Some Notes on Linear Resonators
Part 2: 20-10 and 15-10 Meters

L. B. Cebik, W4RNL (SK)

In Part 1, we examined the fundamentals of linear resonators and then explored their use for 20 and 15 meters with tubular elements for both the main element and the resonator rod. We varied many of the structural variables for the dipole. A 20-meter independent resonant dipole is about 398" long with common tubing sizes and has a feedpoint impedance of about 72 Ohms. The 20-15 dual-band linear-resonator dipole turned out to have a 384" main element to achieve resonance on 20 meters. The 0.25" linear resonator rod spaced 6" from the main element used a length of about 92" with a 16.4 pF capacitor to achieve resonance on 15 meters. We systematically varied most of the individual structural dimensions, but certainly did not cover all possible combinations.

The 20-15-meter dipole shows a 20 meter feedpoint resistance of about 35 Ohms, about half the value for the independent dipole. The resonant impedance on 15 meters varied with the selection of rod length and spacing, as well as the capacitance at the rod center. These values are quite general and not immediately suitable for the construction of a linear-resonator dual-band dipole because the study used NEC-4, which shows a small but significant offset in reported values due to the junction of wires having different diameters. However, we were largely interested in the trends that might prove useful to the experimenter. Changing the main element and the resonator rod had only small effects. The main variables turned out to be the rod length and its spacing from the main element. As we increased the rod length, the required capacitance for 15-meter resonance decreased (and the capacitor's reactance increased). As we widened the spacing between the main element and the resonator rod, the required capacitance decreased (and its reactance increased). Although we encountered at least one case in which we could not find a workable combination of resonator rod length and spacing that would provide a usable passband on 15 meters, most of the variations were usable, with only a preference for a 50-Ohm impedance on 15 meters to determine the "best" dimensions. In virtually all cases, the 20-meter impedance remained relatively stable throughout the range of variations.

We also discovered that the radiation patterns at the two frequencies are not identical. While the lower band provides a typical dipole figure-8 pattern, the upper band shows higher gain with a narrower beamwidth. The change in pattern shape results from the fact that on the upper band, the element is longer than 1/2-wavelength. The use of a linear radiator does not void the pattern changes that occur as center-fed elements exceed 1/2-wavelength.

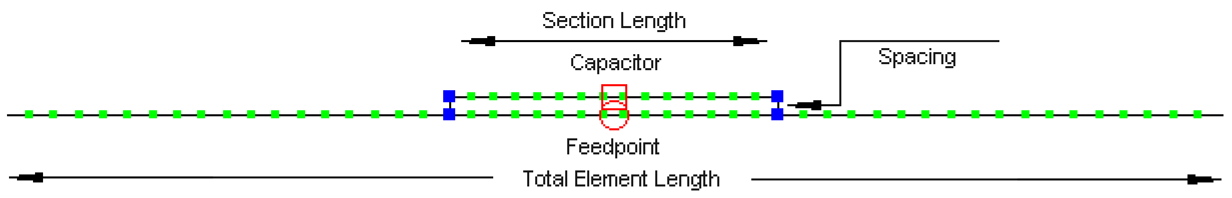
As our starting point, we used the combination of 20 and 15 meters, perhaps the most common application of linear-resonator techniques. The 1.5:1 frequency ratio is above the commonly believed 1.4:1 lower limit of linear resonator use. Whether the 1.4:1 limit (based on Moxon's citation of the square root of 2 in one of his notes on the subject) is absolute or not forms one of the questions that remain for us to explore. At the other end of the scale, we should also see what happens to linear resonators when we use a wider frequency ratio--perhaps 2:1.

In this part of our exploration of linear resonators, we shall look at the wider frequency ratio using the combination of 20 and 10 meters. We shall also press the lower limit by seeing if we can develop a dual-band linear-resonator dipole for 15 and 10 meters. To be consistent with the work in the first part, we shall continue to use tubular elements.

A 20-10-Meter Dual-Band Linear-Resonator Dipole

Fig. 1 shows the general model used for the examination of a wider frequency spread. Compared to the earlier models, the new one uses fewer segments in the center section, because it is shorter. The goal is to maintain as closely as possible the same segment length between the end sections and the center section of the main element. We shall continue to use NEC-4 models. In fact, the 20-10-meter antenna showed an average gain test (AGT) score of 0.986 on the lower band and 1.007 on the upper band. Both values are closer to the ideal (1.000) than we found when using the 20-15-meter model.

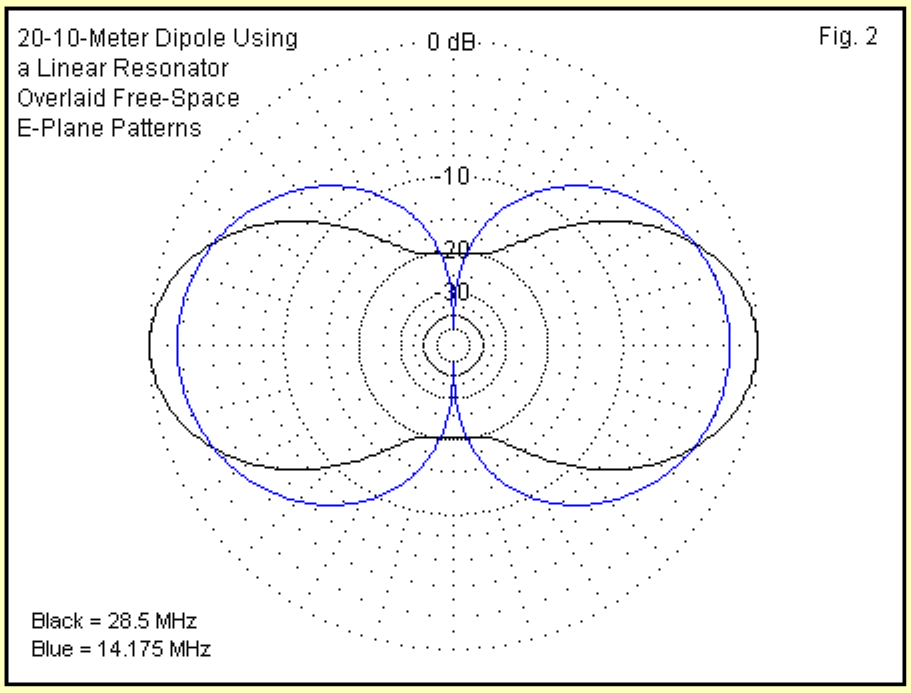
Fig. 1



Basic Model of a Dipole for 20 Meters with a Linear Resonator for 10 Meters

The 20-meter or main element uses 0.875" diameter tubing. The resonator rod and its 6" connections to the main element are 0.25" in diameter. The first change to note is that the 20-10-meter combination requires a 1" increase in the length of the main element (from 384" to 385") to achieve resonance on 20 meters. The change is small but not insignificant. Wider frequency separations require longer main elements for a constant lower band.

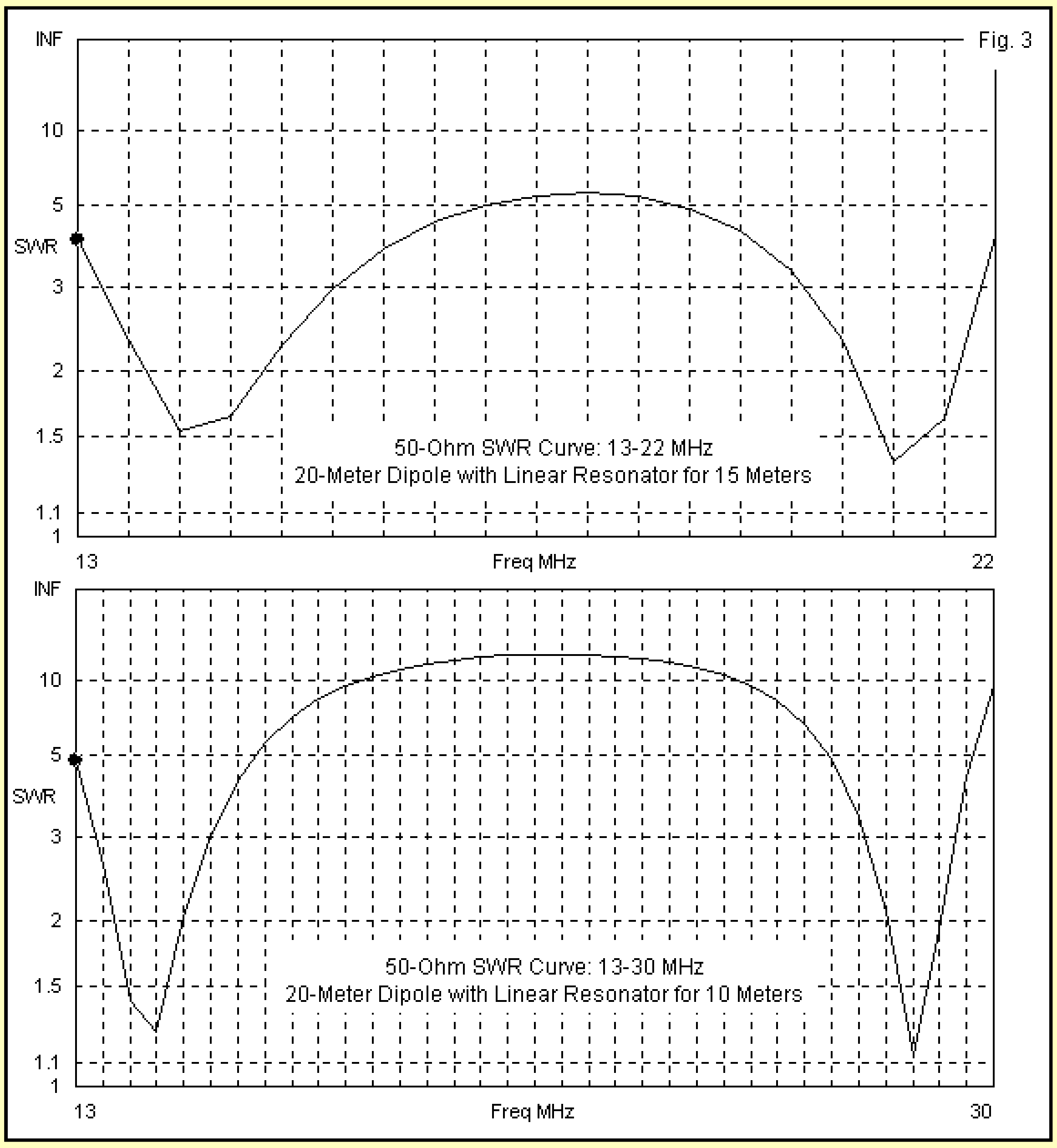
The second change involves the radiation patterns. **Fig. 2** overlays the free-space E-plane patterns for 20 and 15 meters for one of the models in the total set. In fact, the new dipole parallels the ones used in earlier notes in that the gain on both bands does not change by even 0.1-dB as we vary the important physical dimensions. However, the two patterns depart from one another due to the increased length of the element at 10 meters as a function of what we expect from a 1/2-wavelength dipole. The antenna length at 10 meters is nearly a full wavelength, and the pattern shows further increases in gain and beamwidth narrowing that we expect from antennas nearing that length.



If you look careful at the overlaid patterns in **Fig. 3** of Part 1, you will see that the side null depth on 15 meters is not as great as on 20 meters. The 10-meter pattern continues this trend and shows even shallower side nulls that are only about 20-dB below the maximum gain level. (On the 20-15-meter models, the side null depth at 21.225 MHz was about 25 dB.)

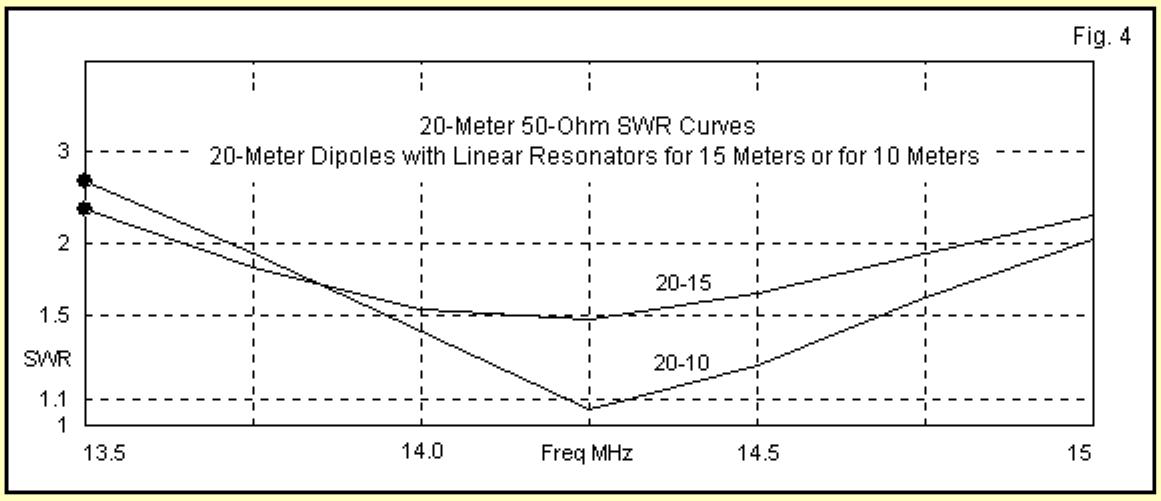
The resonator rod assembly, including its 6" connecting rods, is an appreciable structure. As such, it adds a small H-plane component to the radiation pattern that accounts for the shallower side nulls at the upper frequency. In the models, all resonator-rod assemblies are "above" the main element relative to the plane of the radiation patterns shown. Had we taken the pattern on a plane through the main element and the resonator rod, we would discover a small directional affect. The pattern would show on the upper band a slight offset with higher gain in the direction of the resonator rod. The 20-15-meter combination shows a 0.5-dB front-to-back ratio on 15 meters. The 20-10-meter combination has a 0.6-dB front-to-back ratio on 10 meters. Remember from our basic discussion of dual-band linear-resonator dipoles that the current on the resonator rod at the upper frequency is very high--higher even than the current on the main element in the same region. Hence, on the upper band, the resonator rod contributes to the radiation pattern shape and strength. In contrast, on the lower band, the resonator-rod current is quite low. In fact, it distorts the expected dipole pattern by well under 0.1 dB and yields side nulls that are greater than 40 dB.

The third major change between the 20-15-meter and the 20-10-meter dual-band dipoles is the wide-band SWR curve. We shall continue to use a 50-Ohm standard. As shown in **Fig. 3**, the wider frequency span between the two design frequencies allows the 50-Ohm SWR to climb to very high values before it decreases as we approach the new upper band.



The graphs both begin at 13 MHz, but they terminate separately. The 20-15-meter curve just about reaches 6:1 as a maximum value between the dips that mark the usable frequencies. In contrast, the 20-10-meter combination exceeds an SWR value of 11:1 between the dips. As we shall see, the peak SWR value does not have a significant affect on the upper band SWR bandwidth.

However, if we compare the SWR values of both curves near the lower end of the swept passband, we discover the fourth change between the 20-15 and the 20-10 combinations. **Fig. 4** expands the graph by sweeping a narrower frequency range with a smaller increment.



The 20-10 combination shows a lower minimum SWR value that stems from the higher value of the resistive component of the feedpoint impedance on the 20-meter band. The 20-15-meter combination exhibited a resistive impedance value of about 35 Ohms. The 20-10-meter combination has a resistive impedance of about 49 Ohms (consistently for all models in the group). Although this value is over 20 Ohms lower than an independent resonant 20-meter dipole, it does suggest a trend: the wider the frequency spread between the lower and upper frequencies of a linear-resonator dipole, the higher will be the lower-band resistive impedance. We shall have a chance to confirm this trend before we complete this part of our work.

One consequence of the higher low-band impedance is that we may focus our examination on the upper band (10-meters) as we begin to vary the physical dimensions of the new 20-10-meter combination. We learned from our work with the 20-15-meter combination that the rod diameter and the main element diameter have little effect on the required capacitance for a resonant upper band. Therefore, we shall concentrate on the effects of the rod length and the spacing of the rod from the main element as we examine the 20-10-meter combination.

Resonator Rod Length

The 20-10-meter dipole uses a 385" long 0.875" diameter main element. The initial placement of the 0.25" diameter resonator rod is 6" from the main element (measured center-to-center). Within these fixed dimensions, we may use rod length from about 100" to 112" and obtain usable results on 10 meters. Since 10 meters is a very wide HF band, I have let the first MHz of the band (28.0 to 29.0 MHz) serve as the spread for which we shall want to have less than 2:1 50-Ohm SWR. **Table 1** shows the modeling results for changes on resonator rod length in 4" increments.

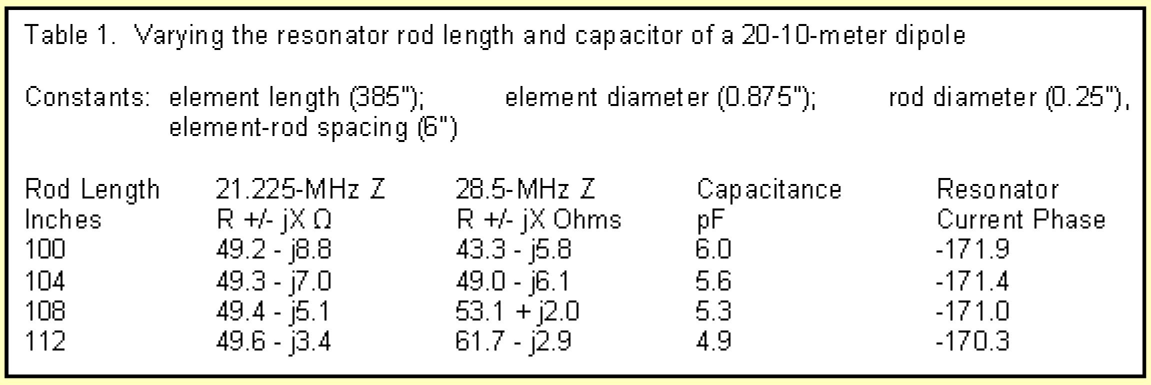


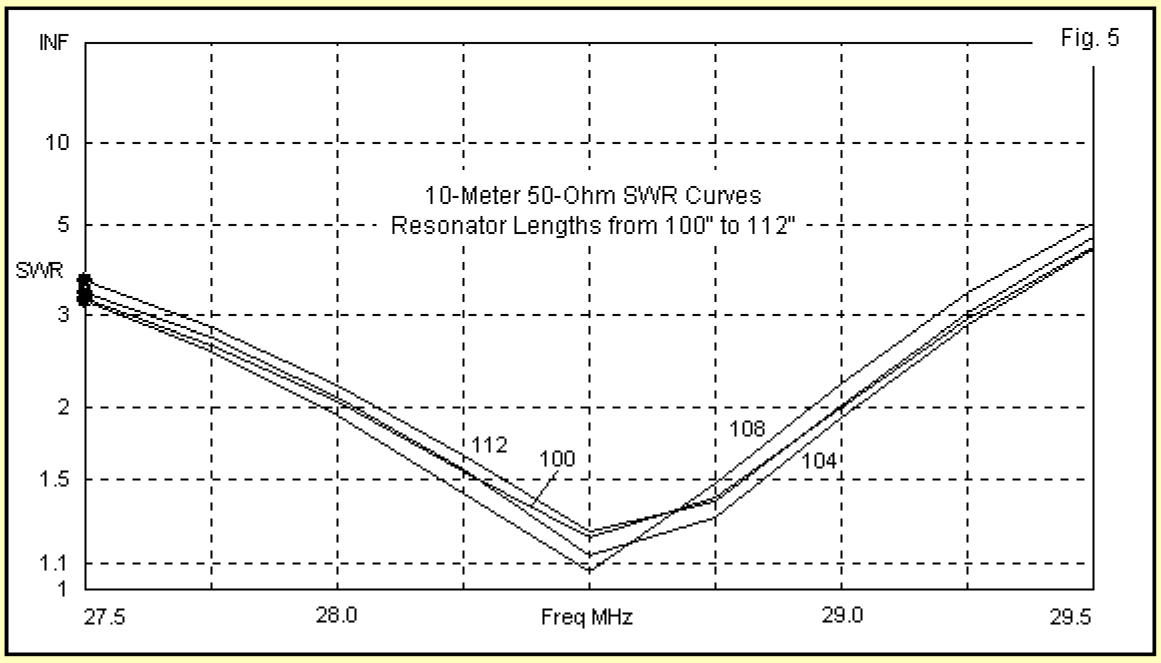
Table 1. Varying the resonator rod length and capacitor of a 20-10-meter dipole

Constants: element length (385"); element diameter (0.875"); rod diameter (0.25"), element-rod spacing (6")

Rod Length Inches	21.225-MHz Z R +/- jX Ω	28.5-MHz Z R +/- jX Ohms	Capacitance pF	Resonator Current Phase
100	49.2 - j8.8	43.3 - j5.8	6.0	-171.9
104	49.3 - j7.0	49.0 - j6.1	5.6	-171.4
108	49.4 - j5.1	53.1 + j2.0	5.3	-171.0
112	49.6 - j3.4	61.7 - j2.9	4.9	-170.3

As expected, the 20-meter (14.175-MHz) impedance values vary only slightly as we change the rod length. Note that the impedance is very close to 50 Ohms due to the wide separation of the two operating ranges. The 10-meter (28.5-MHz) impedance varies more widely across the sampled range of rod lengths. In addition, the range of required resonating capacitance is very small: 4.9 to 6.0 pF. Since the capacitance is very low, a parallel or side-by-side rod arrangement (see Part 1) is likely to allow fine tuning more easily than a concentric capacitor made from a center rod and a surrounding tube.

The 10-meter resonator rod current phase is about 10 degrees closer to being directly out of phase with the feedpoint current (at 0-degrees phase angle) than we found for the 20-15-meter combination. As well, it varies over a small range, as does the reactance at 10 meters. As a result, we can fairly easily (assuming mastery of capacitor adjustment) arrive at an SWR curve that covers nearly the entire first MHz of 10 meters. **Fig. 5** shows the SWR curves between 27.5 and 29.5 MHz to confirm this fact.



The 104" rod produces perhaps the broadest SWR curve, but only by a narrow margin. Obtaining satisfactory 10-meter operation should be fairly straightforward, since the linear resonator may have a variety of lengths and still function effectively. Only the very low value of required tuning capacitance might hinder implementation of the scheme.

Resonator-Rod-to-Element Spacing

Let's select the 104" resonator rod as a prime candidate. As well, we shall retain the 385" long, 0.875" diameter main element, along with the 0.25" diameter resonator rod. With these constant, we may vary the spacing between the rod and the main element in appropriate increments to see what happens to the performance and to the required capacitance for our desired SWR bandwidth. Since 10-meter is a higher frequency than 15 meters, we shall vary the spacing in 1" increments. **Table 2** shows the results of these modeling experiments.

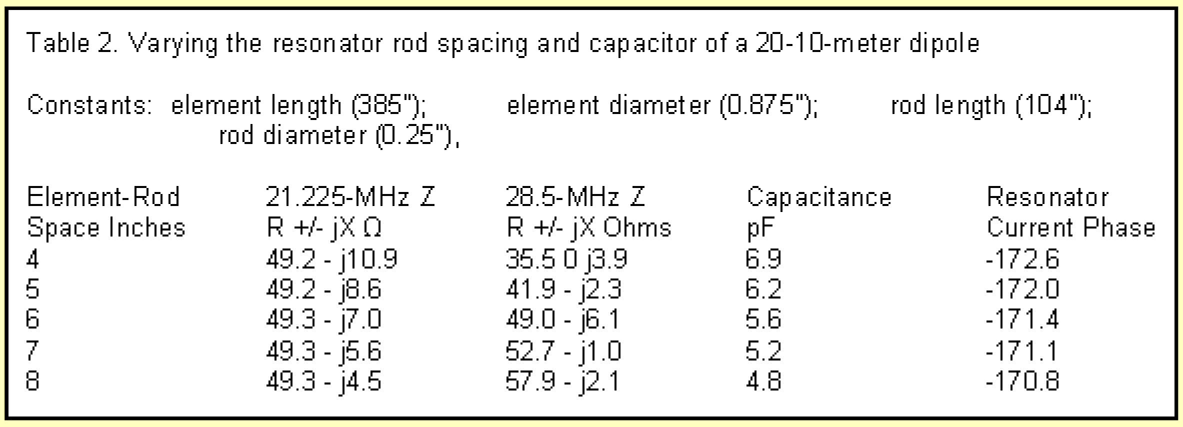


Table 2. Varying the resonator rod spacing and capacitor of a 20-10-meter dipole

Constants: element length (385"); element diameter (0.875"); rod length (104"); rod diameter (0.25"),

Element-Rod Space Inches	21.225-MHz Z R +/- jX Ω	28.5-MHz Z R +/- jX Ohms	Capacitance pF	Resonator Current Phase
4	49.2 - j10.9	35.5 0 j3.9	6.9	-172.6
5	49.2 - j8.6	41.9 - j2.3	6.2	-172.0
6	49.3 - j7.0	49.0 - j6.1	5.6	-171.4
7	49.3 - j5.6	52.7 - j1.0	5.2	-171.1
8	49.3 - j4.5	57.9 - j2.1	4.8	-170.8

Once more, the 20-meter impedance varies over a very small range as we change the rod spacing. At 10 meters, we obtain a wider impedance range and a wider range of required capacitance values. Likewise, the 10-meter resonator current phase also varies over a wider range.

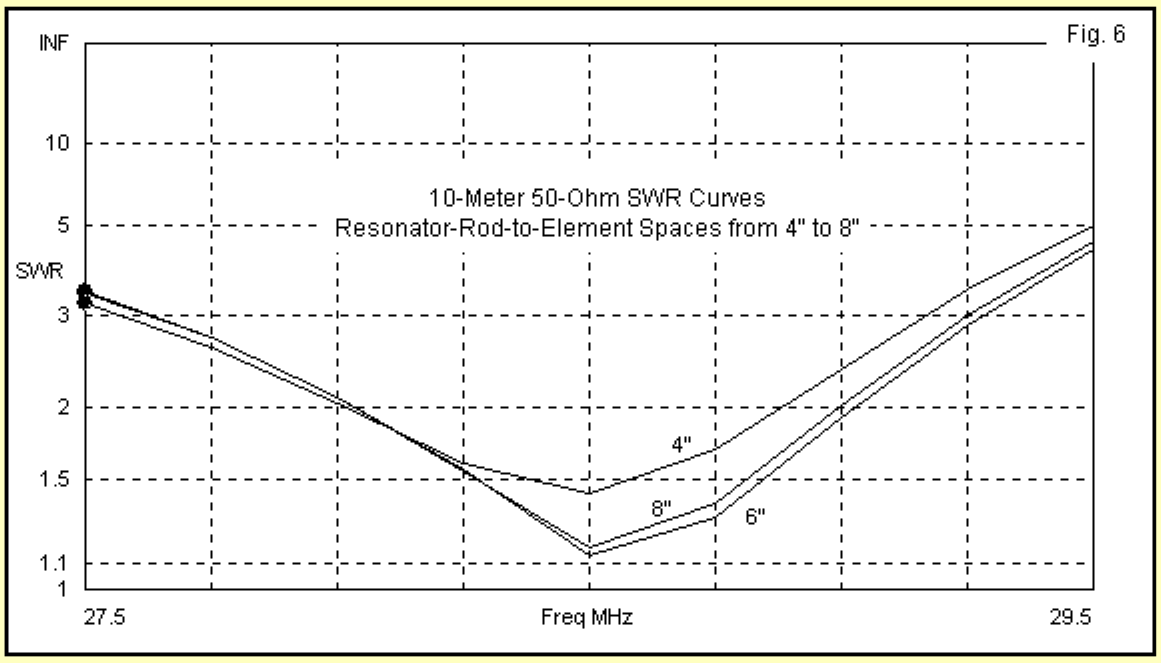


Fig. 6 shows the SWR curves for the center (6") spacing and for the extremes within the set (4" and 8"). Very close spacing limits the SWR bandwidth due to the lower resistive impedance (about 35 Ohms). However, as spacing increases, the rate of 10-meter impedance change slows considerably. Although the 6" spacing shows a marginal improvement over 8", both values are very close to the best that we may obtain.

Once we set up a linear resonator within the proper "ball park," final adjustments--except for the finicky capacitor--are likely to be very easy. The chief initial problem is likely to be estimating what rod length and spacing to use. Although these modeling results are subject to the slightly non-ideal AGT values produced by the NEC-4 models, they may serve to reduce the initial fumbling and frustration in developing a dual-band 20-10-meter linear-resonator dipole--at least of the tubular variety.

A 15-10-Meter Dual-Band Linear-Resonator Dipole

One apparently popular belief about linear resonator dipoles is that we may obtain satisfactory operation only if the frequency ratio between the higher and the lower band is greater than 1.4:1. We may put this idea to a simple test by trying to create a linear-resonator dipole for 15 and 10 meters. Here the frequency ratio is only about 1.3:1. Since the lower frequency is a bit higher than in previous combinations, I have reduced the main element diameter to 0.75". At 21.225, a self-resonant dipole with a 0.75" diameter is about 265". For our trials, we shall have to use a slightly short main element: 262". This main-element length reduction is far less than we needed when working with the 20-15-meter combination. The earlier main element shrank by about 3.5%, while the present reduction is just over 1.1%.

Resonator Rod Length

Since I have fixed the main element, you may assume that the experimental models were successful in obtaining resonance on both 15 and 10 meters (21.225 and 28.5 MHz). The initial resonator rod for tuning to 10 meters used the same 0.25" diameter material and the same 6" spacing that we have used throughout these trials. The next question then is what length must we use for the resonator--and what value of tuning capacitor? **Table 3** shows a range of rod lengths between 42" and 50" and associated capacitor values.

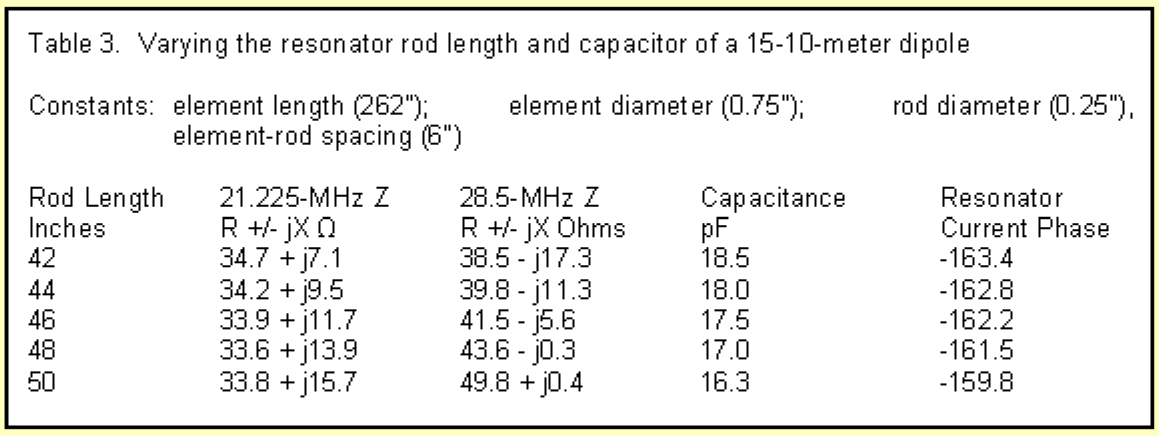


Table 3. Varying the resonator rod length and capacitor of a 15-10-meter dipole

Constants: element length (262"); element diameter (0.75"); rod diameter (0.25"), element-rod spacing (6")

Rod Length Inches	21.225-MHz Z R +/- jX Ω	28.5-MHz Z R +/- jX Ohms	Capacitance pF	Resonator Current Phase
42	34.7 + j7.1	38.5 - j17.3	18.5	-163.4
44	34.2 + j9.5	39.8 - j11.3	18.0	-162.8
46	33.9 + j11.7	41.5 - j5.6	17.5	-162.2
48	33.6 + j13.9	43.6 - j0.3	17.0	-161.5
50	33.8 + j15.7	49.8 + j0.4	16.3	-159.8

On 15 meters, the resistive impedance is down to 33-34 Ohms. However, as we lengthen the resonator rod, the resistance goes down and the inductive reactance goes up. Hence, we may expect somewhat less satisfactory 15-meter SWR curves with longer rods. In contrast, lengthening the resonator rod tends to raise the resistive impedance toward 50 Ohms on 10 meters, while reducing the capacitive reactance. As a result, longer rods produce somewhat better 10-meter SWR curves. **Fig. 7** shows the contrasting trends in a wide bandwidth SWR curve set.

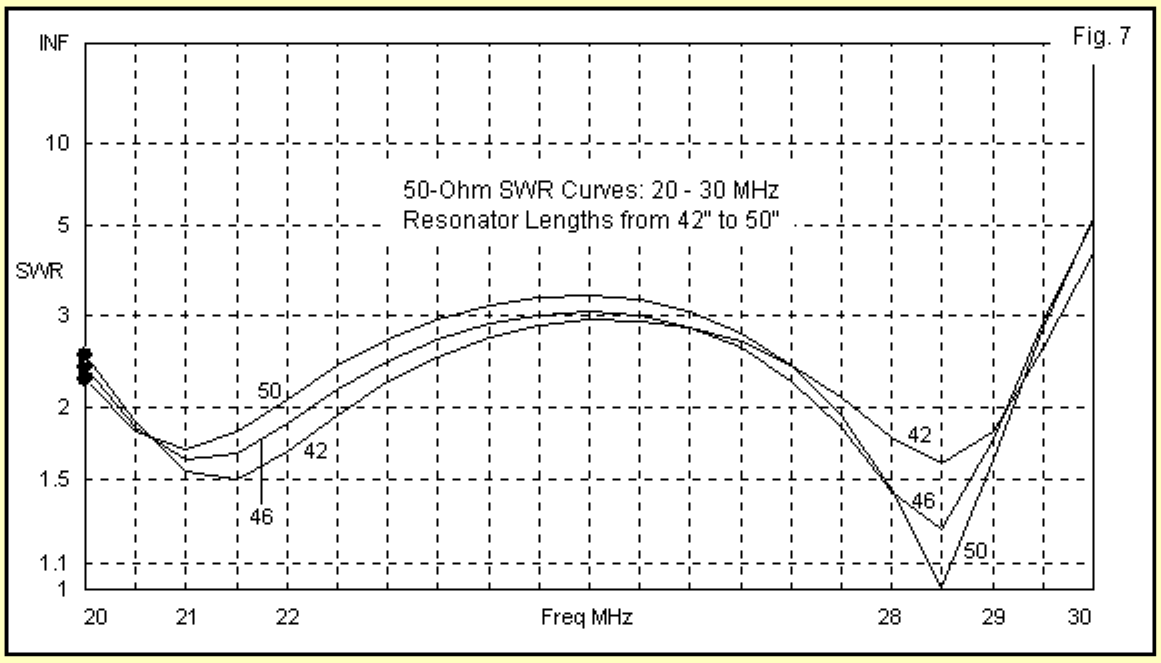


Fig. 7

Perhaps the 46" rod yields the best compromise between the SWR curves at 15 and 10 meters. Note that the smaller frequency difference between the lower and upper bands also limits the peak SWR between bands to about 3:1. Since the precise SWR limit tends to be less problematical in receivers than with transmitters, the 15-10-meter combination dipole would likely be quite usable for short wave listening between the two amateur bands, as well as somewhat below the 15-meter band.

Resonator-Rod-to-Element Spacing

Let's use the 46" long resonator rod and vary its spacing from the main element from 4" to 8" (the same spacing range used for the 20-10-meter combination). We shall discover that the 15-meter impedance varies only slightly across this range, as shown in **Table 4**.

Table 4. Varying the resonator rod spacing and capacitor of a 15-10-meter dipole

Constants: element length (262"); element diameter (0.75"); rod length (46");
rod diameter (0.25"),

Element-Rod Space Inches	21.225-MHz Z R +/- jX Ω	28.5-MHz Z R +/- jX Ohms	Capacitance pF	Resonator Current Phase
4	34.4 + j6.7	33.3 - j20.6	19.8	-164.1
5	34.2 + j9.4	39.6 - j13.2	18.5	-163.0
6	33.9 + j11.7	41.5 - j5.6	17.5	-162.2
7	34.2 + j13.1	47.3 - j4.3	16.4	-160.7
8	34.9 + j14.8	48.0 - j2.7	15.7	-160.2

The table also shows that rate of impedance change on 10 meters decreases as we increase the spacing of the rod from the main element. This is one of the results that appears to be consistent for all of our models. It suggests that in experimenting with linear resonators, we should not be too anxious to form a very compact element and resonator structure. A little extra spacing may result in easier final adjustments. **Fig. 8** shows the SWR curves for the extremes and the middle of the spacing range.

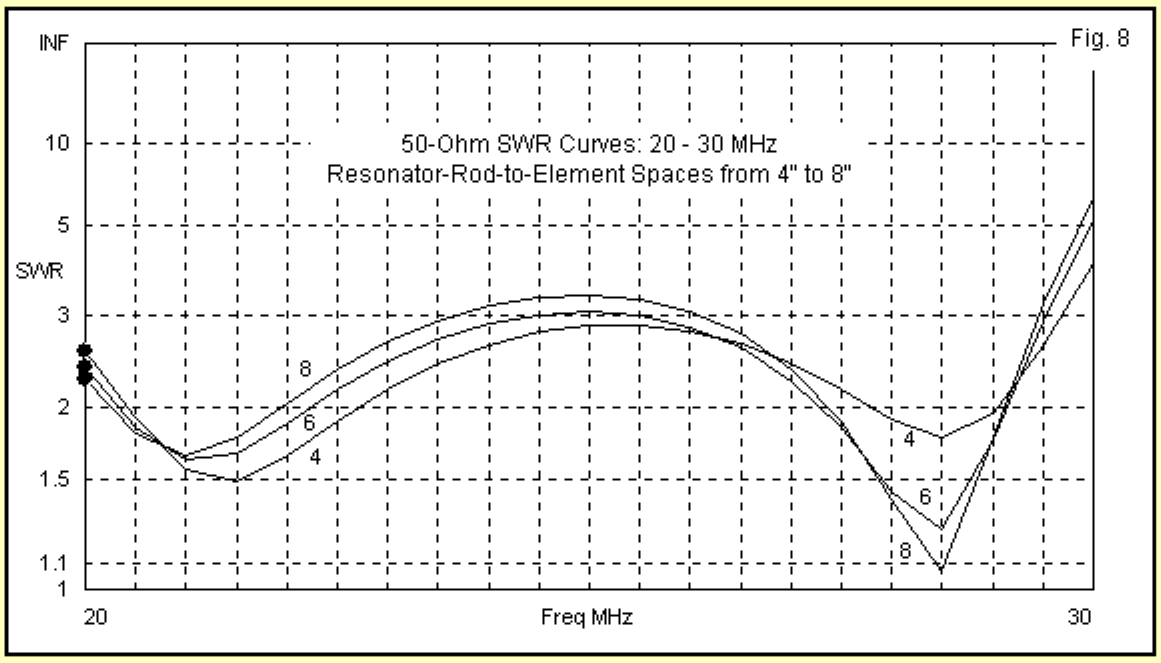
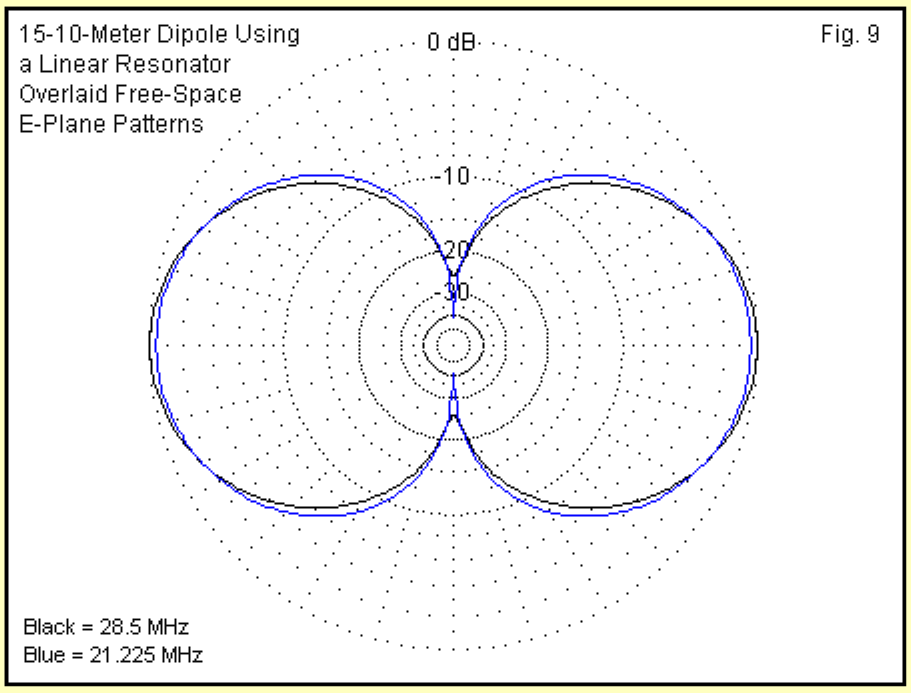


Fig. 8

Once more, we see the conflict that emerged with our rod-length experiments. In this case, close (4") spacing yields a broader 15-meter SWR curve but a less satisfactory 10-meter curve. At the other extreme (8"), we have the best 10-meter curve, but a shallow 15-meter curve. Once more, the best compromise for the other fixed values in the model is the 6" spacing. However, other factors that may enter into the design process may dictate one of the other spacing values.

The 10-meter current phasing values have fallen back into the -160-Ohm range, roughly comparable to the values that we encountered with the 20-15-meter combination. As well, the require capacitance is between 16 and 19 pF, values that also are closer to those we encountered with the 20-15-meter combination. The higher capacitance should ease the process of adjusting the 15-10-meter linear resonator.



The smaller frequency ratio between the two operating frequencies also affects the radiation patterns. **Fig. 9** overlays the 15- and 10-meter free-space E-plane patterns broadside to the resonator structure. Since at 10-meters the antenna is only a bit long as measured in wavelengths and compared to a standard 1/2-wavelength dipole, its gain and beamwidth do not vary much from the 15-meter pattern. As well, because the resonator structure is smaller, the side nulls are about 25 dB lower in gain than the main lobes. In the plane of the resonator structure and te main element, we find a 0.5-dB front-to-back ratio.

Our exercise has been successful in developing models of a dual-band linear resonator dipole for a frequency ratio of about 1.3:1. Whether we can tighten the ratio even further is dubious, since the lower-band impedance appears to decrease with a shrinking frequency ratio. Nonetheless, a 15-10-meter tubular combination is certain feasible.

A Few Comparisons Among All the Modeled Combination Dipoles

We have explored three different dual-band combination dipoles using linear resonators: a 20-15-meter version, a 20-10-meter combination, and finally a 15-10-meter antenna. All three antennas provide 2-band dipole service with adequate 50-Ohm SWR bandwidths for the selected operating frequencies. The main elements are all tubular, using 0.875" diameter material for basic 20-meter operation and 0.75" diameter material for basic 15-meter service. However, in many respects the three antennas have significant differences. **Table 5** shows some of those differences, using mid-range models from each group.

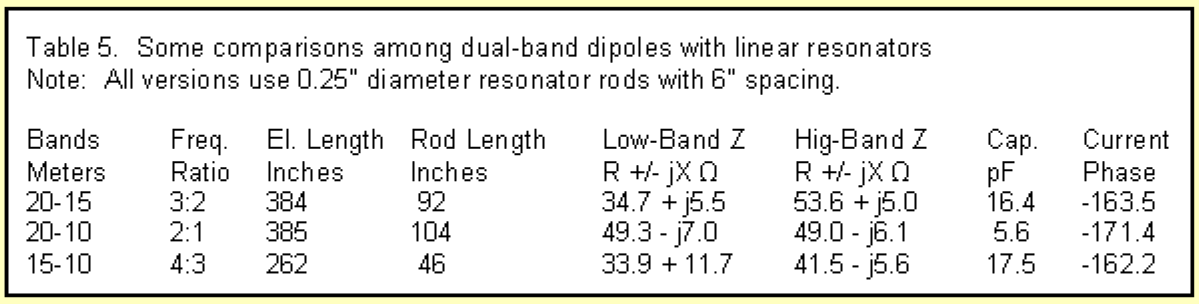


Table 5. Some comparisons among dual-band dipoles with linear resonators
Note: All versions use 0.25" diameter resonator rods with 6" spacing.

Bands Meters	Freq. Ratio	El. Length Inches	Rod Length Inches	Low-Band Z R +/- jX Ω	Hig-Band Z R +/- jX Ω	Cap. pF	Current Phase
20-15	3:2	384	92	34.7 + j5.5	53.6 + j5.0	16.4	-163.5
20-10	2:1	385	104	49.3 - j7.0	49.0 - j6.1	5.6	-171.4
15-10	4:3	262	46	33.9 + 11.7	41.5 - j5.6	17.5	-162.2

We might begin with the frequency ratios of each antenna. As the ratio between the upper and lower frequency decreases, so too does the lower-band impedance. Each lower-band dipole would be self-resonant as an independent structure at about 72 Ohms. The impedance drops to less than 34 Ohms with a frequency ratio of 4:3 (1.33:1). Although there is only a small difference between the 20-15 and the 15-10 combinations on each antenna's lower band, it appears that the lower-band impedance will eventually become too low to produce a satisfactory 2:1 or less 50-Ohm SWR across the band.

As the frequency ratio becomes smaller, we find that the upper band resonator phase angle departs further from 180 degrees. As well, the required tuning capacitance becomes greater. If we treat the linear resonator as a series-tuned circuit, then we might be tempted to determine the reactance of the capacitor as being equal to the reactance of the combined reactances yielded by the two element lengths and the mutual inductance between them. The results would look like the simple calculations in **Table 6**.

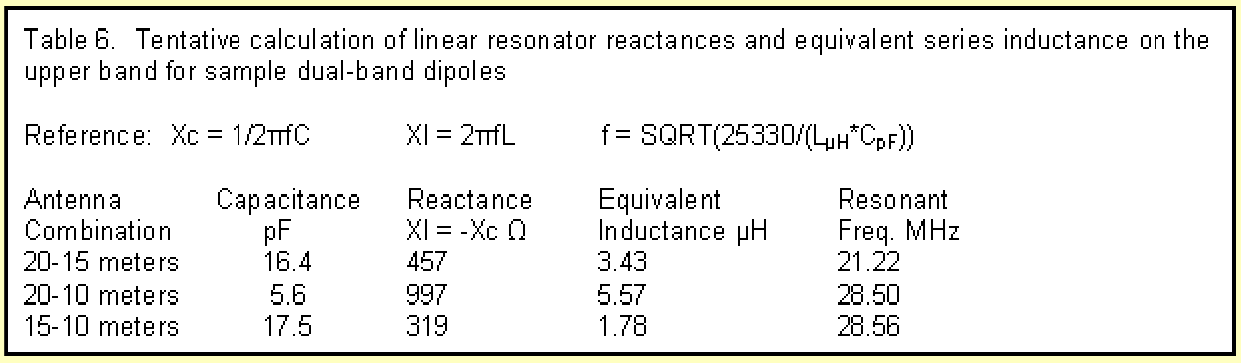


Table 6. Tentative calculation of linear resonator reactances and equivalent series inductance on the upper band for sample dual-band dipoles

Reference: $X_c = 1/2\pi fC$ $X_l = 2\pi fL$ $f = \mathrm{SQRT}(25330/(L_{\mu H}*C_{pF}))$

Antenna Combination	Capacitance pF	Reactance Xl = -Xc Ω	Equivalent Inductance µH	Resonant Freq. MHz
20-15 meters	16.4	457	3.43	21.22
20-10 meters	5.6	997	5.57	28.50
15-10 meters	17.5	319	1.78	28.56

Although the calculations hold well enough to establish the approximate series-tuned-circuit resonant frequency at the higher frequency, the role of this circuit in the antenna is far from simple. One clue is the departure of the legs from being out of phase with each other. A more important clue lies in the main element ends after we subtract the linear resonator section. **Table 7** lists the remaining leg length after removing the linear resonator section of each antenna. On the left for reference are the lengths of resonant independent dipoles.

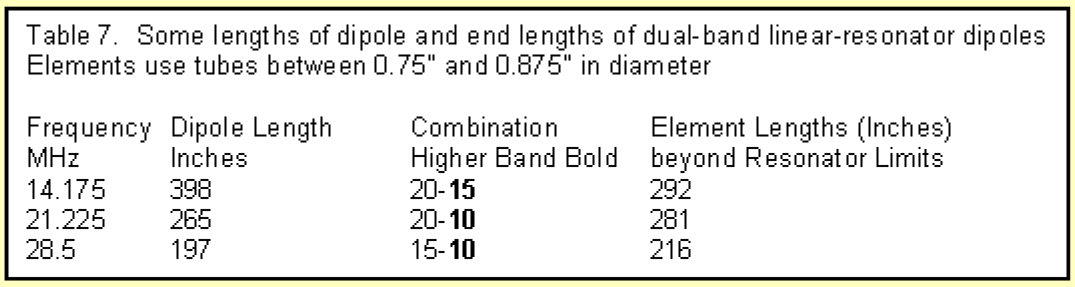


Table 7. Some lengths of dipole and end lengths of dual-band linear-resonator dipoles
Elements use tubes between 0.75" and 0.875" in diameter

Frequency MHz	Dipole Length Inches	Combination Higher Band Bold	Element Lengths (Inches) beyond Resonator Limits
14.175	398	20-**15**	292
21.225	265	20-**10**	281
28.5	197	15-**10**	216

One popular notion about linear resonators is that they simply short out the center section of the dipole. If that assumption were true, then the leg ends should show more than a distant correlation to the length of a dipole at the upper frequency. In the 20-15-meter combination, the leg ends are 27" or 10% longer than a 15-meter dipole. Similarly, for the 15-10-meter combination, the leg ends are 19" or just under 10% longer than a 10-meter dipole. The most drastic difference occurs with the 20-10-meter combination where the leg ends are 84" longer than a 10-meter dipole, a 43% difference.

This exercise in **Table 6** only establishes that there is no simplistic relationship between the linear resonator components and the operation of the antenna on the either band. The modeling is insufficient to establish what the more complex relationship is, but it does reflect the free-space E-plane patterns that we viewed along the way. As the frequency ratio increases, the upper-band radiation pattern showed a higher gain and a narrower beamwidth, consistent with a longer effective element length. The pattern results are consistent with the longer element ends that we see for each upper band in the chart.

At this juncture, perhaps the only safe statement to make is that the linear-resonator structure--including the capacitor--modifies the current distribution along an element to yield a bi-directional pattern and a usable 50-Ohm feedpoint impedance on the upper band of operation. The structure is largely but not wholly inert at the lower frequency, as demonstrated by the required main element shortening relative to an independent lower-band dipole. Even with a 2:1 frequency ratio, the lower band resistance drops to 2/3 the value of an independent self-resonant dipole. With closer frequency ratios, the feedpoint resistance on the lower band drops to less than half the value of an independent dipole. The degree of main element shortening is too small relative to the impedance decrease to treat the center section as an inductive reactance similar to a center-loading coil.

The role of the tuned circuit then is not merely to establish resonance at the upper frequency, but as well to establish a current distribution on both bands that yields the best approximation of acceptable feedpoint impedances. In Part 1, we showed the relative current magnitudes on each sections of a 20-15-meter linear-resonator dipole. The curves re-appear in **Fig. 10**.

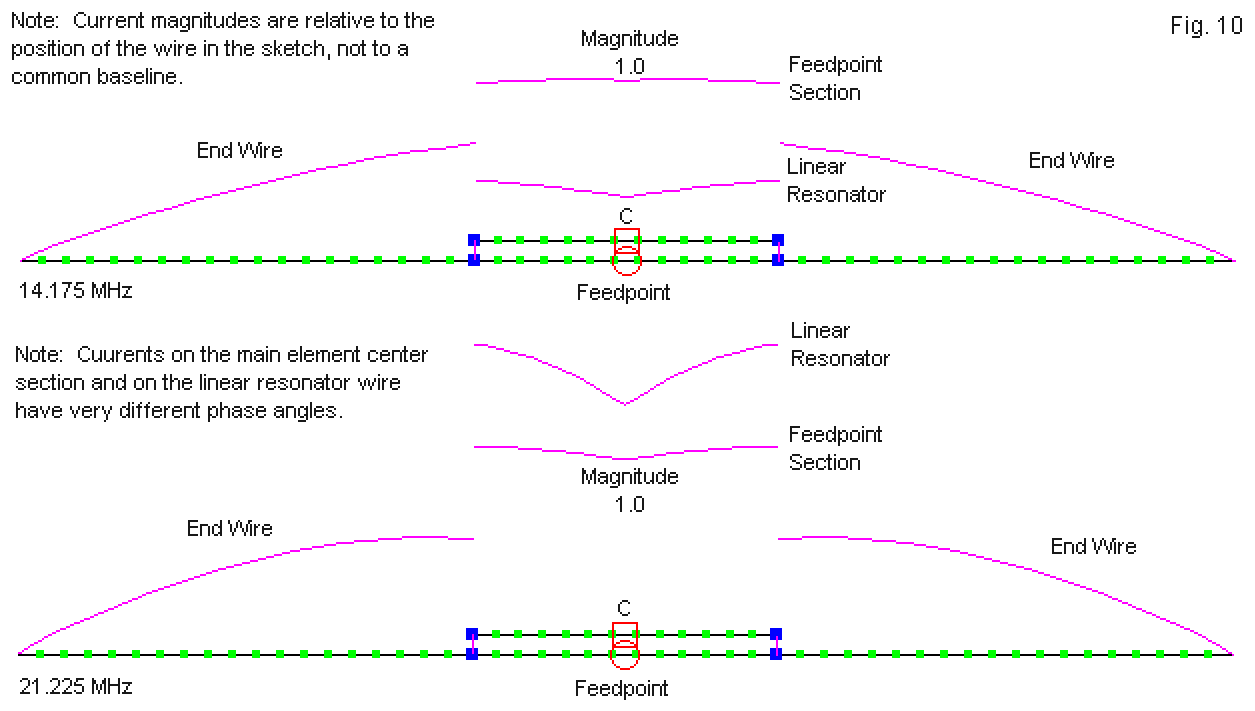


Fig. 10

Relative Current Magnitudes on a Dipole with a Linear Resonator
at 14.175 MHz and at 21.225 MHz

The separation of the center main-element currents from the resonator-rod currents without accounting for the phase angle of each on both bands creates a difficulty in visualizing the overall current distribution. **Fig. 11** corrects the visualization by providing a single curve for the antenna for each of the two mid-band frequencies.

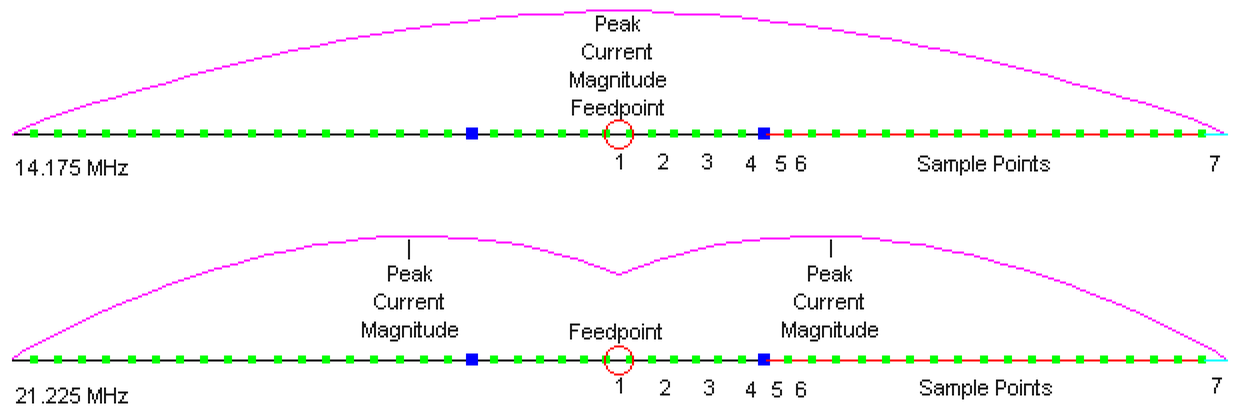


Fig. 11

Net Current Magnitudes on a Dipole with a Linear Resonator
at 14.175 MHz and at 21.225 MHz

We can obtain a set of approximate values for each segment by taking the vector sum of the currents and their phase angles at each corresponding segment within the center section of the antenna. The calculated net values will only be approximate because they do not account for the connecting wire between the main element and the resonator rod. However, they will be close enough to provide smoothed curves, such as those shown in **Fig. 11**. **Table 8** provides a sample of the calculations for the two frequencies. The sample points refer to the numbered segments in **Fig. 11**. Points 5 and 6 are the first two segments on the common end wire. Point 7 is the end segment to establish the approximate total phase change along the wire. The values for sample 7 in both cases yield total phase changes that closely correlate with a single wire of the same length as the linear-resonator dipole when used at each frequency.

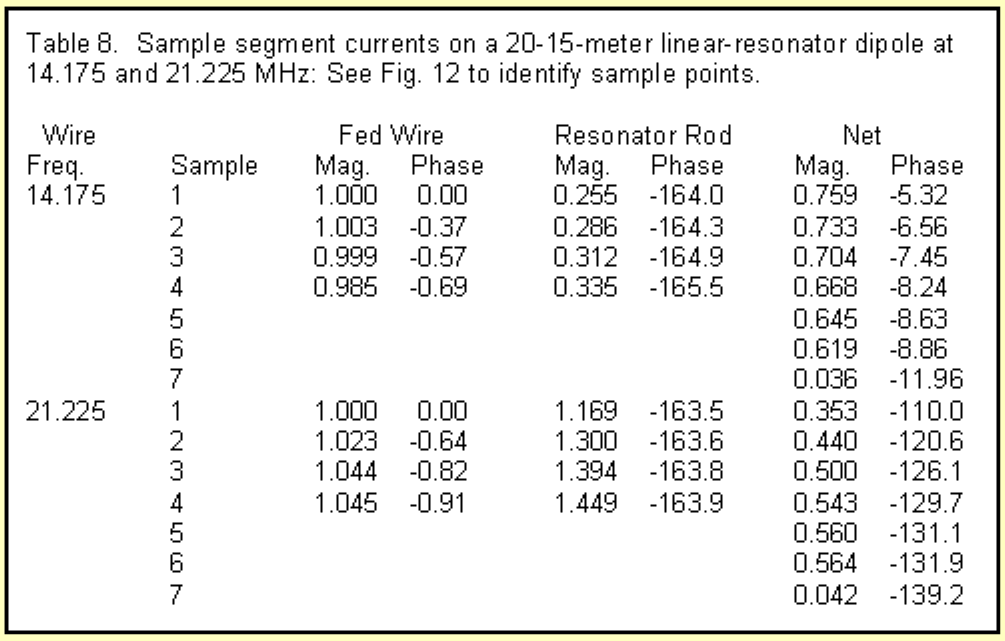


Table 8. Sample segment currents on a 20-15-meter linear-resonator dipole at 14.175 and 21.225 MHz: See Fig. 12 to identify sample points.

Wire Freq.	Sample	Fed Wire Mag.	Fed Wire Phase	Resonator Rod Mag.	Resonator Rod Phase	Net Mag.	Net Phase
14.175	1	1.000	0.00	0.255	-164.0	0.759	-5.32
	2	1.003	-0.37	0.286	-164.3	0.733	-6.56
	3	0.999	-0.57	0.312	-164.9	0.704	-7.45
	4	0.985	-0.69	0.335	-165.5	0.668	-8.24
	5					0.645	-8.63
	6					0.619	-8.86
	7					0.036	-11.96
21.225	1	1.000	0.00	1.169	-163.5	0.353	-110.0
	2	1.023	-0.64	1.300	-163.6	0.440	-120.6
	3	1.044	-0.82	1.394	-163.8	0.500	-126.1
	4	1.045	-0.91	1.449	-163.9	0.543	-129.7
	5					0.560	-131.1
	6					0.564	-131.9
	7					0.042	-139.2

The calculations and the graphed curves show the typical dipole current distribution on 20 meters. On 15 meters, we have a double peak for the current, with the peaks just beyond sample point 6. The double peak is typical of a center-fed wire antenna that is a little less than 0.7-wavelength long. The current distribution, of course, is fully consistent with the different radiation patterns that we obtain for the two bands.

Because a dual-band linear resonator dipole is not amenable to simple treatment, it will remain for now in the experimenter's domain. These notes may give some general guidance, but they are far from definitive. One limitation noted along the way is the offset created by NEC-4's variable accuracy with junctions of wires that have different diameters. A second limitation is the fact that materials used by antenna builders may vary across a very wide range of diameters--for both the main element and the resonator rod.

Indeed, we have so far restricted ourselves to working with relative fat elements. One may only wonder what the results might be had we begun the exercises with thin wire, perhaps the ubiquitous AWG #12 (0.0808" or 2.05-mm diameter). That exploration demands an entirely new modeling effort.

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