length of about 403". One feature that we shall look for is the amount of reduction that the use of a linear resonator forces on the overall element length. With the tubular models, we found a usable constant main-element length that was about 14" or 3.5% shorter than a self-resonant 20-meter dipole. Shifting to wire does not change the level of reduction, but it does introduce a new factor into the building equation. Changing the length of the resonator also requires a change in the length of the main element. For every 4" decrease in resonator rod length, we find a 2" increase in the main element length.

As shown by the data in **Table 1**, the survey covers rod lengths from 92" to 108". At the same time, the main element changes from 390" to 382". The range of resonating capacitance for the entire spread is about 3 pF--from 18 to 21 pF. The average value is itself about 3-pF higher than the average value needed for the tubular models of Part 1.

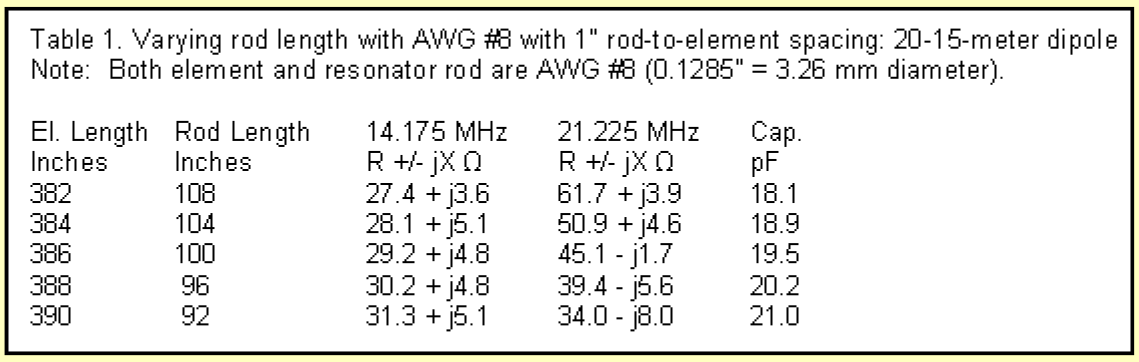
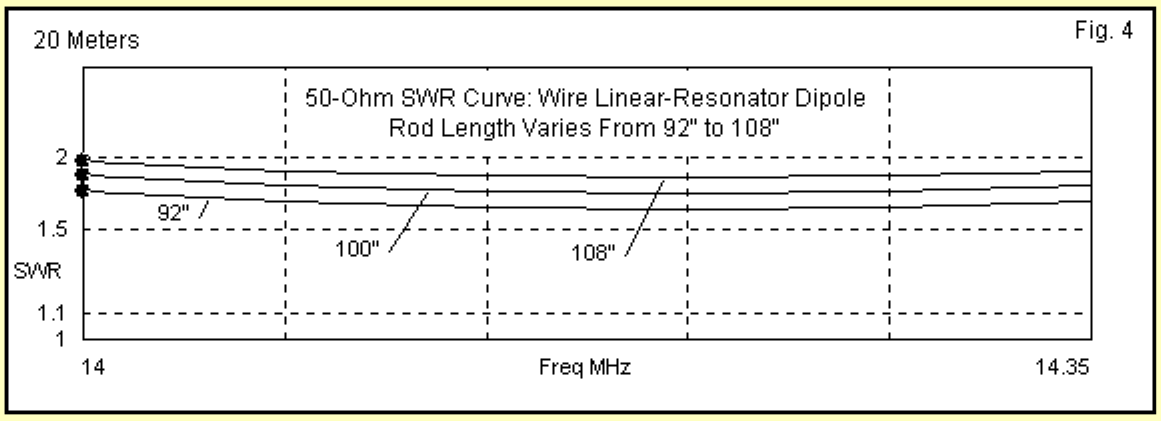


Table 1. Varying rod length with AWG #8 with 1" rod-to-element spacing: 20-15-meter dipole
Note: Both element and resonator rod are AWG #8 (0.1285" = 3.26 mm diameter).

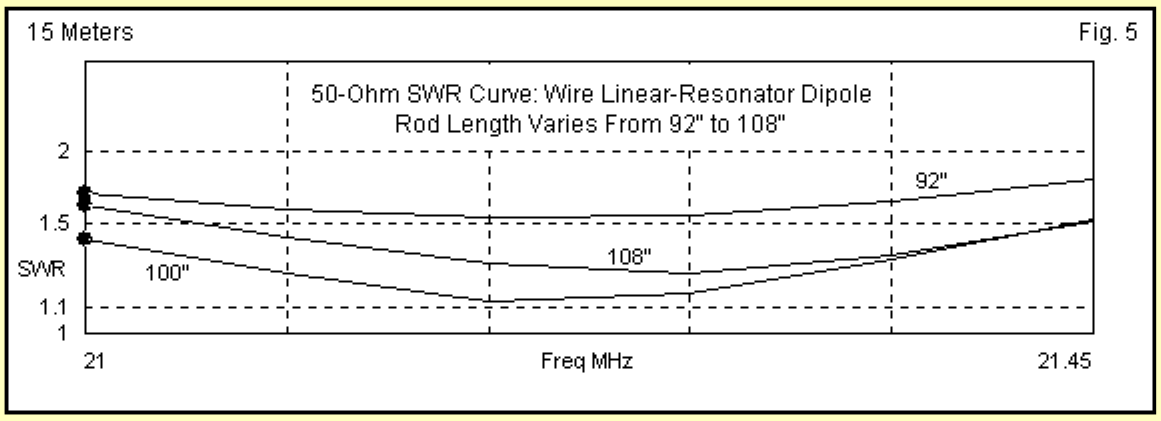
El. Length Inches	Rod Length Inches	14.175 MHz R +/- jX Ω	21.225 MHz R +/- jX Ω	Cap. pF
382	108	27.4 + j3.6	61.7 + j3.9	18.1
384	104	28.1 + j5.1	50.9 + j4.6	18.9
386	100	29.2 + j4.8	45.1 - j1.7	19.5
388	96	30.2 + j4.8	39.4 - j5.6	20.2
390	92	31.3 + j5.1	34.0 - j8.0	21.0

We have already viewed a wide-band SWR sweep for a typical dipole from the group. In fact, that sweep used the version with a 100" rod and a 386" main element. We may therefore confine our examination of 50-Ohm SWR values to the specific operating bands. The impedance values at 14.175 MHz give us an additional reason for taking a close look at the in-band SWR values. As we reduced the element sizes in Part 1, we saw a decrease in the 20-meter resistive impedance. We also wondered at what rate the impedance would continue to decrease as we reduced the element size further. At some diameter, the impedance might slip below 25 Ohms, removing all hope of obtaining 20-meter performance with less than a 2:1 50-Ohm SWR. As the mid-band impedance values show, we are getting close.



Using AWG #8 wire allows us to obtain a barely usable SWR curve across 20 meters. The shorter the resonator rod (and the longer the main element), the better SWR curve that we obtain. Unlike the tubular elements, the wire elements required that we adjust both the main element and the rod lengths to arrive at this result.

The corresponding SWR curves for 15 meters appear in **Fig. 5**. On this band we face a different challenge created by the increasingly narrow-banded performance of thinner elements. Between rod-length increment changes, the mid-band impedance on 15 meters changes more rapidly, and this factor limits our ability to obtain a satisfactory SWR curve.



The 92" resonator rod that gave us the best 20-meter SWR curve produces the least satisfactory SWR curve on 15 meters--although the performance is usable. As the rod length increases, the SWR curve tends to improve, at least through the 100" length. Further increases in rod length degrade the SWR curve. Nevertheless, all of the 15-meter curves within the set are usable. In general, 15-meter performance is less problematical than 20-meter performance with a wire-based dual-band dipole.

Varying the Rod-to-Element Spacing

For further tests, I selected the model that used a 100" rod and a 386" main-element length as perhaps (but not absolutely) the best compromise in performance on both bands. The next test involves seeing what happens as we increase the spacing in small increments from the 1" initial value. (I judged that a smaller spacing is probably not feasible in most practical applications.) In these tests, the wire diameter remains constant (AWG #8). However, all other dimensions of the antenna are allowed to change. **Table 2** shows the results of these modeling tests.

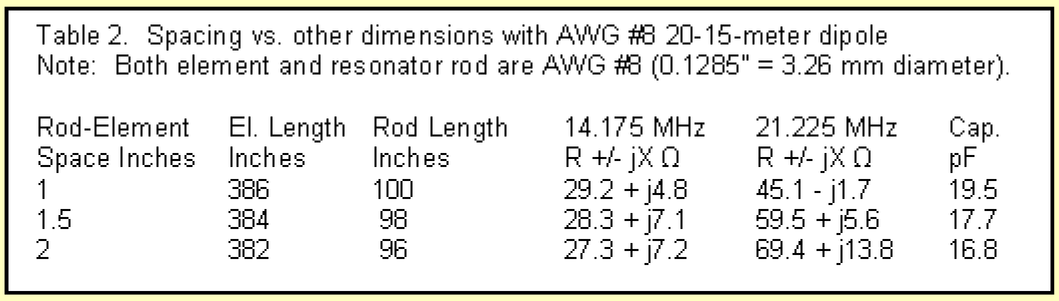
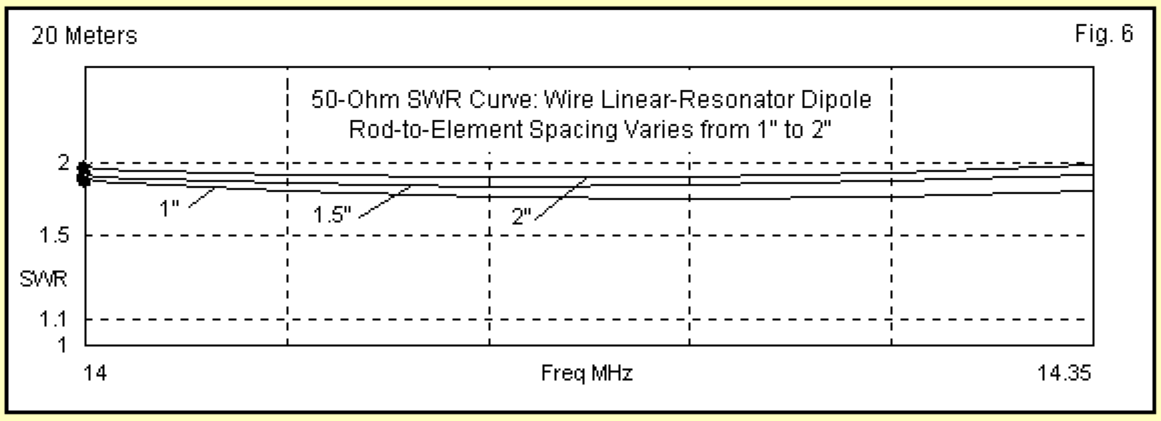


Table 2. Spacing vs. other dimensions with AWG #8 20-15-meter dipole
Note: Both element and resonator rod are AWG #8 (0.1285" = 3.26 mm diameter).

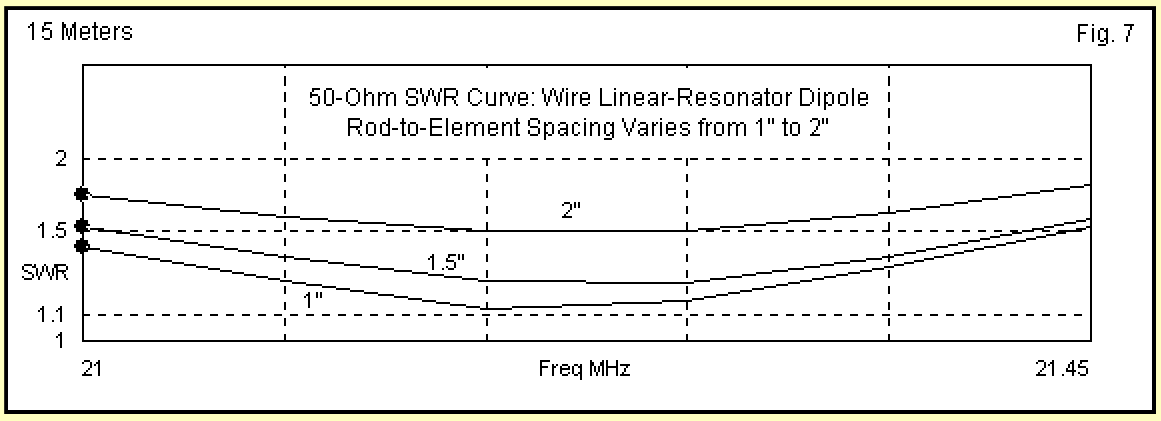
Rod-Element Space Inches	El. Length Inches	Rod Length Inches	14.175 MHz R +/- jX Ω	21.225 MHz R +/- jX Ω	Cap. pF
1	386	100	29.2 + j4.8	45.1 - j1.7	19.5
1.5	384	98	28.3 + j7.1	59.5 + j5.6	17.7
2	382	96	27.3 + j7.2	69.4 + j13.8	16.8

As we increase spacing between the main element and the resonator rod, the required lengths of the main element and of the resonator rod decrease. So too does the required capacitance for the resonator capacitor. (Otherwise expressed, the capacitive reactance increases.) These numbers show the physical demands of increasing the spacing.

The spacing increase also has consequences for the impedances on each band and the resulting SWR performance. **Fig. 6** provides SWR curves for 20 meters.



The mid-band impedance values for 20 meters suggest that the 50-Ohm SWR curve may grow less satisfactory as we increase the spacing between wires. **Fig. 6** confirms the suspicion. Indeed, although the curve for 2" spacing appears barely to meet the standard, it might not be so easy a matter to place that curve precisely when pruning an actual antenna. In general, 20-meter performance depends upon using the narrowest feasible spacing between the resonator and the main element wires.



The 15-meter 50-Ohm SWR curves in **Fig. 7** tell much the same story. As the spacing increases, the SWR curves grow less satisfactory. On 15 meters, the problem is not a decreasing feedpoint impedance. Rather, the problem arises from an increasing resonant impedance. The bottom line for the spacing tests is that a wire-based linear-resonator dipole does not offer the flexibility of fatter elements. Narrow spacing is a requisite on both bands when the frequency ratio is fairly low.

Varying the Wire Size

Admittedly, AWG #8 wire is somewhat impractical for end-supported antennas. In copper, its weight is excessive, and in aluminum, the wire junctions become difficult. I selected #8 because it permitted me to find all of the dimensions required in the model for a successful design using a 1" spacing between wires in the assembly. Whether AWG #8 represents a limit for a practical antenna depends on what we find if we vary the wire size. For this test, I held the spacing constant at 1". As well, I held the rod length to a constant 100" length. I used standard AWG wire gauges from #6 through #12, letting the remaining physical dimensions settle at the most optimal values. **Table 3** shows the results of this test set.

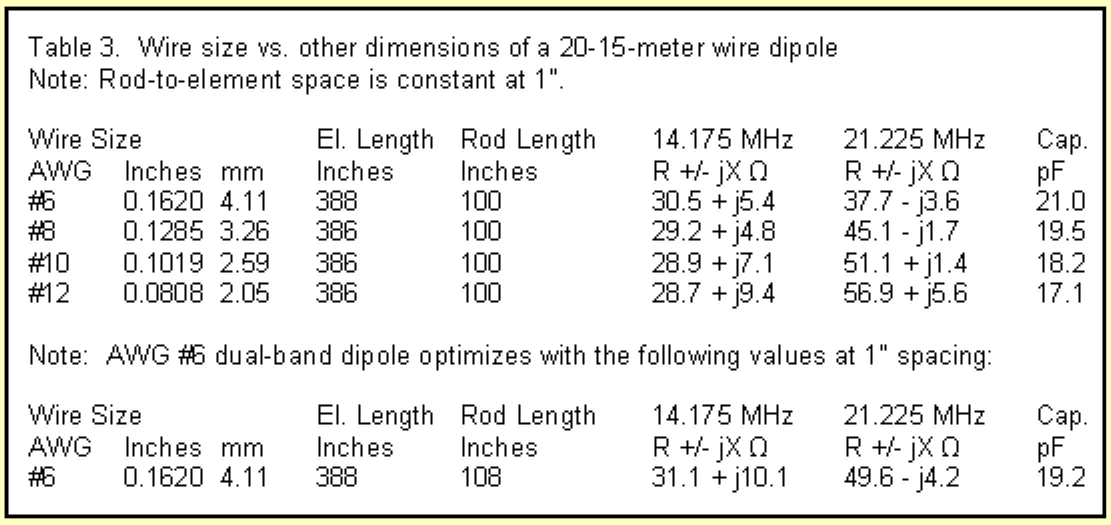


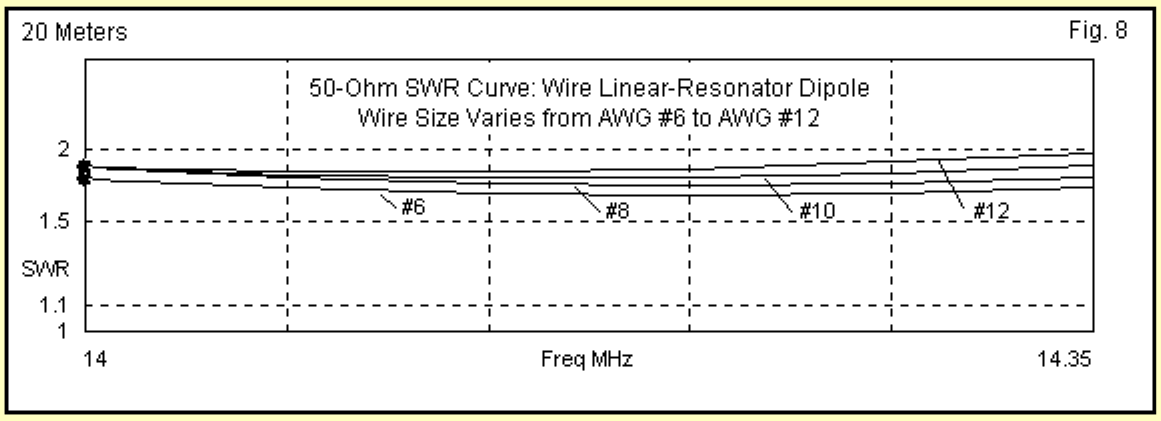
Table 3. Wire size vs. other dimensions of a 20-15-meter wire dipole
Note: Rod-to-element space is constant at 1".

Wire Size AWG	 Inches	 mm	El. Length Inches	Rod Length Inches	14.175 MHz R +/- jX Ω	21.225 MHz R +/- jX Ω	Cap. pF
#6	0.1620	4.11	388	100	30.5 + j5.4	37.7 - j3.6	21.0
#8	0.1285	3.26	386	100	29.2 + j4.8	45.1 - j1.7	19.5
#10	0.1019	2.59	386	100	28.9 + j7.1	51.1 + j1.4	18.2
#12	0.0808	2.05	386	100	28.7 + j9.4	56.9 + j5.6	17.1

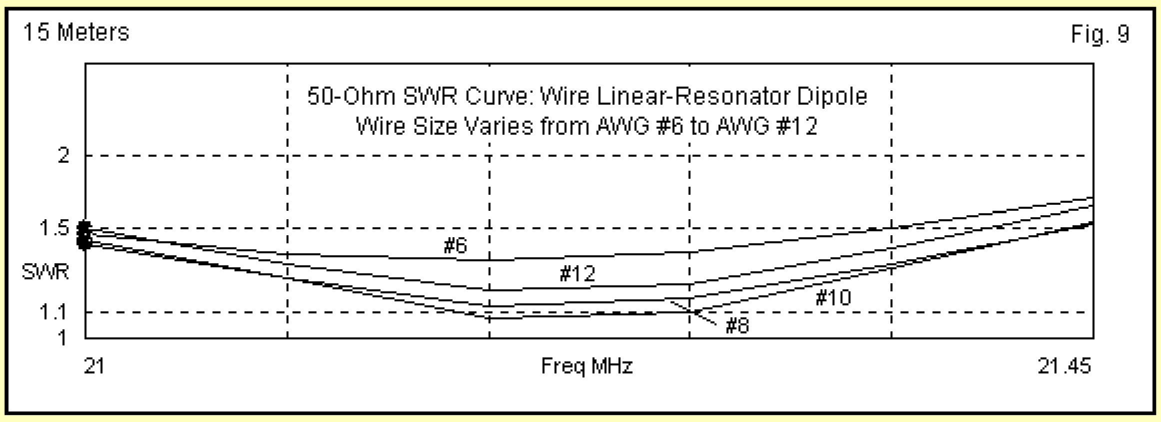
Note: AWG #6 dual-band dipole optimizes with the following values at 1" spacing:

Wire Size AWG	 Inches	 mm	El. Length Inches	Rod Length Inches	14.175 MHz R +/- jX Ω	21.225 MHz R +/- jX Ω	Cap. pF
#6	0.1620	4.11	388	108	31.1 + j10.1	49.6 - j4.2	19.2

The table has a special section noting the most optimal settings for the AWG #6 sample. By increasing the length of the resonator rod 8", we obtain a marginally higher 20-meter impedance. We also obtain a superior 15-meter impedance and a capacitor value that approximates the value used with AWG #8 wire at its optimal resonator rod length. I did not include in the table models for AWG #10 and #12 wire with similar adjustments to the resonator lengths. Each of those models would have required significant resonator-rod shortening to obtain the desired 15-meter results. However, those rod lengths would have produced lower impedances on 20 meters, disallowing the use of the antenna on that band within the project terms of a maximum 2:1 SWR value.



With the values shown in the table, the 20-meter SWR curves become increasingly marginal as we reduce the wire size, as revealed by **Fig. 8**. The major problem of trying to optimize the resonator rod lengths with thinner wire is not so much the mid-band impedance. We likely can find a satisfactory impedance with less than a 2:1 50-Ohm SWR. The major difficulty lies at the band edges, where every reduction in resistance provides the reactance with a proportionately higher influence on the SWR level.



The difficulty does not extend to 15 meters. The SWR curves in **Fig. 9** all fall within the highly acceptable range. The curve for AWG #6 wire is for the model using a 100" resonator rod. With a 108" rod, the curve largely overlaps the curve for AWG #8 wire.

Some Summary Thought for the 20-15-Meter Wire Dipole

Increasing the diameter of the wires in a linear-resonator dipole with a frequency ratio of 1.5:1 between bands is always advisable. The increased diameter of the elements raises the flexibility of the antenna to accept wider spacing. Although I have not modeled such an antenna, one might consider using wire pairs for the main element and the resonator rod to simulate fatter conductors in a wire structure.

The essential difficulty faced by anyone experimenting with a wire version of the 20-15-meter dipole is the impedance on 20 meters. As the wire grows thinner, we require narrower spacing between rod and element wires to prevent the 20-meter impedance from dropping below the critical 25-Ohm value. Thinner wires also reduce the capacitance-per-inch of the rod wires that form a capacitor at the center. Finally, the narrow-band nature of thin wires increases the finickiness of adjustments--and their ability to hold during extremes of weather.

Nevertheless, the intrepid experimenter may wish to see what is possible with wire in a 20-15-meter linear-resonator dipole. To this end, the modeling experiments may serve as a guide. As with all of the modeling experiments, these are not design plans. Rather, they illustrate some of the trends in operation for a linear-resonator dipole with a small frequency ratio.

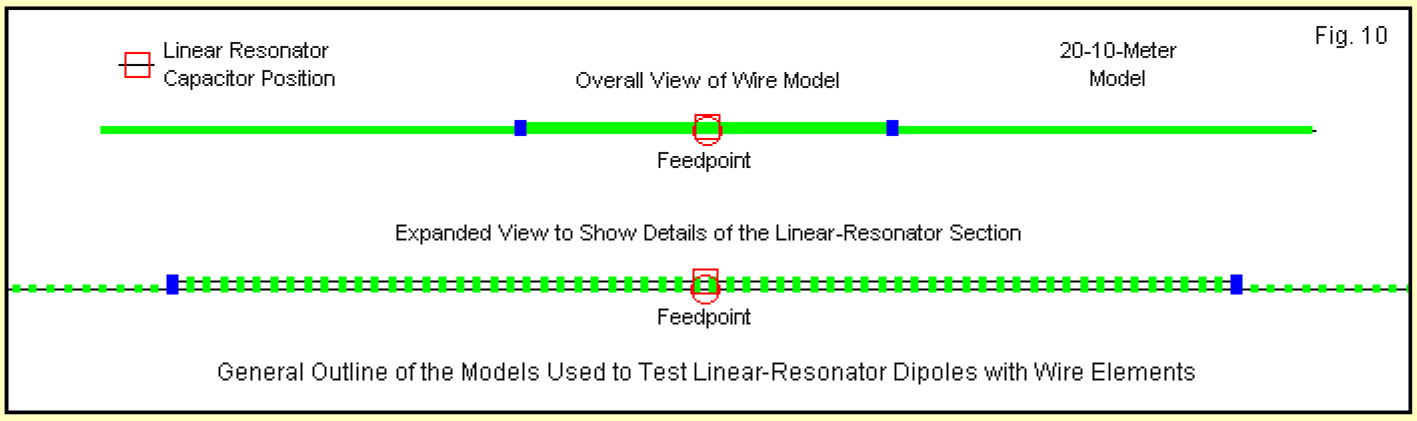
A 20-10-Meter Wire Linear-Resonator Dipole

In Part 2, we examined a fat-element linear-resonator dipole for 20 and 10 meters. Using a 0.875"-diameter 20-meter dipole and a 0.25"-diameter resonator rod, with a spacing of 6", we obtain some results that reversed the difficulties for the antenna. On 20 meters, the antenna showed a near-50-Ohm impedance that easily yielded excellent SWR curves. However, 10-meters proved more problematical, since we barely obtained full-band coverage, even reducing the band to the first MHz.

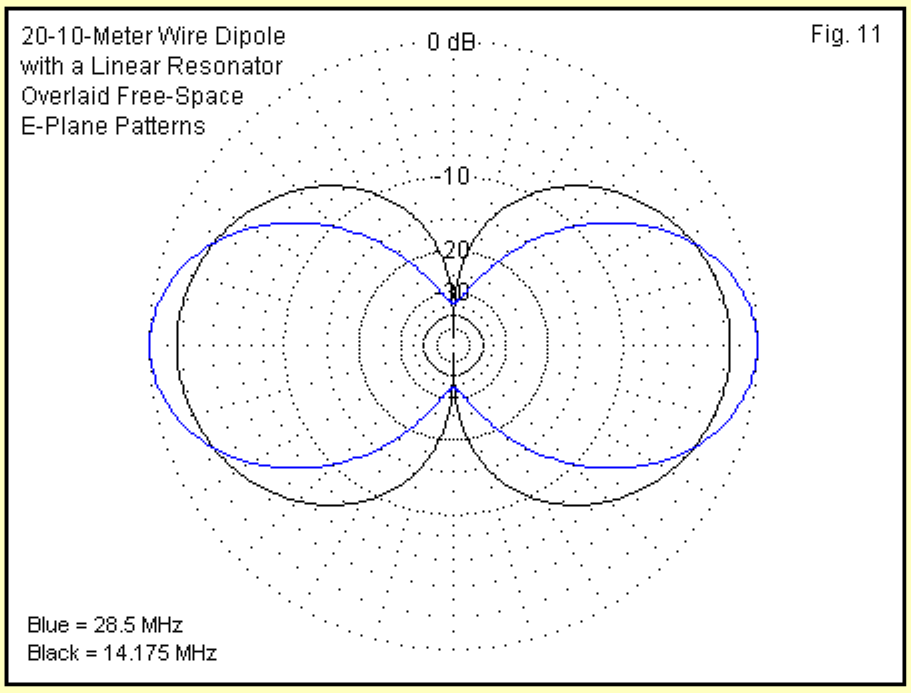
When we reduce the elements to wire size, two major questions confront us. First, will the 20-meter operation continue to show near-50-Ohm impedance values? Second, will the narrow-band properties of thinner wires result in reduced 10-meter coverage?

Interestingly, some of the difficulties that we experienced with the 20-15 combination do not reappear with the 20-10-meter version. For example, as subsequent tables will show, an AWG #8 wire settles in at 392" long for all cases. The presence of the linear resonator section does result in a shorter 20-meter antenna than we find with a simple 20-meter dipole (392" vs. 403"). However, variations in the resonator rod length and the spacing have very little affect on the overall element length, since the second frequency is so far removed from the first. As well, the 20-10 version is an average of about 3" longer than the 20-15 combination.

Like the 20-15 antenna, the 20-10 dipole requires increased segmentation to handle the 1" spacing between the element and the resonator rod. **Fig. 10** shows both the overall structure and an expanded view of the linear resonator area of the model used. The segmentation detail differs slightly from the earlier model, since the 10-meter linear resonator sections are longer than those used to cover 15 meters. Nevertheless, the AGT scores of the antennas for both bands are very similar.



Just because we have reduced the element diameter and the spacing between wires, we do not lose the radical difference between the patterns for 20 and 10 meters. **Fig. 11** shows overlaid free-space E-plane patterns for 14.175 MHz and 28.5 MHz using a typical AWG #8 wire antenna. The 10-meter pattern has a 1.6-dB gain advantage over the 20-meter pattern, with a corresponding reduction in beamwidth.



Like the 20-15-meter antenna, the reduced spacing between wires yields a much smaller differential in gain in the plane of the resonator on the higher band. The difference is only 0.1 dB. As well, the 10-meter front-to-side ratio is nearly 34 dB, a considerable improvement over the models using fatter elements.

In concert with the 20-15-meter wire antenna, the 20-10 wire model shows a much higher 50-Ohm SWR peak value between operating frequencies than did the fat-element antenna for the same coverage. **Fig. 12** provides a wide-frequency sweep (13-30 MHz) to show the overall performance tendency.

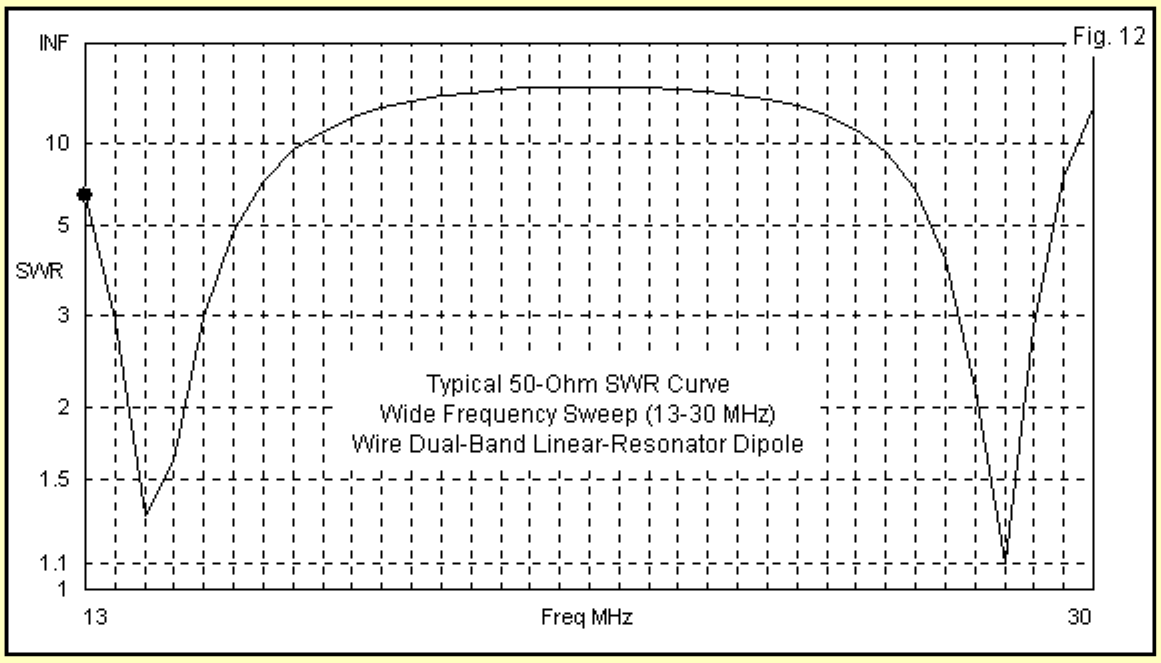


Fig. 12

The peak 50-Ohm SWR value approaches 25:1 in the middle region of the plot, nearly twice as high as the peak value for the antenna with a 7/8"-diameter element. The increased peak 50-Ohm SWR value suggests that the operating bandwidth as defined by a 2:1 SWR maximum value may be reduced relative to either the wire 20-15 model or the fat-element 20-10 model.

Even though some dimensions of the wire 20-10-meter dipole may remain stable, the data to follow will have the same form as used with the 20-15 antenna. Except for the spacing test, the models will use a 1" uniform spacing between the main element and the resonator rod. I shall allow all other dimensions to settle to their near-optimum values.

Varying the Resonator Rod Length

The initial test involves finding the resonator rod length and the corresponding capacitor value that most closely approaches perfection on both bands, as determined by the SWR curves. In fact, I found no significant reason to vary the main element from 392" in the entire set of test runs. The 10-meter resonator rods average about 20" longer than the rods required by the 20-15 wire model. **Table 4** shows the results for varying the rod length from 112" up to 124".

Table 4. Varying rod length with AWG #8 with 1" rod-to-element spacing: 20-10-meter dipole
Note: Both element and resonator rod are AWG #8 (0.1285" = 3.26 mm diameter).

El. Length	Rod Length	14.175 MHz	28.5 MHz	Cap.
Inches	Inches	R +/- jX Ω	R +/- jX Ω	pF
392	112	48.5 + j3.6	64.9 + j15.0	5.2
392	116	48.7 + j5.1	56.1 + j16.1	5.6
392	120	49.0 + j0.4	51.7 + j4.4	5.9
392	124	49.1 - j1.8	45.7 + j2.6	6.3
392	128	49.4 - j4.1	40.8 - j0.8	6.7

The table shows mid-band impedances for 20 meters that are very close to those found in fat-element models. For the larger frequency ratio in this antenna, we may obtain a nearly ideal impedance at the middle of 20 meters. As the band-specific SWR curve in **Fig. 13** reveals, 20-meter SWR is not a significant concern, despite the use of thin elements. The lowest SWR shifts position as we change the length of the resonator rod, but never enough to elevate the SWR to 1.5:1 at the band edges.

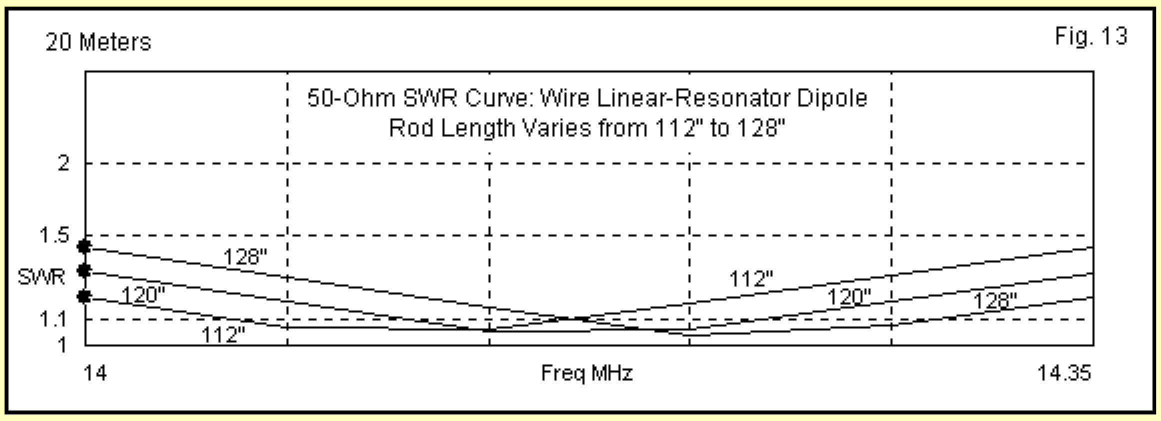


Fig. 13

As we change the length of the resonator rod, the required capacitance varies over a narrow range from 5.6 to 6.7 pF. This range is very comparable to the range for the fatter model in Part 2 (4.9-6.0 pF). However, the resonator rod ranges differ: 100"-112" for the earlier model and 112" to 124" for the current wire model. Some of that difference results from the longer main element length of the wire model (392") over the 7/8"-diameter model (385").

As we suspected, the use of thinner wire elements results in narrower coverage on 10 meters. **Fig. 14** shows the 50-Ohm SWR curves for several of the rod lengths sampled.

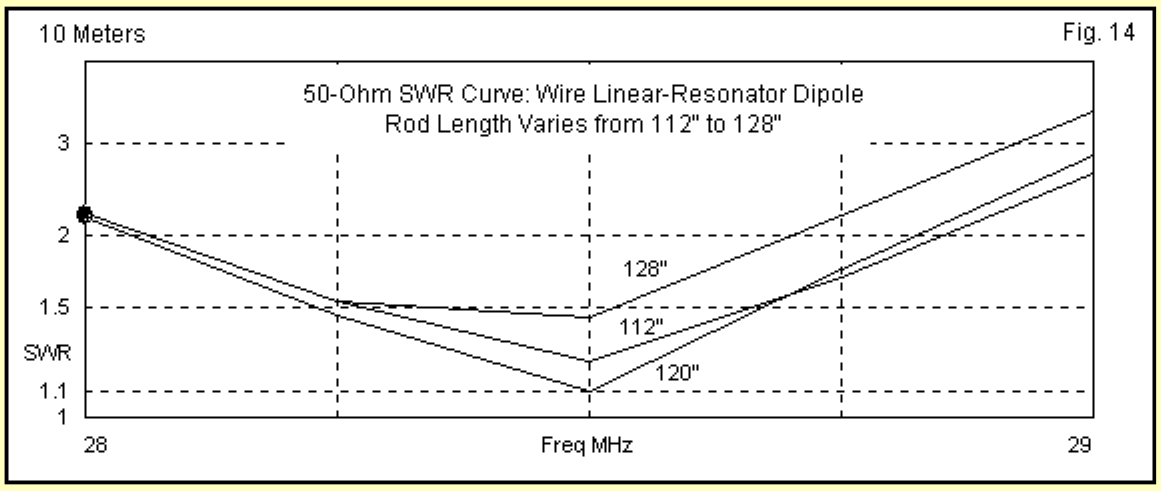


Fig. 14

All of the curves show just above a 2:1 SWR at 28 MHz. However, only the shorter rod lengths provide coverage as high as 28.7 MHz with a 2:1 SWR. The mid-band impedance values in **Table 4** do not themselves reveal the more rapid change of impedance for each small frequency increment, relative to the fat-element models that allowed coverage of a full MHz of the band. One of the limitations of the 20-10 thin-wire model, then, is reduced upper-band coverage.

Varying the Rod-to-Element Spacing

In concert with the 20-15-meter wire model, I varied the spacing between the main element and the resonator rod in half-inch increments between 1" and 2". The baseline model used a 120" resonator rod with 1" spacing. I allowed the dimensions to settle at the most desirable values for each spacing increment. **Table 5** shows the results of this small experiment.

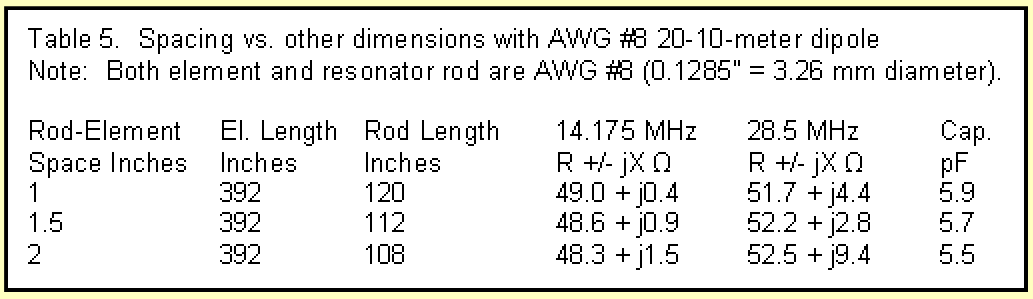


Table 5. Spacing vs. other dimensions with AWG #8 20-10-meter dipole
Note: Both element and resonator rod are AWG #8 (0.1285" = 3.26 mm diameter).

Rod-Element Space Inches	El. Length Inches	Rod Length Inches	14.175 MHz R +/- jX Ω	28.5 MHz R +/- jX Ω	Cap. pF
1	392	120	49.0 + j0.4	51.7 + j4.4	5.9
1.5	392	112	48.6 + j0.9	52.2 + j2.8	5.7
2	392	108	48.3 + j1.5	52.5 + j9.4	5.5

In all cases, the main element held its length. The 20-meter mid-band impedance does show a small decline as we increase the spacing. However, the decrease is in no way fatal to the SWR curves, which appear in **Fig. 15**. In fact, I have not identified the curves individually, since they form too tight a group to distinguish individual lines.

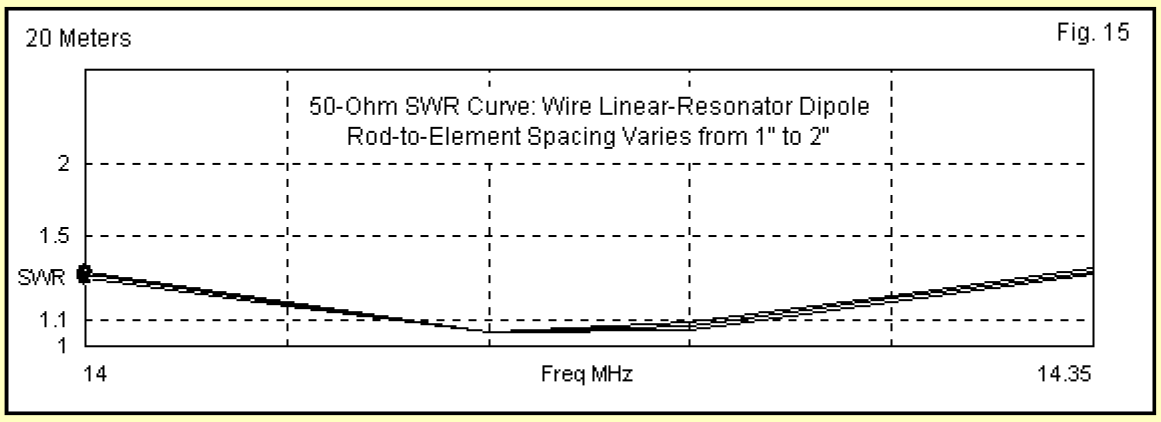


Fig. 15

The data show that as we increase the spacing, we must reduce the length of the resonator rod in order end up with a near-50-Ohm impedance at 28.5 MHz. The required capacitance also goes down with increased spacing (indicating an increase in capacitive reactance). The effects of these changes on the SWR curves for 10 meters appear in **Fig. 16**.

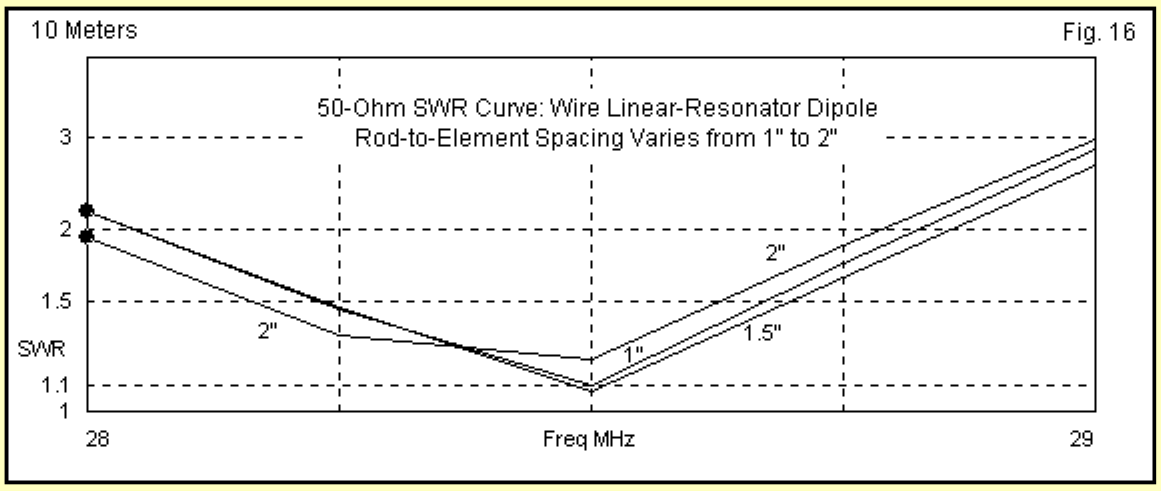


Fig. 16

The curves do not show any significant difference of bandwidth, although increased spacing does appear to have a small advantage over narrow spacing. However, increased spacing does require a lower capacitance value and may prove harder to adjust to perfection. The displacement of the curve for a 2" space results from my restriction of capacitance increments to 0.1 pF. Linear adjustment of parallel or side-by-side rods used to implement the resonator capacitor might make finer adjustment feasible, but difficult to hold as the weather changes from summer to winter and back gain.

Due to the ever-lower value of required capacitance, I limited the test range to a maximum spacing of 2". In terms of raw impedance values, we might in theory continue the progression, since the 20-meter impedance changes very slowly and increased spacing may yield wider 10-meter operating bandwidths. At a rate of about 0.4-pF-per-inch of spacing, it is doubtful that the spacing could reasonably approach the 6" value used for the fat-element models.

Varying the Wire Size

Despite the narrower coverage of 10 meters, the use of thinner wire may be feasible for frequency ratios in the 2:1 range. The chief obstacle to using thinner wire for the wire 20-15 combination was the reduced 20-meter impedance as the wire grew thinner. The models that we have surveyed so far for 20 and 10 meters suggest that this problem will not occur. Therefore, I surveyed wires sizes from AWG #6 to AWG #12 using the 1" spacing and letting all other values settle to their optimal levels. The results appear in **Table 6**. We may initially note that by letting each resonator rod settle at its most perfect length, we obtain tuning capacitance values that vary over a very small range.

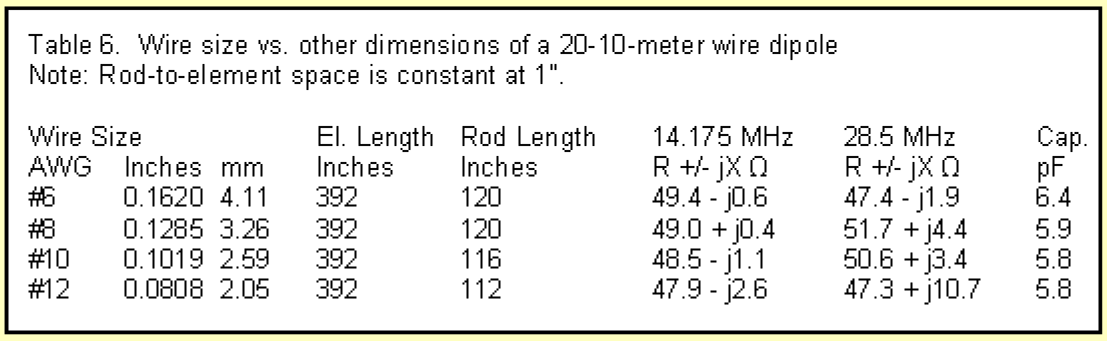
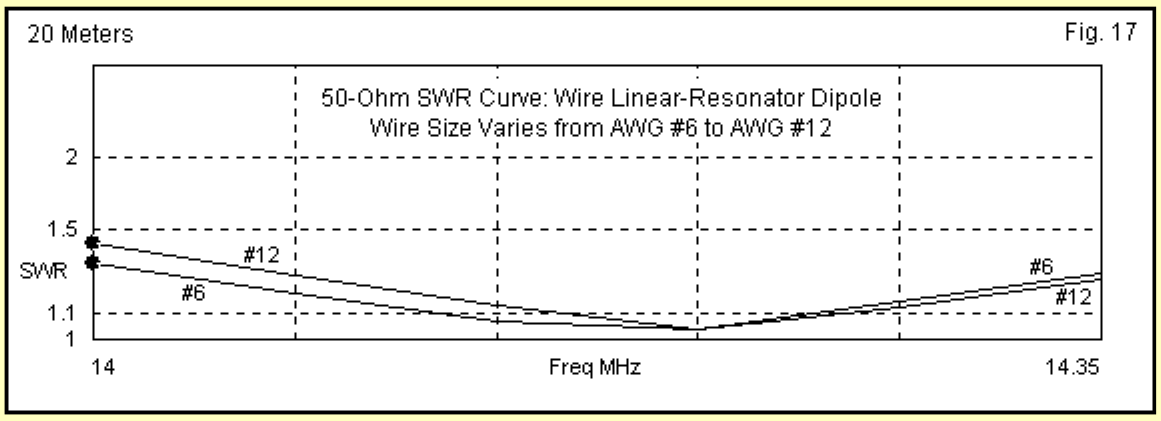


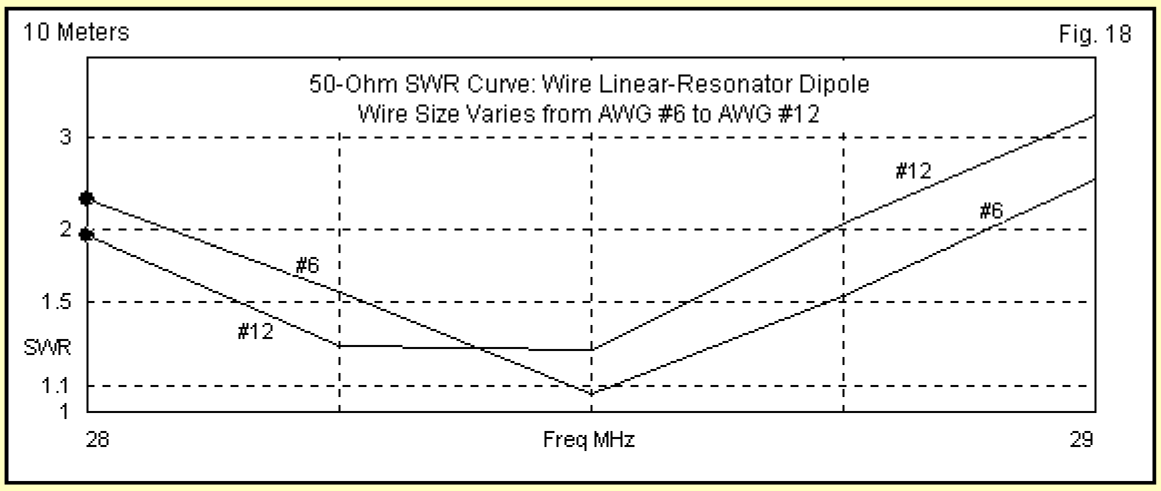
Table 6. Wire size vs. other dimensions of a 20-10-meter wire dipole
Note: Rod-to-element space is constant at 1".

Wire Size AWG	 Inches	 mm	El. Length Inches	Rod Length Inches	14.175 MHz R +/- jX Ω	28.5 MHz R +/- jX Ω	Cap. pF
#6	0.1620	4.11	392	120	49.4 - j0.6	47.4 - j1.9	6.4
#8	0.1285	3.26	392	120	49.0 + j0.4	51.7 + j4.4	5.9
#10	0.1019	2.59	392	116	48.5 - j1.1	50.6 + j3.4	5.8
#12	0.0808	2.05	392	112	47.9 - j2.6	47.3 + j10.7	5.8

All models in the set required no alteration in overall length. With the 392" main element length and resonator rods suited to the 10-meter requirements, the mid-band 20-meter impedance decreases quite slowly as we thin the wire to AWG #12. **Fig. 17** shows the resulting 20-meter 50-Ohm SWR curves for AWG #6 and AWG #12 wire. Although these curves are distinguishable, adding the other two wire sizes would have created a fat blurry line. As the curves make clear, the 50-Ohm SWR is always less than 1.5"1 across the 20-meter band with any of the wire sizes.



The situation differs a bit on 10 meters. Due to the use of a 0.1-pF increment in the tuning capacitance, the SWR curves for 10-meters do not overlay each other as neatly as they do in 20 meters. Hence, the curves in **Fig. 18** require a bit of interpretation. Essentially, at the 2:1 SWR crossing points, the AWG #12 curve is only about 93% of the width of the curve for AWG #6 wire, despite the 2:1 ratio of wire diameters. The difference amounts to about 50 kHz (750 kHz vs. 800 kHz--approximately).



Although the use of AWG #12 wire is not fatal to the construction of a 20-10 combination with 1" element-to-rod spacing, the narrower operating bandwidth will make antenna adjustment more difficult. As well, as we increase the diameter of the element, we also gain some flexibility in selecting the rod-to-element spacing. Nevertheless, for any size element, the most difficult adjustment to master and to make endure through all kinds of weather will be the capacitance.

Conclusion

In this final section of our work, we have established that wire-based dual-band linear-resonator dipoles are feasible if we are willing to observe some restrictions. Foremost among the limitations is the need for close spacing of the resonator rod and the main element. Especially for antennas with a lower frequency ratio, such as 1.5:1, the close spacing is necessary to achieve even a usable impedance on the lower band--using 50 Ohms as the standard. Close spacing is not quite as necessary where the frequency ratio is higher, such as 2:1, but wider spacing does reduce the required capacitance to a level at which stability may become a problem.

The second restriction requires that we use the largest diameter wire feasible. For lower frequency ratios, thin wire may reduce the low-band impedance below the acceptable level. Again, high frequency ratios are less of a problem on the lower band, but thinner wire tends to reduce the upper band operating bandwidth.

Wire versions of linear-resonator dual-band antennas also suffer from some finickiness of tuning, since virtually no dimension is fixed. Hence, adjustments to the resonator-rod length may affect the overall main element length. This potential difficulty is especially apparent with lower frequency ratios.

Perhaps the most difficult challenge for linear-resonator antennas using a higher frequency ratio involves the high capacitive reactance and low capacitor value required for precise tuning. Concentric and parallel capacitors formed by the resonator rods and associated materials are subject to linear expansion and contraction as the temperature changes. Replacing a test set-up with a wide-temperature-range fixed capacitor may prove useful in some cases. However, the experimenter must gauge this move against the knowledge that the linear resonator rod itself will change length with frequency.

As we close our look at linear-resonator dipoles, I should again remind you that all of the numbers fall far short of design plans. Rather, they reliably indicate only the trends in values. In an assembly as tricky as a linear-resonator dipole, field experimentation and adjustment must take precedence over NEC modeling results.

Nevertheless, linear resonators are a feasible means of producing a double 50-Ohm resonance from essentially a single element. It may be the case that frequency ratios of 1.7:1 or 1.8:1 produce the most desirable results. The low-band impedance would be less marginal and the high-band operating bandwidth would be more adequate and less finicky to establish. As well, the required tuning capacitance would likely fall around 9-10 pF, a value that might be usable in practice. Combinations for 30 and 17 meters or for 20 and 12 meters fall in this range. In both cases, the upper band is quite narrow, so tuning in one season would not yield an unusable SWR 6 months later.

Whether the linear resonator has applications in multi-element arrays remains in the category of work to be done. The wider we make the frequency ratio, the more that the radiation pattern changes from the lower to the higher frequency. How that change might affect the required dimensions for a multiband array remains to be discovered. For the moment, we may be doing all that we can by digesting the basic properties, potentials, and limitations of linear-resonator dial-band dipoles.

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