**The Dual-Element Wideband Dipole:  Some Preliminary Notes**

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Occasionally, one finds an antenna design with fascinating potentials.  Such is the case with the dual-element wideband dipole (DEWD), the first sample of which comes from Nikolay Kudryavchenko, UR0GT.  (See http://forum.cqham.ru/viewtopic.php?p=207160#207160.)  He developed a relatively simple wire antenna that would cover the entire 80-meter band with a 50-Ω SWR of less than 2:1 without the need for special matching systems.  How or why the antenna works as it does is subject to some discussion.  Our interest will be in better describing the behavior patterns as it works.  It is only a dipole, with a typical bi-directional pattern when set horizontally over ground.  Still, it has some very unique features.

These preliminary notes fall into three parts.  The first section will examine the basic properties of a well-designed DEWD across its passband.  We shall uncover some facets of operation that do not appear to be shared by other antennas with dipole radiation characteristics.  Although the antenna is unusual, its behavior is regular within its own pattern.  The second section of these notes will describe the systematic modeling and regression analysis that make it possible for anyone to design a DEWD for virtually any frequency whatsoever.  The work has been transferred to a spreadsheet that anyone can download from my website.  (See http://www.cebik.com/content/a10/trans/ant-design.html  for .qpw and .xls versions of the spreadsheet.)   The final section of the notes will describe some diverse potential applications for the DEWD antenna.

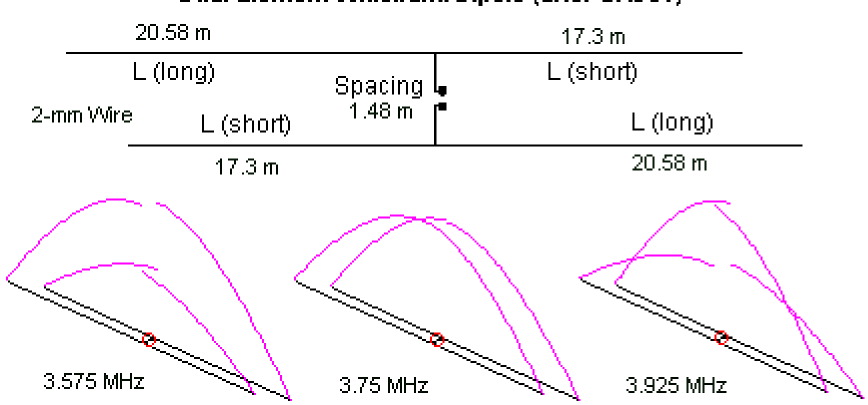


*DEWD Basic Properties*

The DEWD antenna consists of two nearly identical elements separated by a small but critical distance and offset from each other.  At the very center of the length of the element pair, there is a cross wire between elements.  The 50-Ω feedpoint is at the center of the cross wire.  **Fig. 1** outlines the basic portions of the antenna.  The measurements apply to a version of the antenna similar to the UR0GT 80-meter original, but covering 3.5-4.0 MHz.

Dual-Element Wideband Dipole (after UR0GT)

Fig. 1




Current Magnitude Curves at Selected Frequencies between 3.5 and 4.0 MHz

For many purposes, we may think of DEWD as having 5 parts:  two longer half-elements, two shorter half-elements, and the crossing feed wire, marked as “spacing” in the sketch.

Interestingly, at the lower end of the passband, the longer half-elements are more active, that is, have a higher current magnitude than the shorter half-elements. At the upper end of the passband, the opposite is true. At mid-band, both elements have approximately the same current magnitude. The active region of the antenna, then, appears from the current magnitude curves in **Fig. 1** to proceed from one end of one type of half-element to the far end of the same type of half-element, proceeding across the feedpoint. However, at any frequency within the defined passband, both element types (longer and shorter) are significantly active. The impedance and performance patterns do not replicate those of the design if we try to move both long half-element to one side of the cross wire.

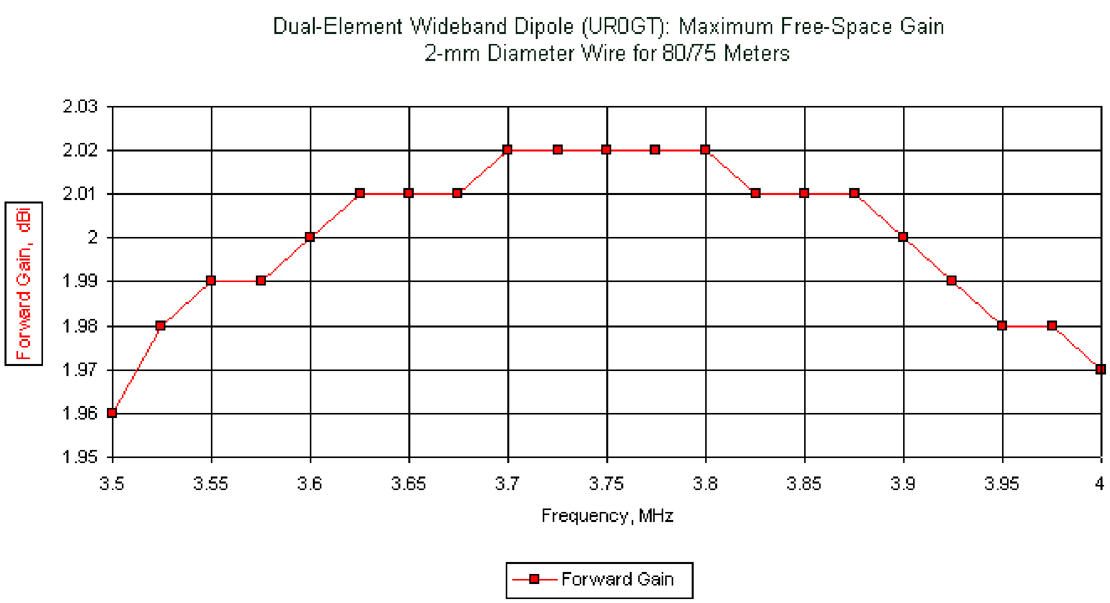


Fig. 2

As shown in **Fig. 2**, the bi-directional maximum gain of a DEWD does not significantly change across a defined passband. The total gain change across the 80/75-meter band for the sample antenna is 0.06 dB, a virtually immeasurable amount. (The stair stepping in the graph results from the fact that the gain values only use 2 decimal places.)

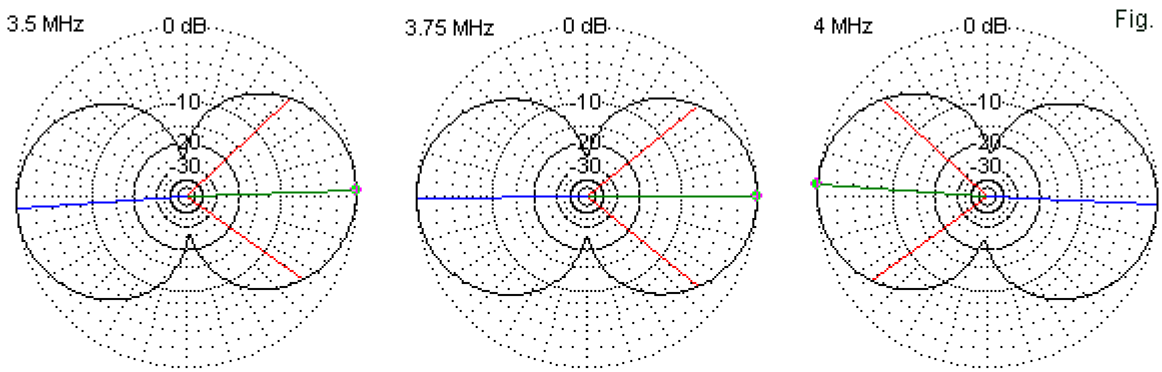


Fig. 3

Free-Space E-Plane Patterns: Dual-Element Wideband Dipole (UR0GT)

Because the elements are offset and have a slight space between them, the free-space E-plane patterns show slight variations from true broadside directions at the extreme ends of the operating passband. **Fig. 3** shows that at mid-band, the pattern is truly broadside. At the band edges, the variation from the broadside is 3° or less, an amount that one could not detect in operation with an antenna having a half-power beamwidth approaching 80°.

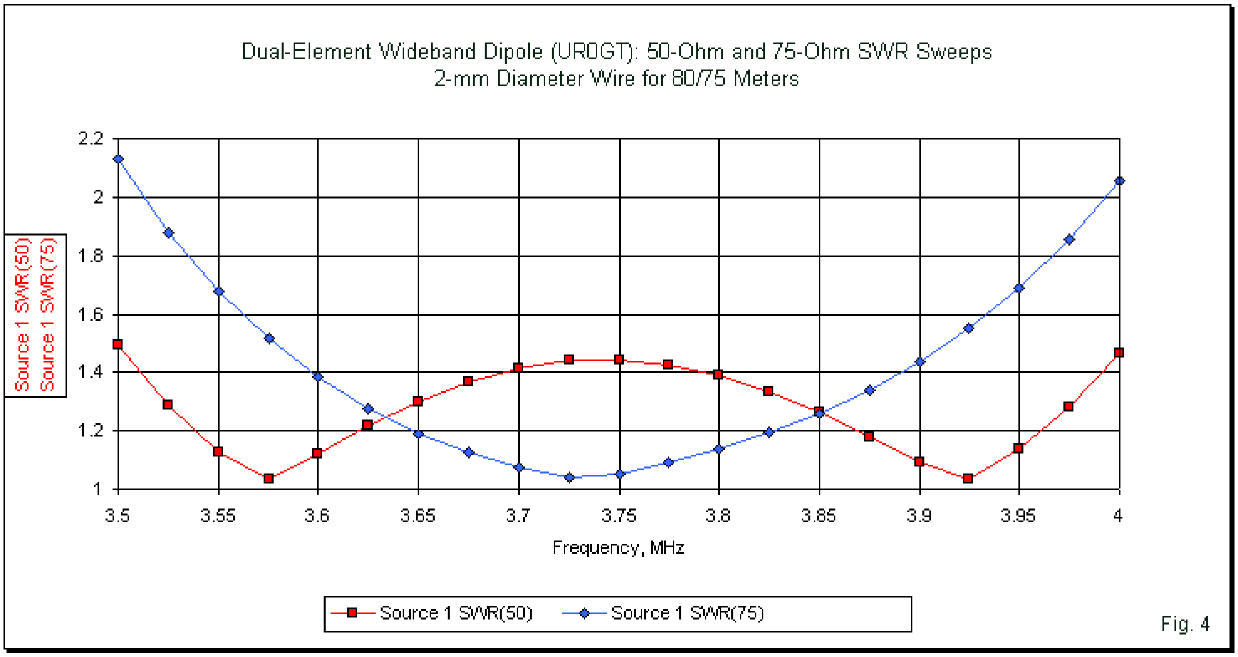


Fig. 4

**Fig. 4** presents the modeled 50-Ω and 75-Ω SWR curves for the sample free-space DEWD. Operationally, the 50-Ω curve is the more important of the two, since the antenna design calls for the use of a 50-Ω coaxial cable as the feedline. The most important feature of this curve is the fact that the SWR does not reach 1.5:1 anywhere within the 80/75-meter band. In this respect, the antenna has potential to serve even high power amateur stations using amplifiers with very sensitive fold-back circuits. Clearly apparent are the two 50-Ω resonant frequencies, one near each end of the operating spectrum.

The 75-Ω SWR curve registers an important and somewhat unique feature of the DEWD element arrangements. The SWR reaches a very low value at mid-band, indicating a third resonant point within the passband. The situation with respect to resonant frequencies becomes clearer in **Fig. 5**, which traces the feedpoint resistance and reactance across the band. The resistive component of the feedpoint impedance describes a single curve with a value close to 38 Ω at the band edges and a peak value of about 72 Ω at mid-band.

The reactance forms an interesting S-curve that is close to –j10 Ω at the low end of the band and close to +j10 Ω at the upper end. Outside the passband, the reactance continues its band-edge progression, and the rising reactance values, combined with the falling resistive component, provide the operational limits for the antenna. Between those extremes, the reactance crosses the zero line three times. Two of those crossing coincide with the 50-Ω SWR minimums, while the mid-band crossing coincides with the 75-Ω SWR minimum. The DEWD 50-Ω SWR curves resemble those produced by open-sleeve coupled elements sometimes used to broaden 80/75-meter performance. However, the pattern of resistance and reactance is very different for the two types of broadband antenna arrangements. Between open-sleeve coupled element resonant frequencies, we find a significant mid-band region reactance value rather than a mid-band resonant frequency.

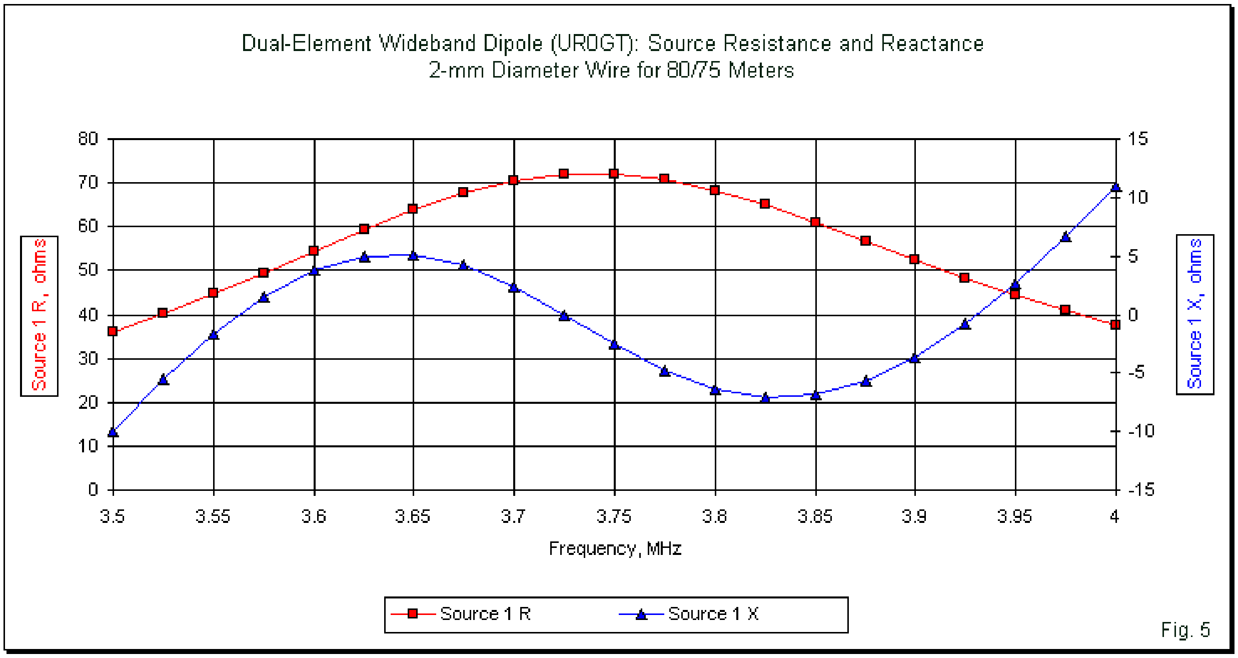


Fig. 5

| DEWD: 80-75-Meter Currents | | | | | | Table 1 |
|---|---|---|---|---|---|---|
| | Long Element | | Short Element | | Mag. | Angle |
| Freq MHz | Mag. | Angle | Mag. | Angle | Ratio | Difference |
| 3.500 | 0.7924 | 162.72 | 0.3345 | 44.05 | 2.37 | 118.67 |
| 3.525 | 0.8014 | 160.63 | 0.3555 | 47.33 | 2.25 | 113.30 |
| 3.550 | 0.8085 | 158.50 | 0.3821 | 50.04 | 2.12 | 108.46 |
| 3.575 | 0.8132 | 156.03 | 0.4143 | 52.02 | 1.96 | 104.01 |
| 3.600 | 0.8142 | 153.31 | 0.4515 | 53.18 | 1.80 | 100.13 |
| 3.625 | 0.8106 | 150.38 | 0.4929 | 53.47 | 1.64 | 96.91 |
| 3.650 | 0.8015 | 147.26 | 0.5371 | 52.91 | 1.49 | 94.35 |
| 3.675 | 0.7859 | 144.04 | 0.5822 | 51.58 | 1.35 | 92.46 |
| 3.700 | 0.7636 | 140.82 | 0.6262 | 49.59 | 1.22 | 91.23 |
| 3.725 | 0.7348 | 137.71 | 0.6671 | 47.10 | 1.10 | 90.61 |
| 3.750 | 0.7004 | 134.84 | 0.7032 | 44.27 | 1.00 | 90.57 |
| 3.775 | 0.6618 | 132.34 | 0.7333 | 41.24 | 0.90 | 91.10 |
| 3.800 | 0.6208 | 130.33 | 0.7570 | 38.16 | 0.82 | 92.17 |
| 3.825 | 0.5794 | 128.88 | 0.7743 | 35.14 | 0.75 | 93.74 |
| 3.850 | 0.5391 | 128.04 | 0.7860 | 32.26 | 0.69 | 95.78 |
| 3.875 | 0.5012 | 127.83 | 0.7927 | 29.57 | 0.63 | 98.26 |
| 3.900 | 0.4668 | 128.23 | 0.7955 | 27.09 | 0.59 | 101.14 |
| 3.925 | 0.4262 | 129.19 | 0.7952 | 24.84 | 0.54 | 104.35 |
| 3.950 | 0.4098 | 130.63 | 0.7927 | 22.80 | 0.52 | 107.83 |
| 3.975 | 0.3874 | 132.47 | 0.7886 | 20.98 | 0.49 | 111.49 |
| 4.000 | 0.3689 | 134.61 | 0.7833 | 19.34 | 0.47 | 115.27 |
| Notes: | See Fig. 1 for long and short element orientations. | | | | | |
| | Mag. = current magnitude relative to source magnitude of 1.0 | | | | | |
| | Angle = current phase angle relative to source angle of 0.0 deg. | | | | | |
| | Mag. Ratio = ratio of long to short element current magnitude | | | | | |
| | Angle Difference = long phase angle - short phase angle | | | | | |
| | Antenna is a 2-mm copper wire array in free space environment | | | | | |

The current patterns across the operating passband of the sample DEWD are fascinating in their own right. **Table 1** tracks the current magnitude and phase angle on both the shorter and the longer half-elements, using the first model segment adjacent to the cross wire junction. The values are the same for both half-element pairs. **Fig. 6** can help use sort out the data. For example, if we examine red and blue lines for current magnitude, we find almost perfectly opposing trends in value. For example, the longer half-element current magnitude declines rapidly above the mid-band frequency at which it equals the current magnitude of the shorter element. As we reduce the operating frequency, the current magnitude rises very slowly until it reaches the lower-end resonant frequency, after which it declines slightly. In contrast, the shorter half-element declines rapidly in value below the mid-band frequency, but rises only slowly above it until we reach the higher-end resonant frequency.

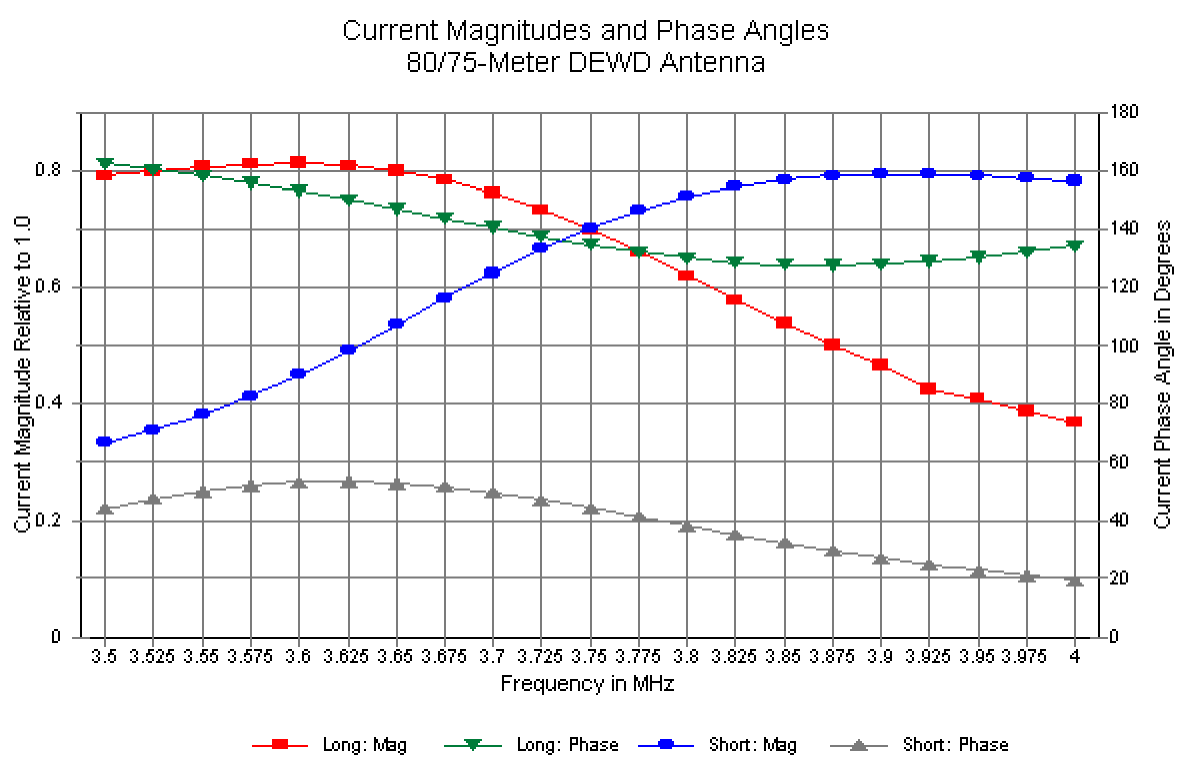


Fig. 6

The phase angle curves are also symmetrical opposites. At mid-band, a properly designed DEWD will show close to a 90° phase difference between the shorter and the longer half-elements. Above mid-band, the shorter half-element current phase angle decreases almost linearly, while below mid-band the longer half-element current phase angle shows a nearly linear increase. On the opposite half of the band for each half-element, the current phase angle increases of decreases, depending upon the half-element, to limit the departure from a 90° phase difference between elements. The progression continues up to the lower and higher resonant frequencies, beyond which the phase angle divergence increases rapidly. The current behaviors of the DEWD coincide with the patterns of resistance and reactance across the band in terms of ultimately limiting the useful bandwidth of the antenna.

**Fig. 7** graphs the two facets of current behavior in the longer and shorter half-elements in two ways. The current magnitude curve records the ratio of longer to shorter half-element current magnitude. Although not quite linear, the curve does record the very close relationship of the current magnitude behaviors on each side of the mid-band frequency. The phase-angle curve records the difference in phase angles between the longer and the shorter half elements across the passband. The curve is nearly but not quite symmetrical, partly because the actual frequency at which the current phases are 90° apart is just below the passband middle frequency. Nevertheless, the increasing rate of phase difference at more extreme frequency differences from mid-band is clearly apparent.

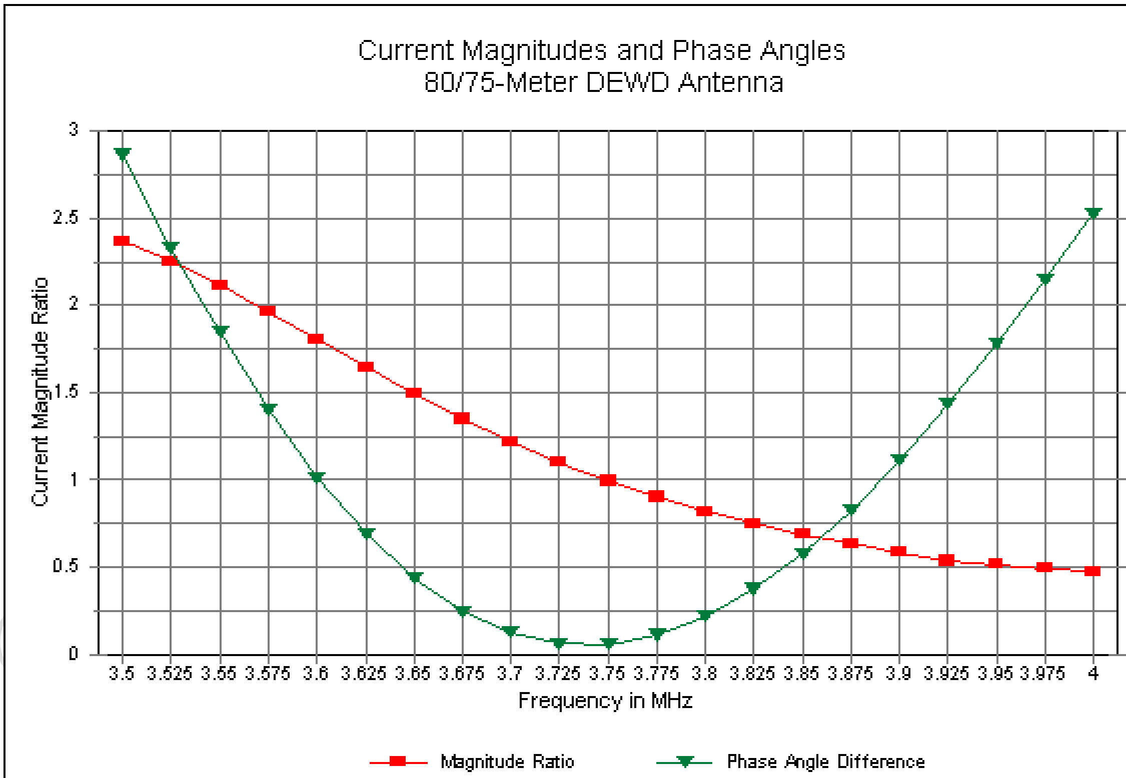


Fig. 7

Virtually any well-designed DEWD will display almost identical characteristics to the ones shown for the sample 80/75-meter antenna. As we shall eventually see, we may vary the resonant mid-band impedance for special purposes. As well, we may obtain quite satisfactory broadband performance with less attention to matching the lower- and higher-end resonant points relative to the band edges. We may also widen the operating bandwidth by selecting larger element diameters. Nevertheless, the notes so far have revealed the very general properties of the DEWD antenna.

*Calculating DEWD Dimensions*

The design of a DEWD requires attention to several structural variables and also requires a decision on the part of the designer. Let's examine the decision first. The SWR bandwidth of most antennas rests upon the rise in SWR at the passband edges. The DEWD also depends upon these values, but also upon the mid-band impedance. We may set the mid-band impedance to a range of values, normally above 50 Ω. The result will be a mid-band 50-Ω SWR value greater than 1:1. Since the mid-band frequency is resonant, we may calculate the mid-band SWR just by taking the ratio of the impedance to 50 Ω. The resulting SWR value then becomes a marker for determining the overall operating bandwidth, since passband edge SWR values that exceed this value will, by definition, fall outside the operating passband.

Although SWR values of 2:1 at the band edges normally set the limits of amateur antenna operating ranges, other communications efforts may set limits either higher or lower than the amateur standard. I have set a 1.5:1 limit for this exercise. The limit is arbitrary apart from a specific mission. However, the potential DEWD operating bandwidth, even within this standard, is great enough that demanding such performance seems reasonable and proper. For other communication mission, a designer may select a maximum SWR value appropriate to the mission goals.

The immediate consequence of setting an SWR limit is determining the mid-band resonant impedance of any DEWD design. 75 Ω becomes that impedance limit. In the examples that follow, the mid-band impedance will actually range from about 71 to 73 Ω, with up to a few Ohms of reactance.

**Fig. 1** lists the variables applicable to designing a DEWD antenna. In terms of length values, the short and long half-elements and the spacing or length of the cross feedpoint wire are the design keys. However, the most fundamental variable—usually a designer selection—is the element diameter. **Fig. 8** shows the outlines of 3 optimized DEWD antennas that meet the 1.5:1 SWR standard, but use very different wire diameters, listed in terms of wavelengths. The top figure uses a very thin element, a bit smaller than the 2-mm wire used in the 80/75-meter sample. The lowest sketch uses a very fat element, but not outside the range that we might find in a UHF antenna. The middle sketch uses an intermediate size wire. Its size is exactly mid-range if we take the base-10 log of each wire size.



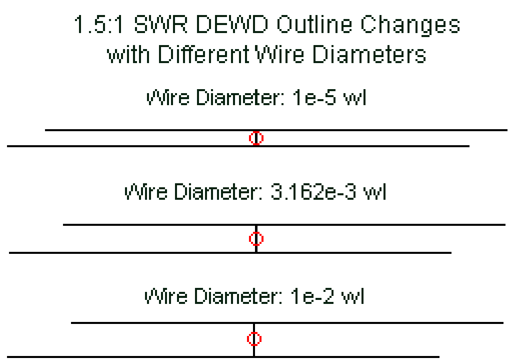



Fig. 8

The sketches are to scale. Clearly the longer half-element does not change length by enough to show in the graphic representation. However, the shorter half-element shrinks with increasing element diameter. In addition, the spacing or cross wire increases in length with increasing element diameter. These two aspects of DEWD design are interactive, since the required half-element lengths are functions not only of the path length from one tip to the corresponding other tip, but as well of element interactions. As we increase the spacing between element sections, the longer element varies only slightly, but the shorter element requires considerable shortening to place its upper-end 50-Ω resonance at a frequency that produces a mid-band resonance of the desired impedance. Shortening the shorter half-element pushes the upper resonant frequency high in frequency. The longer half-element requires only a small adjustment because the longer tip-to-tip path automatically lowers its lower-end resonant frequency by nearly the correct amount.

We may employ these trends to develop optimized NEC-4 models of DEWDs with uniform element diameters, using selected element diameter values. Significant variations of DEWD dimensions occur as we increase the diameter logarithmically rather than linearly. Therefore, the selected wire sizes use values that result in a linear progression of the base-10 logs of the diameters. **Table 2** shows the results of optimizing seven versions of DEWD—all within the SWR limit previously set—for wire diameter values from 1e-5 up to 1e-2 wavelengths. Each entry lists the dimensions of each half element and the cross wire. The table also records the operating bandwidth between passband SWR limits of 1.5:1, where the value is the difference in frequency between the upper and lower limit divided by the center design frequency and multiplied by 100 to obtain a percentage.

| DEWD 1.5:1 SWR Model Calculation Data Points | | | | | Table 2 |
|---|---|---|---|---|---|
| Dia wl | log Dia | Spacing | Llong | Lshort | BW% |
| 1E-05 | -5 | 0.0168 | 0.2560 | 0.2185 | 12.3 |
| 3.2E-05 | -4.5 | 0.0195 | 0.2570 | 0.2153 | 13.7 |
| 0.0001 | -4 | 0.0230 | 0.2585 | 0.2100 | 16.0 |
| 0.000316 | -3.5 | 0.0290 | 0.2596 | 0.2030 | 18.3 |
| 0.001 | -3 | 0.0365 | 0.2610 | 0.1940 | 21.7 |
| 0.003162 | -2.5 | 0.0495 | 0.2615 | 0.1785 | 27.0 |
| 0.01 | -2 | 0.0760 | 0.2625 | 0.1610 | 35.0 |
| Notes: | See Fig. 1 for element designations | | | | |
| | All dimensions in wavelengths | | | | |
| | Dia wl = Element diameter in wavelengths | | | | |
| | BW% = 1.5:1 50-Ohm SWR bandwidth | | | | |



For the range of element diameters shown, the operating bandwidth nearly triples with wire-size increases. This situation follows from setting a specific limit to the mid-band impedance. An alternative procedure not used in this exercise would be to set the upper and lower resonant points to the same frequency for each new wire size. A further alternative would be to define band-edge frequencies and then to match the band-edge SWR values to the mid-band SWR value. Any of these systems will result in a usable calculation scheme, but the present system appears to match amateur interests most closely.

Each column in **Table 2** yields a set of data points for regression analysis, using the base-10 log of the wire diameter as the X-axis value to obtain a linear scale.

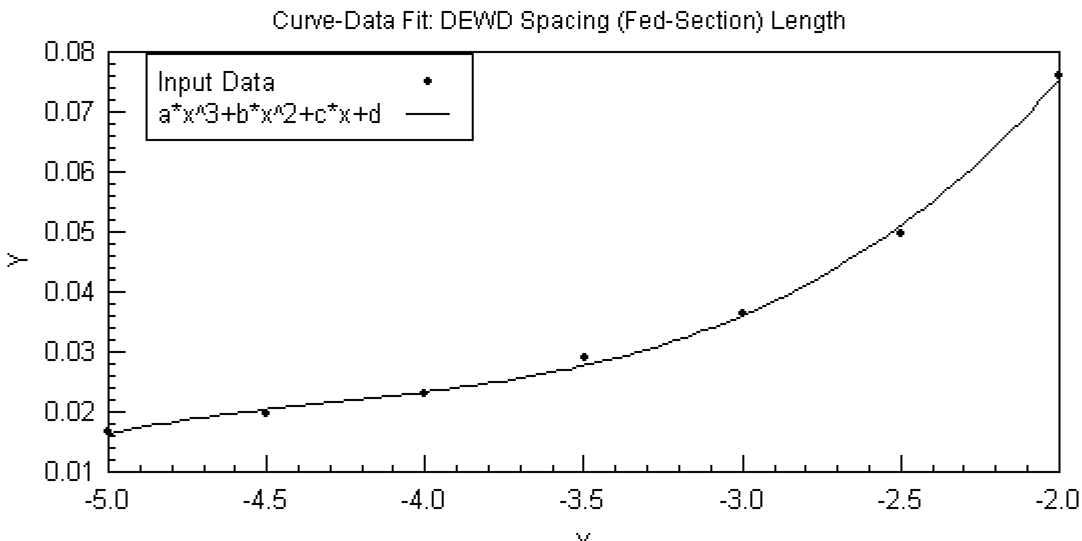



Fig. 9

**Fig. 9** traces both the data points and the resulting 3rd-order curve that “connects the dots” for the spacing or cross-wire value. I shall omit the regression equations from these notes, since they have no electronic significance. For reference, the constants do appear in the spreadsheet noted in the introduction. The curve provides a very close fit despite the 4:1 range of spacing values included. In contrast, the curve in **Fig. 10** for the length of the longer half-elements appears to show a lesser fit. However, the total range of longer half-element values is very small (0.007-λ), so the seeming deviation between dots and the curve is harmless to DEWD design.

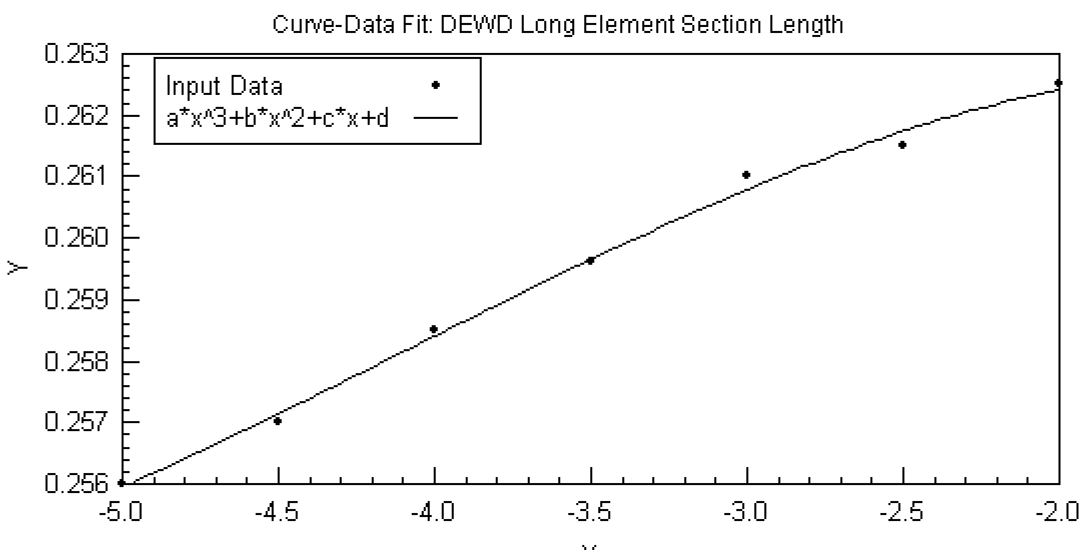



Fig. 10

The curve for the shorter half-elements in **Fig. 11** shows a much closer fit, which is largely a function of the greater range of half-element length values. Indeed, the range is about 10 times greater than the range of longer half-element values. The utility of these graphs is not only to show the fit between the regression-analysis curves and the optimized models, but as well to provide a feel for the dimension changes as we change the diameter of the DEWD elements.

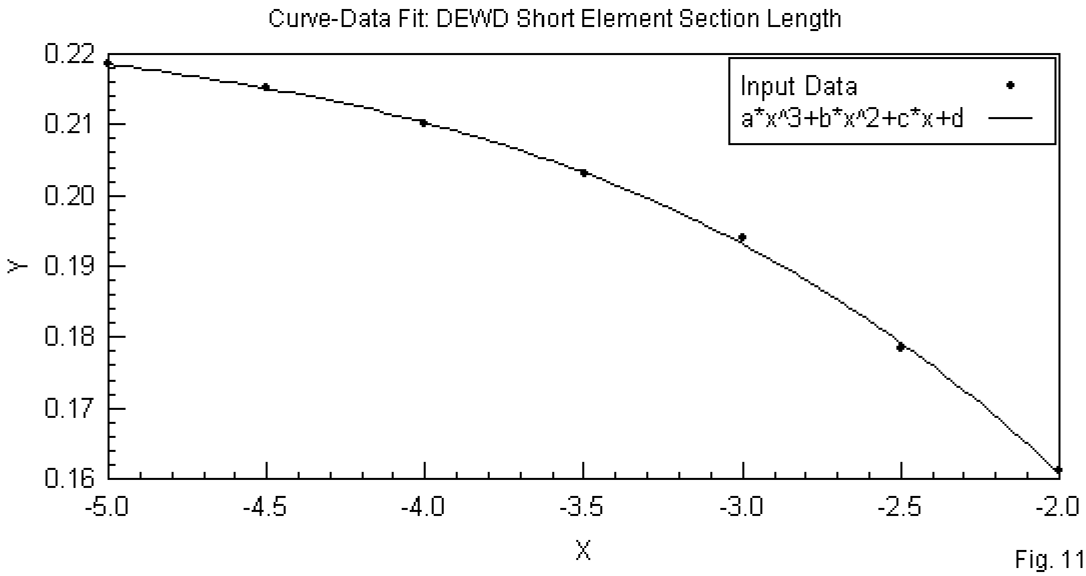



Fig. 11

The final chart in this series, **Fig. 12**, plots the changes in the operating bandwidth with changes in the element diameter, all within the maximum 1.5:1 50-Ω SWR limit across the entire passband. Once more, 3rd-order regression equations provide a good fit, and we may notice that the operating bandwidth increases at a greater than linear rate as we increase the wire size in steps that rest on the base-10 log of the physical size.

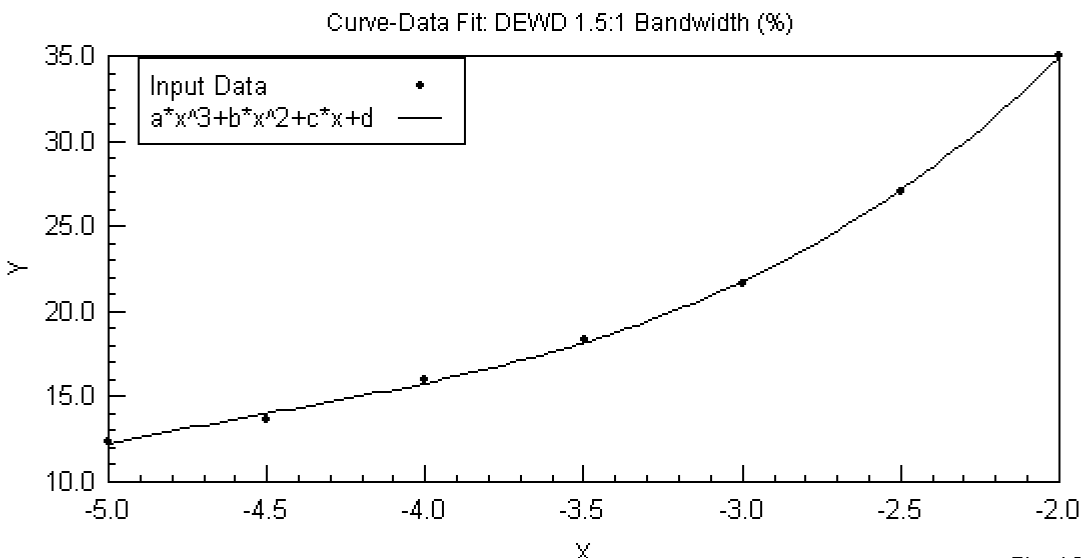



Fig. 12

All of the dimensions within the analysis are registered in wavelengths and presume lossless or perfectly conducting wire. Some adjustment may be required when using very thin wire with conductivity limitations. The referenced spreadsheet requires only two entries. One is the design frequency, or for DEWD, the mid-band frequency. For most versions of the antenna, the bandwidth is symmetrical on either side of the mid-band frequency. The second entry is the element diameter. The spreadsheet allows the selection of an AWG gauge, inches, or millimeters as the element diameter unit of measure. The output dimension data appear in terms of wavelengths, meters, feet, and inches for user convenience.

The calculation scheme yields results that are consistent in models at many frequencies. No model or calculation scheme can account for every construction variable, so there are limits to the application of the spreadsheet and its underlying modeling and regression analyses. Nevertheless, the system should produce replicable versions of the DEWD antenna that perform within the specified parameters with minimal need for field adjustment.

*A Few Sample Applications*

Calculating a set of elements for a DEWD design is only the first step in the process of developing a working antenna. In this section of notes, we shall look at only a few sample applications. Our goal is not just to see some of the potential of the DEWD element arrangement, but also to examine some of the limitations and adjustments that we encounter when transferring the design to the real world.

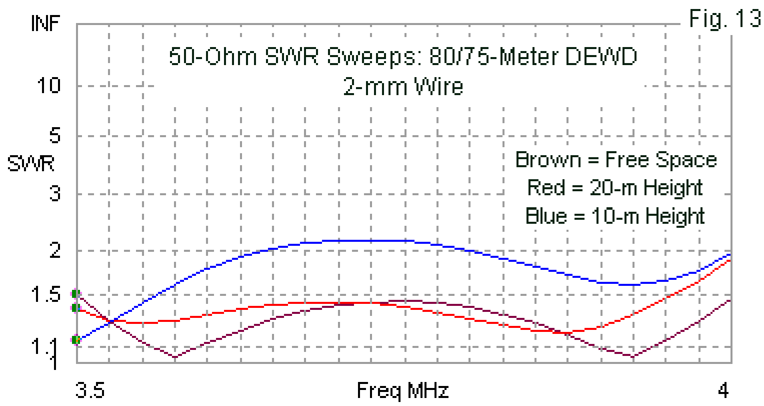
We have already viewed a primary example of DEWD's use: the UR0GT 80/75-meter dipole. **Fig. 1** through **Fig. 7** traced its basic performance parameters in more detail than one might operationally need. Still, there are other facets of the antenna to consider.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DEWD 80-75-Meters, <1.5:1 50-Ohm SWR | | | | | Variation of the original UR0GT Design | | | | Table 3 |
| Calculated dimensions in wavelengths, meters, and feet, verified by NEC-4 models in free-space | | | | | | | | | |
| | Cross Elements (Spacing) | | | Long Half Element | | | Short Half Element | | |
| Wire Size | WL | Meters | Feet | WL | Meters | Feet | WL | Meters | Feet |
| AWG #14 | 0.0191 | 1.531 | 5.022 | 0.2567 | 20.520 | 67.322 | 0.2165 | 17.312 | 56.797 |
| 2-mm | 0.0198 | 1.581 | 5.187 | 0.2569 | 20.537 | 67.379 | 0.2159 | 17.261 | 56.629 |
| AWG #12 | 0.0199 | 1.587 | 5.208 | 0.2569 | 20.540 | 67.387 | 0.2158 | 17.254 | 56.606 |

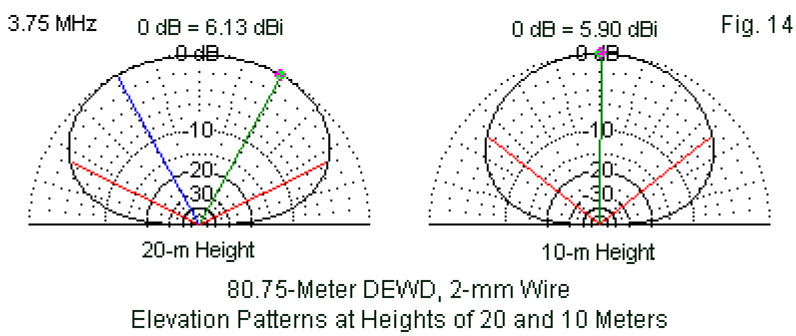


**Table 3** provides the calculated values of the antenna for three popular wire sizes used by amateurs. Since the original antenna was developed prior to the emergence of the calculation spreadsheet, you may notice some very small differences in the dimensions. The calculated and the original antennas perform virtually identically, showing that dimensions are not hypercritical. The table also shows that very small changes in the wire diameter have relatively minimal affect on the dimensions.

More significant is the fact that we normally operate 80-/75-meter antennas at relatively low heights above ground. Any horizontal antenna undergoes cycles of feedpoint impedance change as we raise and lower it above ground, especially below a height of 1 λ. The effect is greater upon dipoles than upon parasitic and phased horizontal arrays, since the feedpoint impedance of the latter types of antenna are subject to control by adjacent elements. Despite its use of multiple elements, DEWD is at heart a dipole and suffers ground effects. **Fig. 13** shows the modeled SWR plots for the free-space model and for models at 10-m (1/8-λ) and 20-m (1/4-λ) above average ground. For a practical DEWD, the designer needs to model the antenna at the anticipated height above the best estimate of ground quality and to make adjustments to the dimensions—especially the spacing and shorter half-elements—to restore to the degree possible the desired passband SWR characteristics. As the figure reveals, a height of 20-m above ground will require far less design adjustment than a height of 10-m. The location of the lower-end SWR minimums suggests that one might begin by shortening the longer half-element somewhat, followed by a juggling of both the spacing and the shorter-half-element values. The high mid-band SWR indicates a high impedance value, suggesting a shortening of the cross-wire dimension to reduce it. At other heights above ground—for example, between 3/8-λ and ½-λ—the required adjustments may be quite different. At some heights, one may be hard pressed to obtain the 1.5:1 50-Ω SWR limit across the entire band.




Still, DEWD is a dipole and exhibits characteristics almost indistinguishable from a single-wire dipole. Dipoles at very low heights have elevation patterns better suited for NVIS operation than for DX communication. **Fig. 14** provides elevation patterns for the modeled antenna at heights of 10-m and 20-m above average ground. More significant than the gain values shown on the plots are the elevation angles of maximum gain.




We need not restrict the use of DEWD to the 80/75-meter band. Indeed, if we are willing to go beyond the uniform-diameter element calculations, we can design some interesting dipoles for other bands. **Fig. 15** shows the dimensions of a 10-meter version designed to cover the entirety of the band (28.0 to 29.7 MHz) with stepped-diameter elements. The inner sections of the antenna use 0.5"-diameter tubing, with 0.375" tubing for the tips. The 48" inner sections of the elements allow the use of 5' tip sections for the longer half-element with a 3" insertion into the inner sections.

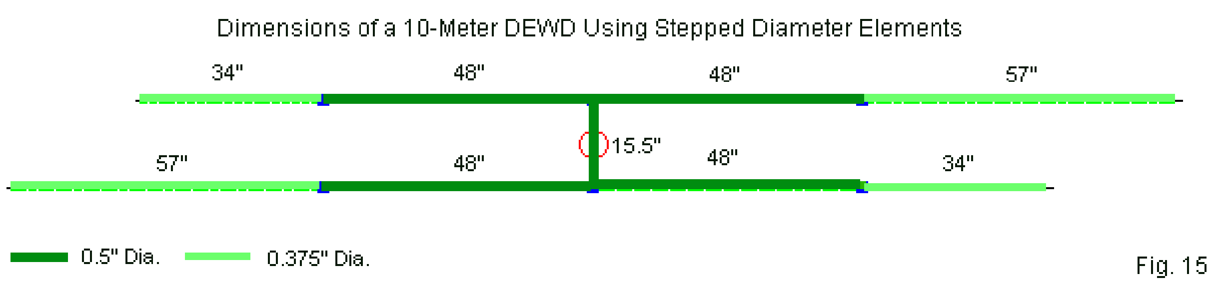
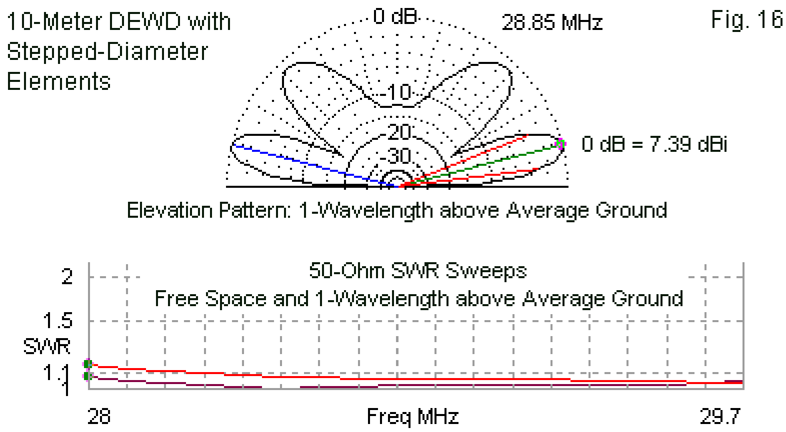



**Fig. 16** provides us with a snapshot of some of the essential performance features of the antenna. The elevation pattern once more shows a typical dipole plot with an elevation angle

for the lowest lobe of 14° with the antenna about 1 λ (35') above ground. As well, the bi-directional gain is typical of dipoles.




Perhaps the most interesting feature of the antenna is the SWR curve. In free space, the 50-Ω SWR never rises to a value of 1.1:1. The curve is only slightly worse at a height of 1 λ above ground. The curve results from judicious adjustment of the aluminum elements, especially the shorter elements, away from their calculated values toward the highly optimized SWR curve. Initial calculations via the spreadsheet called for a spacing of 15.6", longer half-elements of 106.8", and shorter half-elements of 78.1." Adjusting for both the stepped diameter elements and the desired SWR curve resulted in a 15.5" spacing, 105" longer half-elements, and 82" shorter half-elements. Of course, the most radical change affects the shorter half-elements: lengthening them draws the upper resonant frequency closer to mid-band, resulting in a lower mid-band impedance value.



One might well use the 10-meter stepped diameter DEWD as either a horizontal or a vertical dipole. Moreover, the techniques can also provide coverage for 6 meters. Indeed, as the effective diameter of an element material increases with frequency, one might well develop vertical antennas for monitoring not only 2-meters, but as well much of the spectrum both above and below that amateur band.

Not all dipoles are independent antennas. We often use them as drivers for optically based reflector screens, especially in the UHF range. Let's consider a dipole ahead of a 1.2-λ-by-1.2-λ planar reflector, as shown on the left in **Fig. 17**. The 8-mm-diameter dipole is 0.175-λ ahead of the reflector and is 0.437-λ long to obtain a 50-Ω impedance.

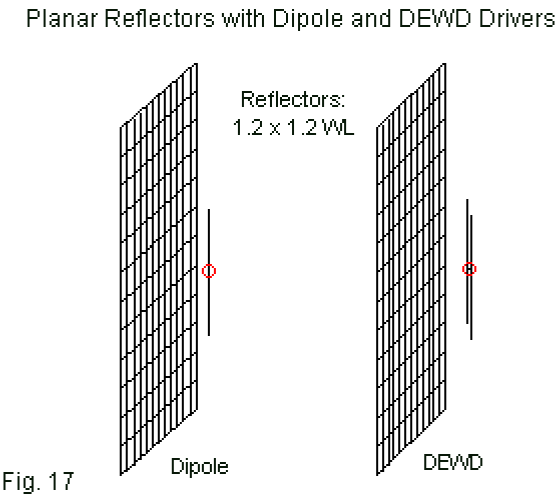


Fig. 17

On the right, we have a DEWD version of the driver using 4-mm-diameter elements. The driver elements are equidistant from the reflector. Obtaining satisfactory performance from a DEWD driver requires some compromises and element dimension adjustments. To preserve a reasonable impedance curve, the distance from the reflector increases to 0.195-λ. The spacing is 0.057-λ, with 0.249-λ longer half-elements and 0.182-λ shorter half-elements. Further optimizing may well be possible. Still, with the DEWD driver, we do not have the simple option of adjusting the driver length for a single resonant frequency at a 50-Ω impedance value for each change in spacing. The DEWD elements are interactive so that adjustment to one part tends to affect the performance of other parts and the performance of the overall array. Nonetheless, the incompletely optimized version of a DEWD planar array will suffice to show its potential with a planar reflector. The goal is to use the DEWD driver to significantly enlarge the operating bandwidth over the use of a simple dipole.

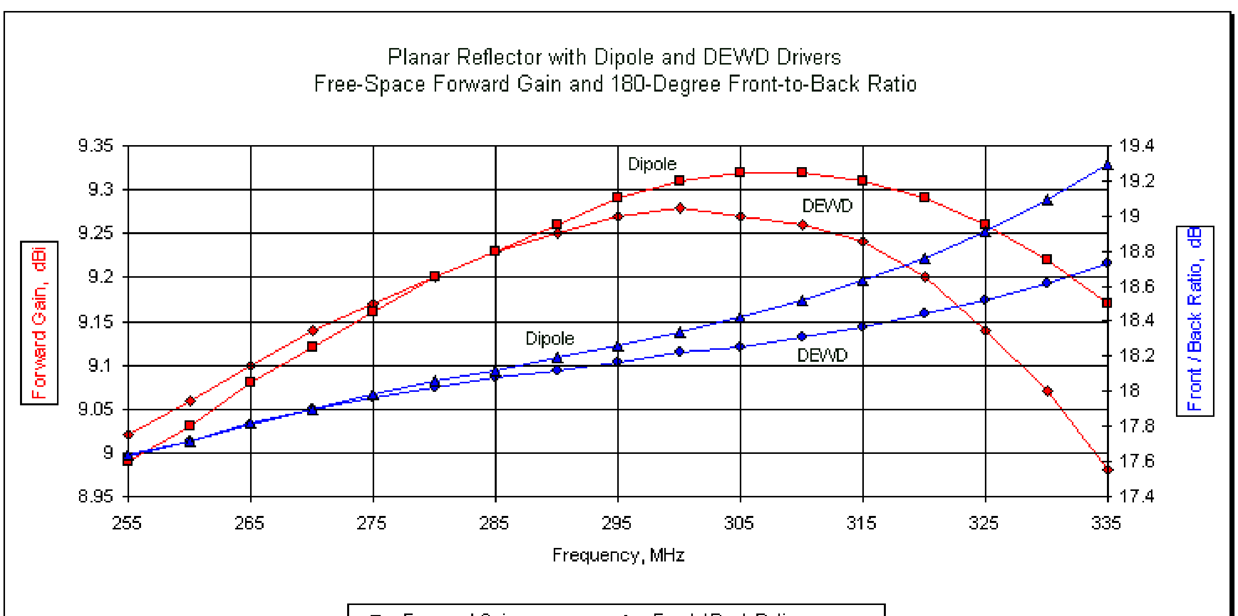
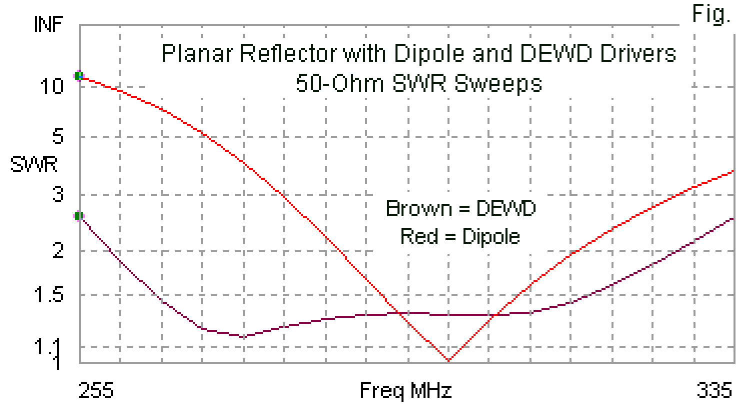


Fig. 18

**Fig. 18** shows the gain and front-to-back curves for both arrays from 255 to 335 MHz, where 300 MHz is the design center frequency. Because the DEWD driver is more widely spaced from the reflector, its values in both categories tend to fall off faster than the values for the dipole. One might take these trends as DEWD disadvantages if the operating bandwidth of the two antennas was as wide as the range over which each antenna shows significant performance values. However, the dipole's SWR bandwidth is far narrower than its performance bandwidth, as shown in **Fig. 19**.

Fig. 19




The 2:1 SWR band for the dipole driver extends from 287 to 316 MHz, a bandwidth of about 9.7%. In contrast, the 2:1 SWR band for the imperfectly optimized DEWD driver runs from 258 to 328 MHz, a 23.3% bandwidth. Although one may do considerably more work to set up the DEWD driver, it still manages a 240% increase in operating bandwidth, using the 50-Ω 2:1 SWR limit as a measure. One might also consider using a DEWD driver with a corner reflector, although obtaining peak performance with spaced elements may prove an interesting challenge. Once more, the goal would not be improved gain, but rather a significant increase in the operating bandwidth.

*Conclusion*

We have examined the dual-element wideband dipole, originated so far as we presently know by UR0GT, from several different angles. I am unaware of any precedents for the antenna, but the history of antennas has a strange way of eventually revealing earlier related work. In our exploration, we tried to describe the basic operating parameters without necessarily providing a complete explanation for the traits. The triple resonance of the antenna across its passband seems to be its most unique feature, the one that allows the antenna to exhibit an exceptionally wide operating frequency range within the category of dipoles. Moreover, it allows the direct use of a 50-Ω transmission line.

The DEWD may be unique, but its properties are as regular as those of any other relatively basic antenna. Hence, we may calculate within quite narrow limits the dimensions and potential bandwidth of a DEWD for any frequency and any reasonable element diameter. The calculation limit rests on one or more design decisions. The decision used to develop a spreadsheet calculation program was to set the maximum mid-band impedance value at 70-75-Ω, for a maximum mid-band 50-Ω SWR of less than 1.5:1.

Finally, we sampled a few potential applications of the DEWD, including a stepped diameter 10-meter antenna and a wideband planar array for UHF. These applications revealed some of the modifications that we can perform to alter the SWR curve over a fair frequency range to a very flat line. As well, the exercises introduced us to some of the challenges involved in optimizing the DEWD for some applications.

In the end, DEWD shows itself to be an antenna design with high, but perhaps not unlimited potential. Its use in parasitic or phased arrays is not as promising as other techniques for expanding the operating bandwidth. Nevertheless, DEWD has interesting properties that offer the antenna designer yet another option. That is sufficient to certify the initial development work of UR0GT.

*Appendix 1: Extended Frequency Separation of DEWD Resonant Frequencies*

Thus far, we have examined only cases in which the DEWD resonant frequencies are close enough together so that the intervening small spectrum segment forms a continuous passband within fairly restrictive SWR values. In other words, by limiting the impedance of the mid-band resonant frequency, the offset element pair forms a single wide-band antenna. This condition is not necessary for proper operation of the element pair. We may in fact select, within limits, widely separated frequencies and obtain dipole operation on each frequency, generally ignoring the region between the frequencies of interest. By judicious selection of half-element lengths and the length of the crossing feed wire, we can obtain proper operation for frequency ratios of well over 2:1 between the lower and upper operating bands, with a limit of sorts emerging at a ratio of about 3:1. As well, we can in most cases obtain very similar resonant impedance values at both frequencies by a correct selection of the dimensions.

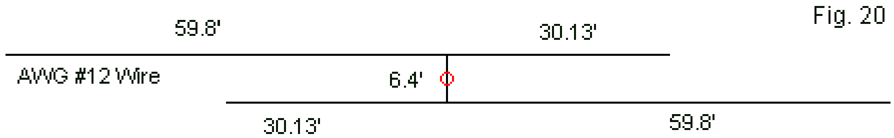


Fig. 20

General Outline and Dimensions of a 75-40-Meter Offset-Element Dual-Band Dipole

**Fig. 20** shows the outline and dimensions of an AWG #12 copper wire antenna for 75 and 40 meters. The resonant frequencies are 3.875 and 7.15 MHz. The resulting patterns on each band resemble those in **Fig. 3** for the band edges of the original DEWD. The tilt angle for patterns taken from the broadside edge of the array increase to about 6° relative to broadside, while the gain is about 2 dBi on each frequency.

The impedance behavior of the dual-band dipole (no longer a single-band wideband dipole) has essentially the same characteristics that we found for the original version of the antenna. **Fig. 21** graphs the resistance and reactance of the antenna from 3.5 to 7.5 MHz. As was the case with the initial antenna, the reactance forms an S-curve that crosses the zero-value line in three places: at the lower and the higher resonant frequencies and at a frequency between the two. As we separate the upper and lower resonant frequencies, the resistance at mid-band resonance becomes very high (about 900 Ω in this instance), while the reactance curve is very steep in this region. The actual resonant frequency is about 4.99 MHz, which does not equal either the arithmetic or geometric mean between the two resonant frequencies.

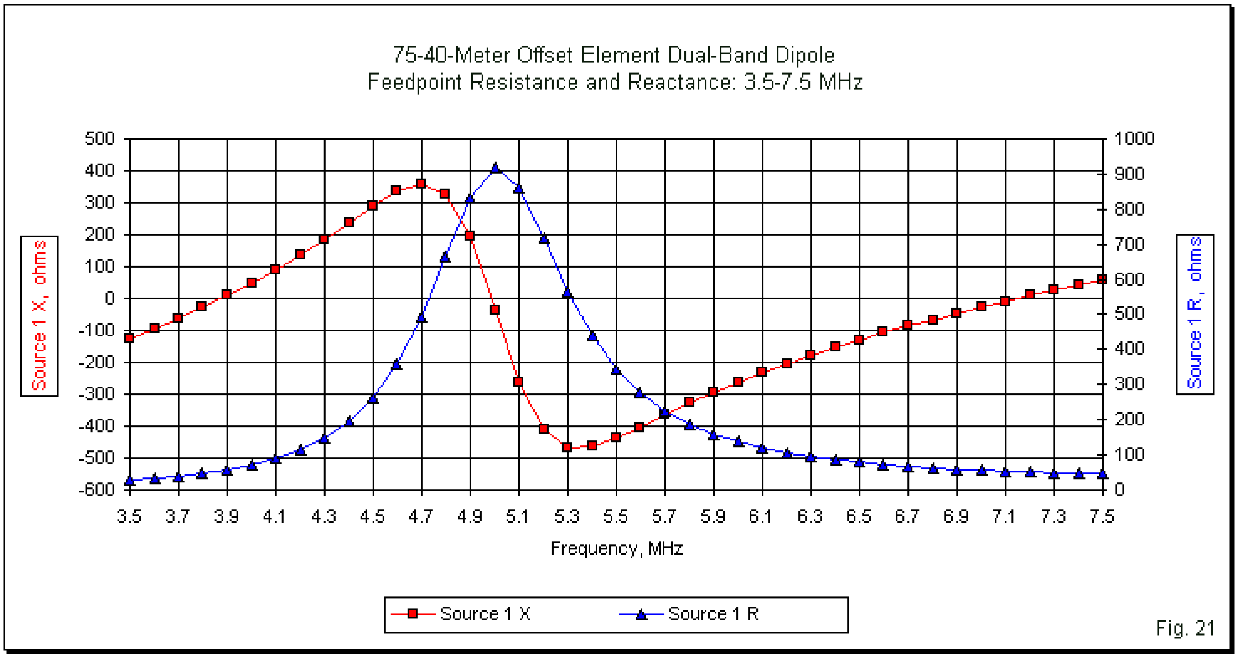


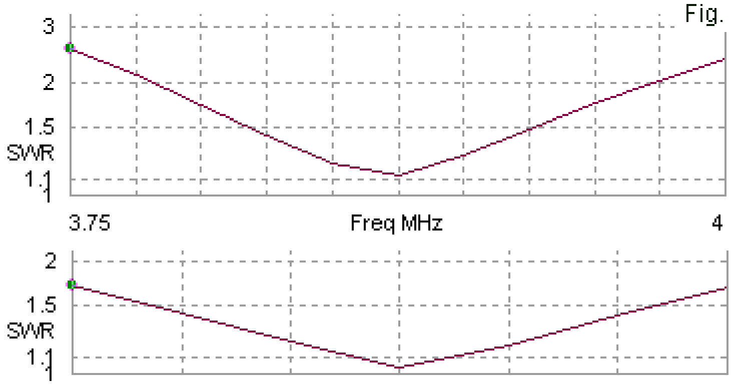
Fig. 21

Within the regions of low-impedance resonance, the antenna exhibits several interesting properties. First, at the lower resonant frequency, the current ratio of longer half-element to shorter half-element is over 9:1, with a 125° phase angle difference. At the upper resonant frequency, the ratio of the shorter to the longer half-elements is about 6:1, with a 135° phase-angle difference. Both the current magnitude ratios and the phase-angle differences are greater than we found for the two resonant frequencies in a single-band wideband version of the antenna.



Most dual-band dipoles using a common feedpoint tend to show a significant reduction in the operating bandwidth of the upper band if the angles that separate the two dipole wires are less than 90°. For example, a typical linear 75-meter dipole with a sloping 40-meter dipole (or inverted-V) suspended below—where both elements use the same feedpoint in a parallel connection—manages to cover only about half the 40-meter band with a 50-Ω SWR value of 2:1 or less. In contrast, as shown in the SWR sweeps on **Fig. 22**, the offset-element dual-band dipole provides full coverage of both bands relative to the performance of independent dipoles for each resonant frequency using the same wire diameter. A wire dipole for 75 meters normally provides a 2:1 SWR passband that is about 180 kHz wide, while a dipole for 40 meters is capable of covering the entire band. The present antenna meets both standards using a 50-Ω reference impedance.

Fig. 22



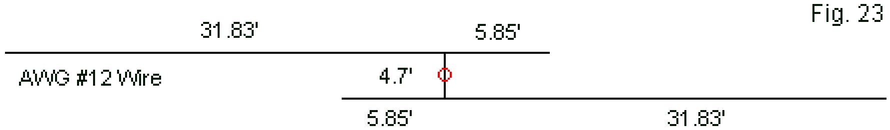

50-Ohm SWR Sweeps of a 75-40-Meter
Offset Element Dual-Band Dipole

There are a number of reasons why a ratio of about 3:1 between the upper and lower frequency resonant frequencies forms a limit to the operation of the offset-element dual-band dipole. The reasons will become virtually self-evident from an example. In past decades, amateurs commonly pressed their 40-meter dipoles into service on 15 meters. Even though the antenna feedpoint impedance usually exceeded 100 Ω on the upper band, the tunable pi-networks commonly used in final amplifier stages could easily handle SWR values up to 3:1 within the tuning range of the components. With the advent of solid-state fixed-component output networks, the practice of covering both 40 and 15 meters with a 40-meter dipole has almost vanished. Moreover, on 15 meters, the typical 40-meter dipole is about 3/2-λ long, yielding a pattern with weak broadside radiation and stronger lobes at an angle to the.



To test whether the offset-element dual-band dipole might overcome the problems of a single 40-meter dipole used on both bands, I reconfigured the antenna for the required 3:1 ratio. The outline in **Fig. 23** is the result. The selected resonant frequencies are 7.15 and 21.225 MHz. The design is a compromise between performance and impedance considerations.

Fig. 23




General Outline and Dimensions of a 40-15-Meter
Offset Element Dual-Band Dipole

Although the resonant frequencies are widely separated, the overall impedance performance continues to follow the established pattern. **Fig. 24** graphs the resistance and reactance behavior. The reactance displays the familiar (distorted) S-curve with three crossings of the zero-level line. Relative to the frequency span between the upper and lower resonant frequencies, the mid-band resonant frequency is quite low (about 10.6 MHz). The greater span between the operating frequencies also yields a very high resistive impedance value at the mid-band resonant frequency (>2500 Ω). The current ratio between longer and shorter half elements at the lower resonant frequency is nearly 30:1, while the phase-angle difference is about 140°. We shall momentarily defer noting the current behavior at the higher frequency resonance.

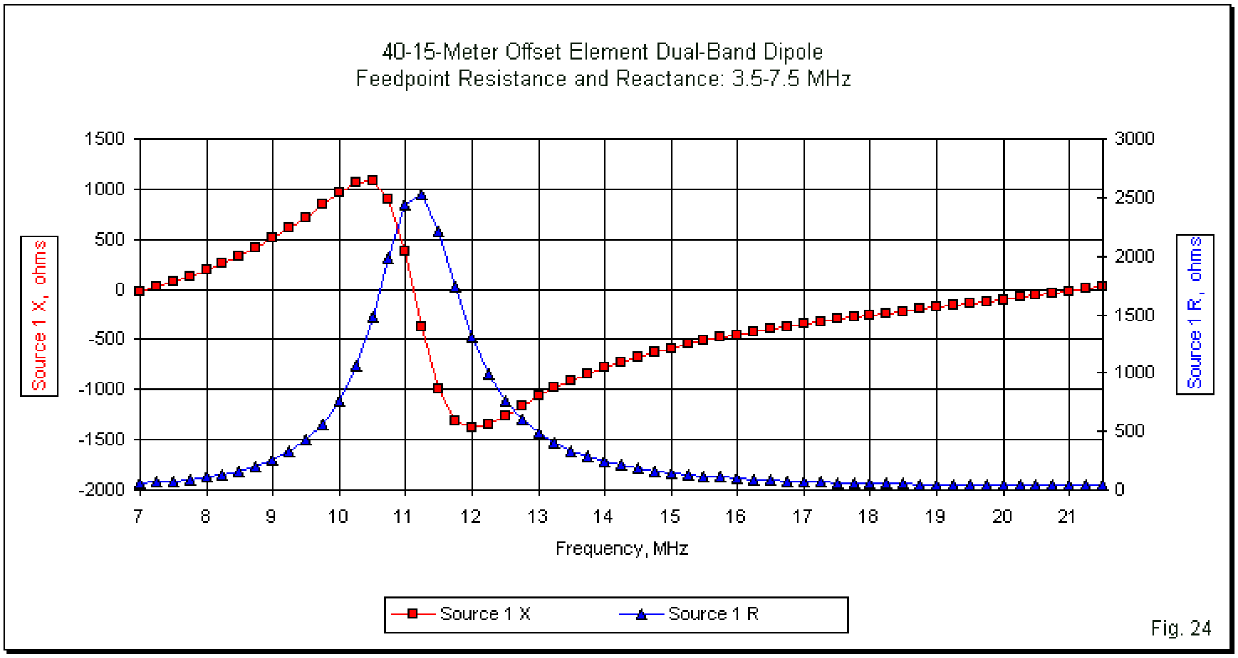
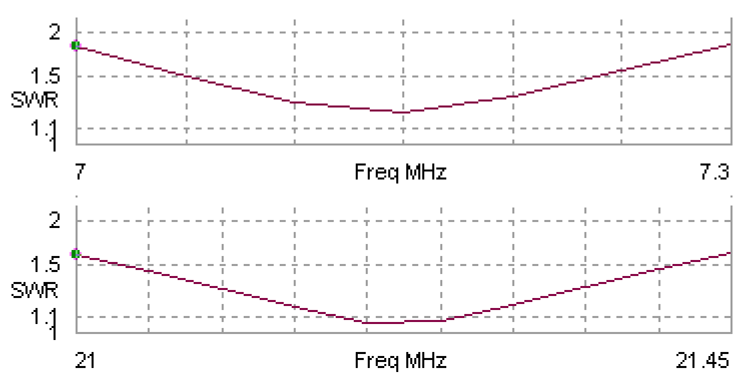



Fig. 24

One major limitation inherent in the offset-element dual-band dipole design involves the impedance at each selected resonant frequency. The diagram shows a 4.7' cross wire (and element spacing). The resulting (free-space model) impedances are about 60 Ω on 40 meters and 52 Ω on 15 meters. We may draw these impedance values closer together by increasing the length of the cross wire. However, we must then shorten the upper frequency half-elements accordingly to maintain resonance at 21.225 MHz. Shortening the upper frequency half-elements reduces the maximum bi-directional gain that we can obtain on 15 meters.



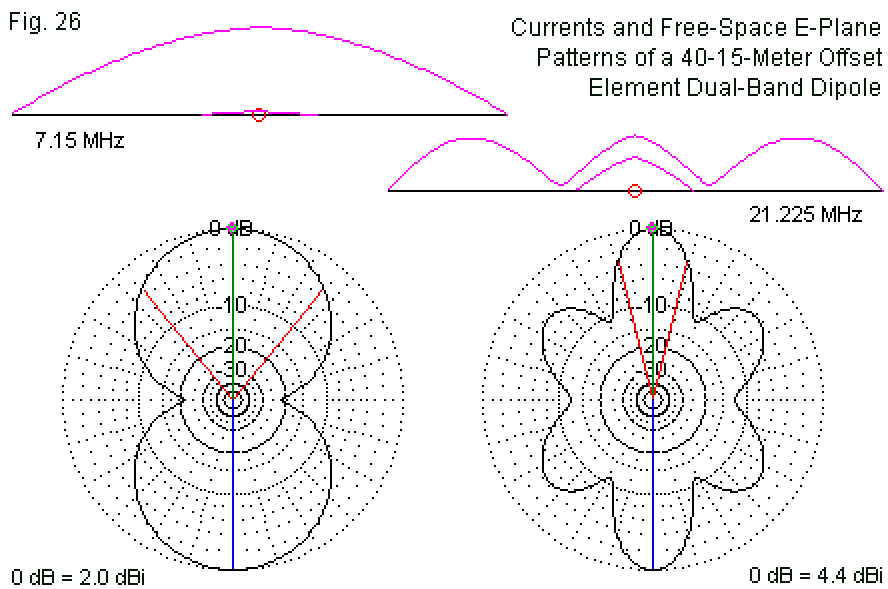
Fig. 25




50-Ohm SWR Sweeps of a 40-15-Meter
Offset Element Dual-Band Dipole

Within each operating band, as shown in **Fig. 25**, the resistance and reactance change relatively slowly. As a result, even with the resonant impedance values listed, the antenna is capable of providing less than 2:1 50-Ω SWR values across each of the bands covered. To preserve the performance level at as high a level as possible, I used the smallest spacing that would yield such SWR curves. When placed over ground at typical amateur heights (say, 45' above average ground) and readjusted for ground effects, the 40-meter impedance tends to rise to about 70 Ω because the height is only about 0.3 λ. The 15-meter impedance remains virtually unchanged since the height at 21.225 MHz is about 1 λ.

Radiation performance is not a concern on the lower of the two bands. As shown in the current distribution curve and free-space E-plane pattern for 40 meters in **Fig. 26**, dipole operation is perfectly normal. On 15 meters, we obtain a wholly different picture. The longer-to-shorter current ratio is about 2.3:1, with a 165° phase-angle difference. As the current distribution curve reveals, the longer element acts like a 3/2-λ element, countered in the center by the nearly out-of-phase shorter element. The result is almost (but not exactly) 3/2 wavelengths in phase. A more closely analogous radiation pattern would be the one generated by a collinear sleeve array. The pattern resembles the plot of an extended double Zepp, with a similar broadside gain level that is nearly 2.5-dB stronger than the dipole on 40 meters. The sidelobes are weaker by about 4.5 dB than the bi-directional main lobes. Widening the spacing between elements and therefore shrinking the length of the shorter half-elements tends to reduce the 15-meter broadside gain.




Neither pattern shows the offset with which we have become familiar. The reason is straightforward. The offset patterns occur when we take patterns off the edge of the plane formed by the two half-element sets. The present patterns are taken off the flat of the plane formed by the elements. The edgewise orientation on 40 meters would yield the familiar pattern tilt from broadside. On 15 meters, the main effect falls on the sidelobes. One pair of side lobes grows stronger, while the other pair diminishes in 180° lines across the E-plane pattern. The stronger sidelobes (down by only about 3.5 dB from the true broadside lobe) tilt toward the shorter half-elements. The weaker sidelobes (down by about 7 dB) angle toward the longer half-elements.

Further increases in the ratio of upper to lower resonant frequencies would have two major consequences. First, the longer half-elements would dominate pattern formation at both frequencies. Second, the shorter half-element would virtually disappear as the entire length would be absorbed in the cross wire. The 3:1 ratio used in the design of the 40-15-meter dual-band dipole represents a practical limit to the use of the offset-element scheme, and has its own imperfections relative to the usual specifications for the design. The upper limit of frequency separation prior to the domination of the longer half-elements at the upper frequency remains unknown at this time.

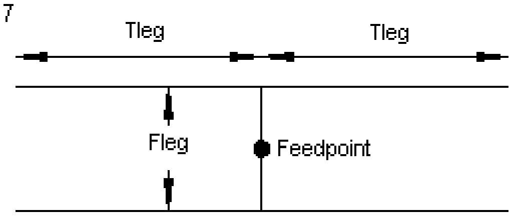
Nevertheless, the exercise in extending the frequency difference between the two operational resonant points does establish that the offset-element dual-band dipole is more general a design than solely for the purposes of developing a single-band wideband antenna. These notes are purely descriptive, based on NEC-4 models of the various antenna geometries considered. In both DEWD and dual-band forms, the antenna provides an interesting set of future exercises, at one extreme, looking for further potential applications and, at the other extreme, providing the design with a suitable theoretical foundation.

*Appendix 2: The Evolution of DEWD from the T-Hatted Dipole*

One way to look at the origins of the offset-element wideband or dual-band dipole is to examine a similar looking antenna: the short dipole with T-hat wires on each end to bring it to resonance. We shall take our journey in three steps. First, we shall confirm the behavior of T-hatted dipoles, even to very short dipole lengths. Next, we shall begin a process of offsetting the T-wires to observe what happens to the radiation pattern and the feedpoint impedance. Finally, we shall optimize the result to end up with our first sample of a DEWD, a wideband antenna covering the entire 80/75-meter band with a 50-Ω SWR of less than 1.5:1. As in most of our other exercises, we shall use 2-mm-diameter copper wire in free space with a design frequency of 3.75 MHz.

Step 1: *Confirming the behavior of T-hatted dipoles*: Of the many ways of resonating short dipoles, placing wire hats on each end of the dipole yields the greatest efficiency. While many such hats use symmetrical arrangements of many wires, we can achieve the same goal with only two wires, each the same length. Two wires in opposite directions provide nearly complete cancellation of radiation from wires beyond the dipole proper. As well, they provide current paths sufficiently long to allow the short dipole to reach resonance. With only two wires at each end of the dipole, as shown in **Fig. 27**, the antenna has acquired an alternative name: the double-T. We find such antennas in use in both vertical and horizontal configurations.

Fig. 27




Outline of a Double-T-Hat Dipole

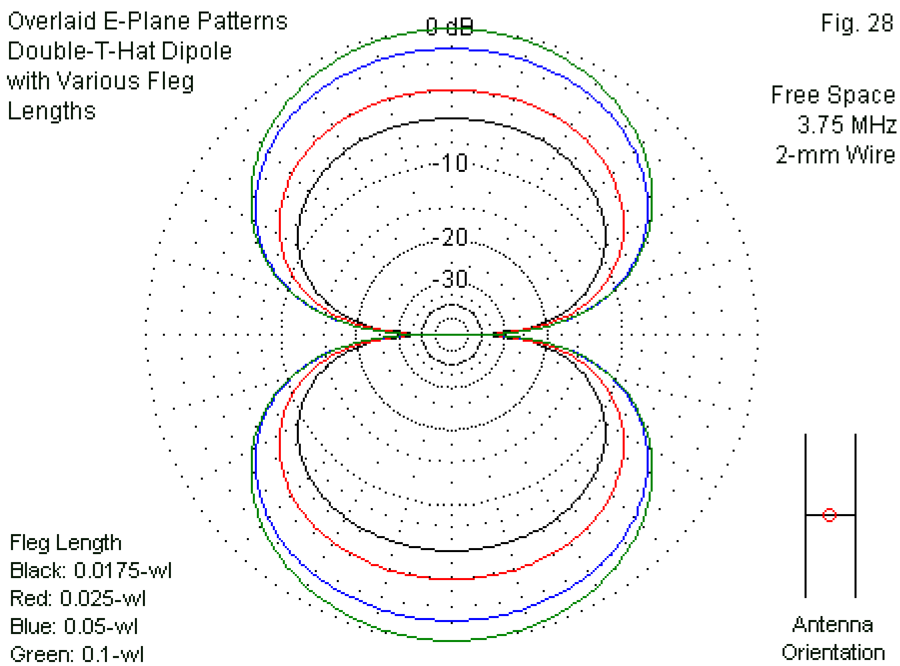
The T-hat dipole has only two significant dimensions besides the wire diameter: the length of the fed dipole (Fleg) and the length of each wire in the Ts (Tleg). Our interest is not in practical T-hat dipole sizes. Instead, we want to see what happens to performance as we reduce the Fleg length to impractically small sizes, namely, from 0.1-λ down to 0.0175-λ. **Table 4** provides the data on the dimensions and the NEC-4 free-space performance values of note.

Table 4. T-hat Dipole dimensions and performance

| Fleg | Tleg | Max Gain | Feedpoint Z |
|---|---|---|---|

| λ | λ | dBi | R +/- jX Ω |
|---|---|---|---|
| 0.1 | 0.165 | 1.07 | 9.0 + j1.0 |
| 0.05 | 0.205 | -0.08 | 3.0 – j0.2 |
| 0.25 | 0.2275 | -2.27 | 1.4 + j0.4 |
| 0.175 | 0.234 | -4.91 | 1.1 – j0.8 |

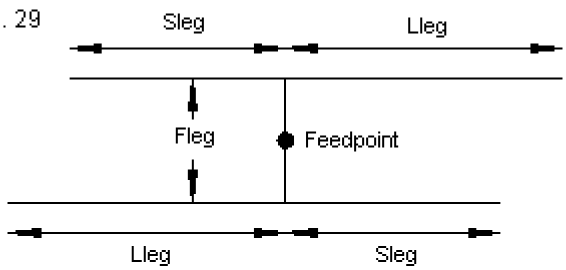
As we shorten the length of Fleg, Tleg grows longer. Both the gain and the feedpoint diminish accordingly. What remains constant is the general shape of the E-plane pattern for all dipole lengths in the sequence. **Fig. 28** overlays the patterns for the four sample T-hat dipoles. Regardless of the dipole length, the patterns form typical figure-8 patterns with maximum gain broadside to the fed dipole element. Effectively, the T-hat wires do not contribute to the radiation pattern.




With the shortest two dipole lengths (0.0175-λ and 0.025-λ), we have elements that are within the range of the fed cross wires of offset-element dipoles. However, so long as the T-hat wires form a perfectly symmetrical arrangement, the dipole radiation is at right angles to the radiation we expect from offset-element arrays.

Step 2: *The evolution of the offset-element dipole pair*: Even the slightest asymmetry in the T-hat end wire assembly begins to erode the figure-8 dipole pattern. The offset-element mode of asymmetry requires that we use a special arrangement of end wires, with two shorter but equal wires and 2 longer but equal wires, where each end of the fed wire joins to one short and one long wire. **Fig. 29** defines the familiar offset pattern, with obvious designations: Lleg, Sleg, and Fleg.

Fig. 29




Outline of an Offset-Hat Dipole

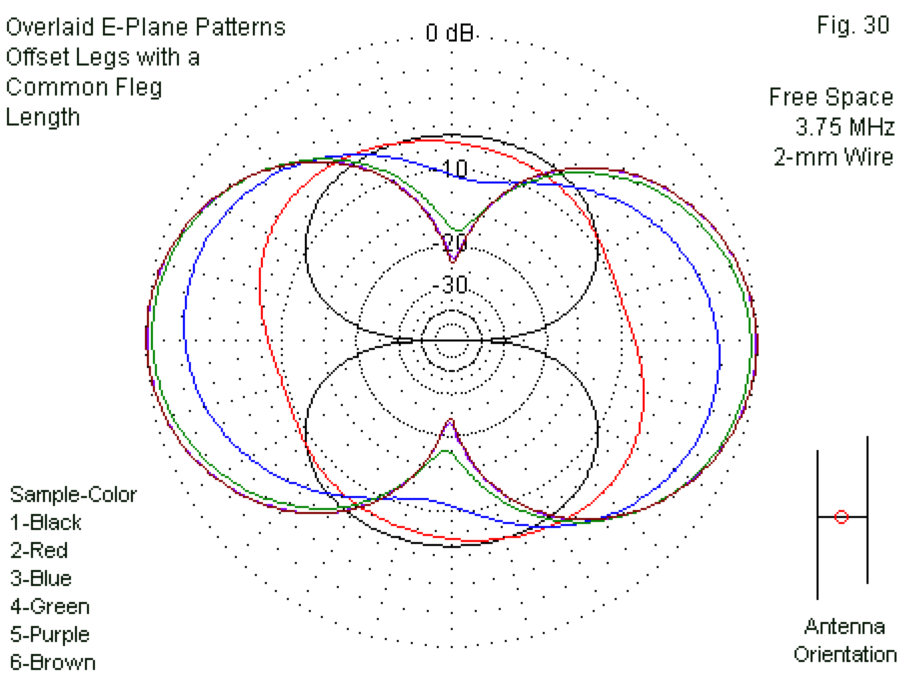
We may begin a slow process of lengthening Lleg and shortening Sleg by equal amounts to preserve array resonance at the 3.75-MHz design frequency. **Table 5** records the dimensions and key performance information for selected points in the process.

Table 5. Offset end elements (Lleg and Sleg) with a constant Fleg (0.175-λ): dimensions and performance

| Sample Number | Lleg λ | Sleg λ | Max Gain dBi | Angle degrees | Feedpoint Z R +/- jX Ω |
|---|---|---|---|---|---|
| 1 | 0.234 | 0.234 | -4.91 | 0 | 1.1 – j0.8 |
| 2 | 0.235 | 0.233 | -4.18 | 45 | 1.3 – j0.8 |
| 3 | 0.237 | 0.231 | -0.27 | 79 | 2.6 – j0.6 |
| 4 | 0.242 | 0.226 | 1.59 | 86 | 11.9 + j0.0 |
| 5 | 0.249 | 0.219 | 1.89 | 88 | 39.5 + j0.6 |
| 6 | 0.251 | 0.217 | 1.92 | 90 | 50.6 + j0.3 |

Notes: 1. Sample 1 is the same as the last sample in Table 4.
2. Angle is relative to the broadside direction from the feedpoint wire.

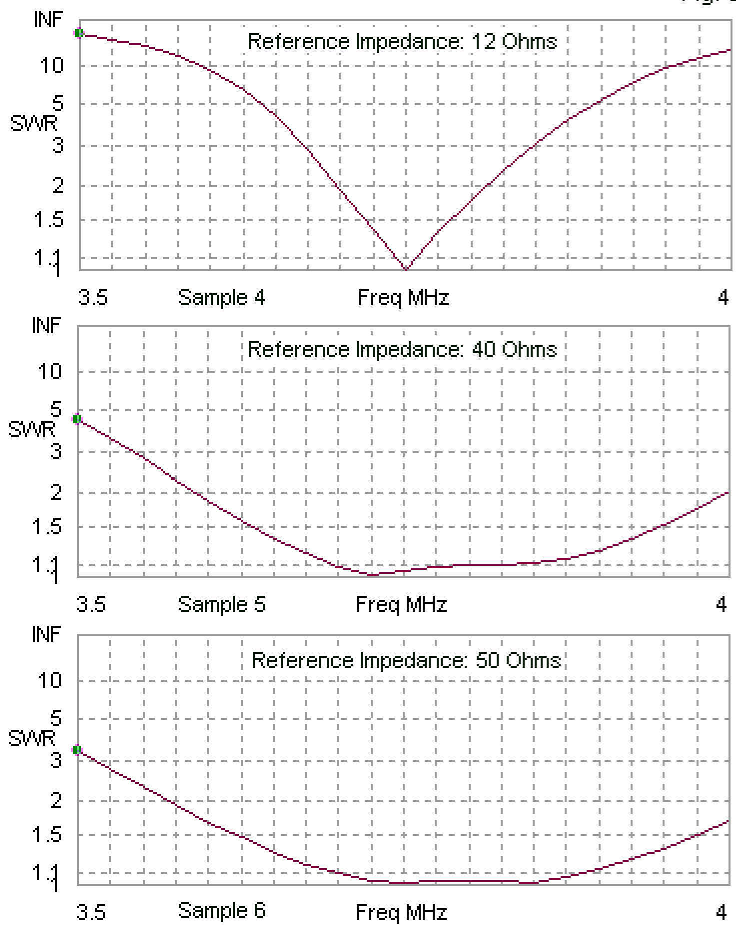




Associated with the tabular data are the overlaid patterns in **Fig. 30**. The data and patterns all use a fed wire that is 0.0175-λ long. Only the T-wires at each end of the fed wire change their relative lengths. The collection begins with the pattern for a symmetrical set of wires and yields a pattern broadside to the center fed wire. Even an offset as small as 0.001-λ per end wire is sufficient to change the directions of maximum gain by 45°, although the overall pattern shape looks to be closer to 30° off the dipole pattern.

As we increase the degree of the offset, the pattern continues to rotate while maintaining resonance. However, the resonant impedance value also increases with each further step of offset. With an offset of 0.017-λ per end wire, the pattern is now broadside to the former hat wires. As well, the 3.75-MHz impedance has climbed to 50 Ω. See **Fig. 31**.

Fig. 31




3.5-4.0-MHz SWR Sweeps of Offset Element Dual Dipoles

As we increase the offset in the end wires, we find not only an increase in the resonant impedance level, but as well a broadening of the operating passband relative to the resonant impedance. Sample 4, with about half the final offset distance, shows both a very low impedance value and a very narrow passband window with a single minimum value. Sample 5 has close to a 40-Ω resonant impedance and reveals an incipient second SWR minimum. The final sample displays two distinct resonant frequencies, the sign of a true offset-element dipole. As well, of all the samples, the last one exhibits the widest passband. The final sample also shows the highest gain of the group, with a broadside pattern relative to the offset wires.

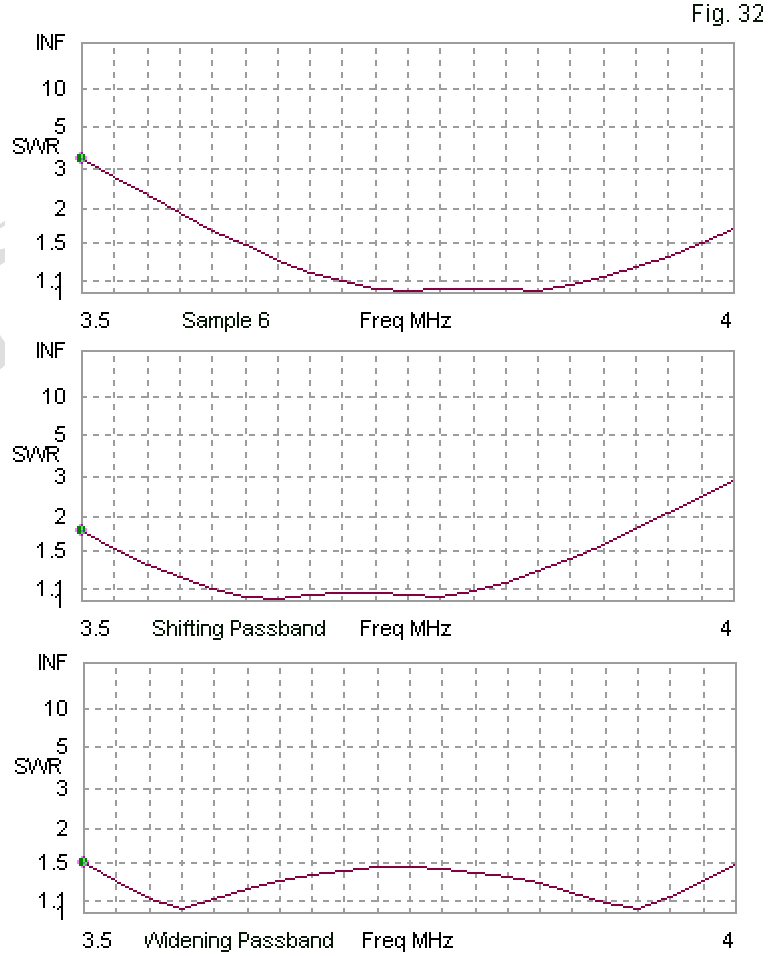
Step 3. *Optimizing the offset dipole for the 80/75-meter band*: The evolution of the T-hat dipole into the offset-element dipole pair retained a resonant impedance value at 3.75 MHz. By a series of routine, although often not simple adjustments, we may manipulate the array dimensions until it satisfies what ever standard we might set up for a wideband antenna covering 3.5 to 4.0 MHz. Although we might mix our work in practice, let's go through the process in the steps shown in **Table 6**. Associated with the table are the 50-Ω SWR sweeps in **Fig. 32**.

Table 6. Optimizing the wideband dual-element dipole

| Step Number | Fleg λ | Lleg λ | Sleg λ | Z @ 3.75 MHz R +/- jX Ω | Res-low MHz | Res-high MHz |
|---|---|---|---|---|---|---|
| 1 | 0.175 | 0.251 | 0.217 | 50.6 + j0.3 | 3.75 | 3.85 |
| 2 | 0.175 | 0.257 | 0.222 | 51.3 – j2.0 | 3.625 | 3.80 |
| 3 | 0.185 | 0.2574 | 0.2164 | 72.1 – j2.5 | 3.575 | 3.925 |

Note: Step 1 is the same as Sample 6 in Table 5.

Fig. 32




3.5-4.0-MHz 50-Ohm SWR Sweeps of Evolving DEWD

The first step replicates the final sample from **Table 5**. With the dimensions shown, it yields resonant frequencies of 3.75 and 3.85 MHz, both of which are clear in the SWR sweep graphs. We may improve the overall position of the passband by adjusting only the values of Lleg and

Sleg, without altering the value of Fleg. The result of this trial is a movement lower into the passband of the dual resonant points. The new resonant frequencies are 3.625 and 3.80 MHz. In the process, the mid-band frequency, 3.75 MHz, falls close to the middle of the passband. However, with nearly symmetrical changes in the lengths of Lleg and Sleg, we did not succeed in widening the passband.

To achieve a wider passband, we must be willing to allow the impedance at 3.75 MHz to rise above the 50-Ω level. As well, we must obtain a greater separation in the 50-Ω resonant frequencies. The third step in the process shows how we can accomplish these goals. By increasing the length of Fleg to 0.0185-λ, we automatically increase the path length between the tips of the two Lleg sections. Therefore, the actual increase in the value of Lleg is only 0.0004-λ to place the lower resonant frequency at 3.575 MHz. To increase the upper resonant frequency, we must shorten Sleg by a greater amount that also compensates for the greater length of Fleg. Hence, we reduce Sleg by 0.0056-λ to achieve a shorter path length between the tips of the two Sleg sections.

The end result is the SWR sweep at the bottom of **Fig. 32**. The 50-Ω SWR just reaches 1.5:1 at the band edges. In fact, we have replicated the 80/75-meter DEWD used as the initial example in this body of notes. The final optimizing steps in our process provide guidance for anyone who wishes to develop DEWDs for custom bandwidths.

Our three-step exercise provides a glimpse into the natural progression of element behaviors, beginning with T-hat dipoles, evolving into offset element dipoles, and ending with an optimized array for use on a very wide (13%) amateur band. Hopefully, the progressions provide some insight into how and why the offset-element dipole array works.

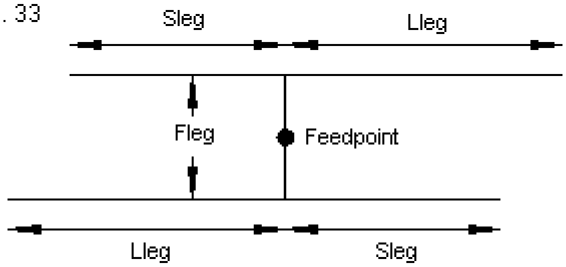


*Appendix 4: The 80/75-Meter DEWD over Real Ground*

The DEWD calculating spreadsheet noted earlier has a limitation. It calculates the dimensions for the dual-element wideband dipole in a free-space environment. Since many antenna's applications will occur from 10 meters upward in frequency for antennas that either are vertically oriented of, if horizontal, are well over 1 λ above ground, the dimensions will be very close to those required for a real-world antenna. They will be within the normal range of construction variables.

One major category of application is an exception to this general rule: use of the DEWD antenna with wire construction to cover the entire 80/75-meter band. To ease the problem of finding applicable dimensions, I am adding this note for guidance.

Fig. 33




DEWD Outline with "Leg" Designations

**Fig. 33** repeats the standard general outline of the DEWD array in order to provide references to the designations used in the guidance table (**Table 7**). Beginning with the free-space calculated dimensions, I customized the antenna at heights from 10 meters up to 80 meters (roughly 1/8-λ up to 1.0 λ) in 10-meter steps. (10 meters is roughly 33'.) This range covers virtually every installation height of which I have heard of for an 80/75-meter antenna over my years in amateur radio. All models are above average ground, so they may require additional adjustment, especially at low heights, for more extreme ground conditions, either better or worse than average. As well, expect variations due to local installation site conditions and constructions methods.

Each height is listed in both meters and feet. The dimensions of each "leg" appear in wavelengths, meters, and feet. The dimensions derive from a design frequency of 3.75 MHz, the arithmetic center of the 80/75-meter band. The wire size is 2-mm, which is intermediate in diameter between AWG #14 (often found in copper-clad steel wire) and AWG #12 (usually hard drawn for antenna use). The very slight differences in wire diameter over this range should not result in dimension variations that fall outside the range of construction variables.

| 80/75-Meter Dual-Element Wideband Dipole (DEWD): Dimensions for Various Heights Above Average Ground | | | | | | | | | | | Table 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ht m | Ht ft | Fleg wl | Fleg m | Fleg ft | Lleg wl | Lleg m | Lleg ft | Lleg wl | Sleg m | Sleg ft | SWR Mx |
| Free Space | | 0.0198 | 1.573 | 5.16 | 0.2569 | 20.410 | 66.96 | 0.2159 | 17.153 | 56.27 | |
| 80 | 262.47 | 0.0192 | 1.525 | 5.00 | 0.2582 | 20.513 | 67.30 | 0.2170 | 17.240 | 56.56 | |
| 70 | 229.66 | 0.0192 | 1.525 | 5.00 | 0.2582 | 20.513 | 67.30 | 0.2162 | 17.176 | 56.35 | |
| 60 | 196.85 | 0.0184 | 1.462 | 4.80 | 0.2565 | 20.378 | 66.86 | 0.2154 | 17.113 | 56.14 | |
| 50 | 164.04 | 0.0185 | 1.470 | 4.82 | 0.2570 | 20.418 | 66.99 | 0.2168 | 17.224 | 56.51 | 1.61:1 |
| 40 | 131.23 | 0.0186 | 1.478 | 4.85 | 0.2595 | 20.616 | 67.64 | 0.2183 | 17.343 | 56.90 | 1.52:1 |
| 30 | 98.43 | 0.0182 | 1.446 | 4.74 | 0.2597 | 20.632 | 67.69 | 0.2162 | 17.176 | 56.35 | |
| 20 | 65.62 | 0.0194 | 1.541 | 5.06 | 0.2556 | 20.307 | 66.62 | 0.2136 | 16.970 | 55.68 | |
| 10 | 32.81 | 0.0220 | 1.748 | 5.73 | 0.2519 | 20.013 | 65.66 | 0.2146 | 17.049 | 55.94 | 1.74:1 |
| Notes: | Ht = height in meters (m) and feet (ft) | | | | | | | | | | |
| | See Figure 33 for meaning of Fleg, Lleg, and Sleg. Lengths in wavelength (wl), meters (m), and feet (ft). | | | | | | | | | | |
| | SWR Mx = maximum 50-Ohm SWR if greater than 1.5:1 | | | | | | | | | | |

For most heights in the chart, it is possible to find dimensions that will allow the array to achieve a maximum 50-Ω SWR of less than 1.5:1 across the band. The key checkpoints are the SWR values at 3.5, 3.75, and 4.0 MHz. In a few cases, this goal proved unachievable. The final column lists the maximum SWR values wherever the SWR exceeded the 1.5:1 limit. In all cases, the maximum SWR falls well below the usual amateur standard of 2:1. However, the SWR peaks at the checkpoints may limit the antenna's use with an amplifier employing a sensitive fold-back circuit.

There are very good reasons why the antenna cannot achieve the bandwidth goals at every height. Every horizontal antenna is sensitive to changes in the feedpoint impedance at heights below about 1.5 λ. Antennas whose feedpoint impedance is partly a function of the interaction of two or more elements, such as in parasitic and phased horizontal arrays, tend to show far less sensitivity to the height above ground than dipoles, which have no other external influence upon the feedpoint impedance than the ground.

**Fig. 34** illustrates the variations in feedpoint impedance with height using an AWG #12 copper wire dipole that is resonant in free space at 3.75 MHz. The resistance and the reactance at the feedpoint progress in cycles that roughly repeat with every half-wavelength of additional height. The peak values of resistance and reactance increase with decreasing height above ground. As a consequence, the resonant length of a dipole will change as we change the antenna's height. A study of the cycles will provide clues as to why some heights are not amenable to holding the DEWD 50-Ω SWR to a value less than 1.5:1.

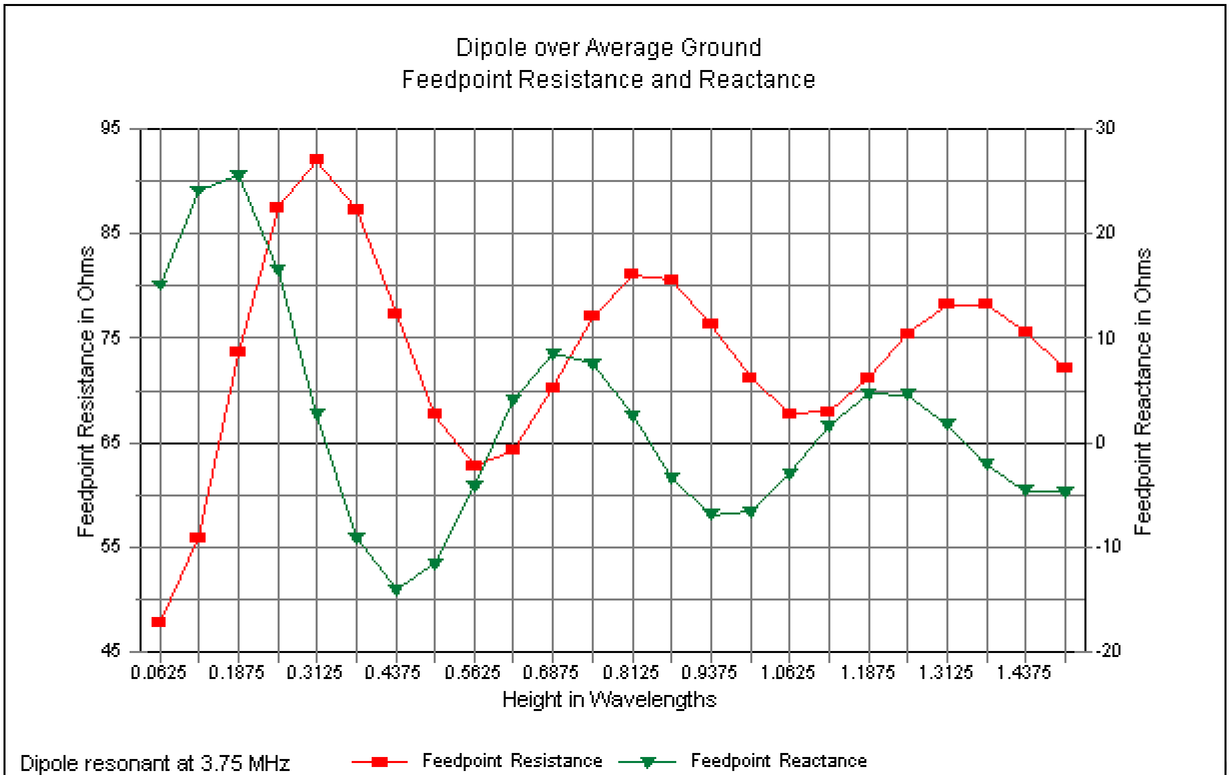


Fig. 34

When exploring the chart, remember that 10 meters of height is approximately 1/8-λ (0.125-λ on the X-axis). One factor is the relatively low dipole resistive component at these heights. **Table 8** provides the resonant lengths and the resonant impedance values for each height based on adjusting the modeled dimensions. In free space, a single wire dipole has an impedance of about 72 Ω. The outer resonant points of a DEWD array is close to 50 Ω, about 70% of the single-wire value. If we select a height with a lower single-wire dipole resonant impedance value, the outer resonant points of the DEWD will tend to decrease their impedance values accordingly. As a second factor, the height region from ½-λ to 5/8-λ falls in a relatively steep portion of the reactance curve on the capacitive side of the zero-line. The table of resonant lengths shows a difference of about 1.2' between the values for ½-λ and 5/8-λ.

To the list we may add a third factor. A wavelength at 3.5 MHz is nearly 15% longer than a wavelength at 4 MHz. Therefore, for a given height, the upper and the lower resonant frequencies fall on different portions of the resistance-reactance variation curves, with the mid-band falling on a third point. At some heights, the combination of variations on the free-space values may result in a situation in which it is not possible to arrive at a compromise set of dimensions that satisfy both the band-edge and the mid-band requirements for a wide-band antenna that has less than 1.5:1 50-Ω SWR everywhere within the passband.

Indeed, there has long been a search for a scheme that will produce a single-element wide-band dipole that alone or in conjunction with carefully constructed feedline combinations will allow full coverage of the 80/75-meter band with less than a 2:1 SWR. Frank Witt, AI1H, has long led the search for and evaluation of such schemes, and the extensive coverage to the subject in Chapter 9 of the current edition of *The ARRL Antenna Book* owes much to his work. The chapter and the referenced articles are necessary background to understanding the DEWD array. Of interest as a footnote is that fact that many of the broadband schemes for the 80/75-

meter band that Witt discusses are height-limited. That is, they work well only within certain height ranges above ground. In general, they favor heights between 50' and 120' above ground, that is, between the 10-meter and the 40-50-meter heights that prove difficult for DEWD to achieve its SWR goals.

| Resonant Lengths and Feedpoint | | | | | | Table 8 |
|---|---|---|---|---|---|---|
| Impedance of a 3.75-MHz AWG #12 Copper | | | | | | |
| Dipole at Various Heights above Average Ground | | | | | | |
| Ht wl | Ht ft | Ht m | Res L wl | Res L ft | Res L m | Res Imp |
| 0.0625 | 16.39 | 5.00 | 0.4825 | 126.55 | 38.57 | 46.7 |
| 0.1250 | 32.79 | 9.99 | 0.4802 | 125.95 | 38.39 | 53.6 |
| 0.1875 | 49.18 | 14.99 | 0.4800 | 125.90 | 38.37 | 70.5 |
| 0.2500 | 65.57 | 19.99 | 0.4823 | 126.50 | 38.56 | 85.0 |
| 0.3125 | 81.96 | 24.98 | 0.4860 | 127.47 | 38.85 | 91.5 |
| 0.3750 | 98.36 | 29.98 | 0.4895 | 128.39 | 39.13 | 88.7 |
| 0.4375 | 114.75 | 34.98 | 0.4910 | 128.78 | 39.25 | 79.3 |
| 0.5000 | 131.14 | 39.97 | 0.4903 | 128.60 | 39.20 | 69.1 |
| 0.5625 | 147.54 | 44.97 | 0.4880 | 128.00 | 39.01 | 63.2 |
| 0.6250 | 163.93 | 49.97 | 0.4858 | 127.42 | 38.84 | 63.8 |
| 0.6875 | 180.32 | 54.96 | 0.4844 | 127.05 | 38.72 | 69.2 |
| 0.7500 | 196.71 | 59.96 | 0.4848 | 127.16 | 38.76 | 76.1 |
| 0.8125 | 213.11 | 64.96 | 0.4860 | 127.47 | 38.85 | 80.7 |
| 0.8750 | 229.50 | 69.95 | 0.4878 | 127.94 | 39.00 | 81.0 |
| 0.9375 | 245.89 | 74.95 | 0.4888 | 128.21 | 39.08 | 77.3 |
| 1.0000 | 262.29 | 79.95 | 0.4888 | 128.21 | 39.08 | 72.0 |
| 1.0625 | 278.68 | 84.94 | 0.4877 | 127.92 | 38.99 | 68.2 |
| 1.1250 | 295.07 | 89.94 | 0.4865 | 127.60 | 38.89 | 67.8 |
| 1.1875 | 311.46 | 94.93 | 0.4855 | 127.34 | 38.81 | 70.6 |
| 1.2500 | 327.86 | 99.93 | 0.4855 | 127.34 | 38.81 | 74.8 |
| 1.3125 | 344.25 | 104.93 | 0.4865 | 127.60 | 38.89 | 78.0 |
| 1.3750 | 360.64 | 109.92 | 0.4875 | 127.86 | 38.97 | 78.5 |
| 1.4375 | 377.04 | 114.92 | 0.4880 | 128.00 | 39.01 | 76.1 |
| 1.5000 | 393.43 | 119.92 | 0.4880 | 128.00 | 39.01 | 72.6 |

One facet of Witt's work has been the calculation of the relative efficiency of each examined system across the 80/75-meter passband. He has found that many proposals achieve a wide SWR bandwidth only at the expense of significant losses. One merit of the DEWD dual-element array is that it maintains quite high efficiency across the entire band. Apart from feedline losses, which depend upon the cable type and length, and ground losses, the DEWD efficiency exceeds 96% from one end of the band to the other.

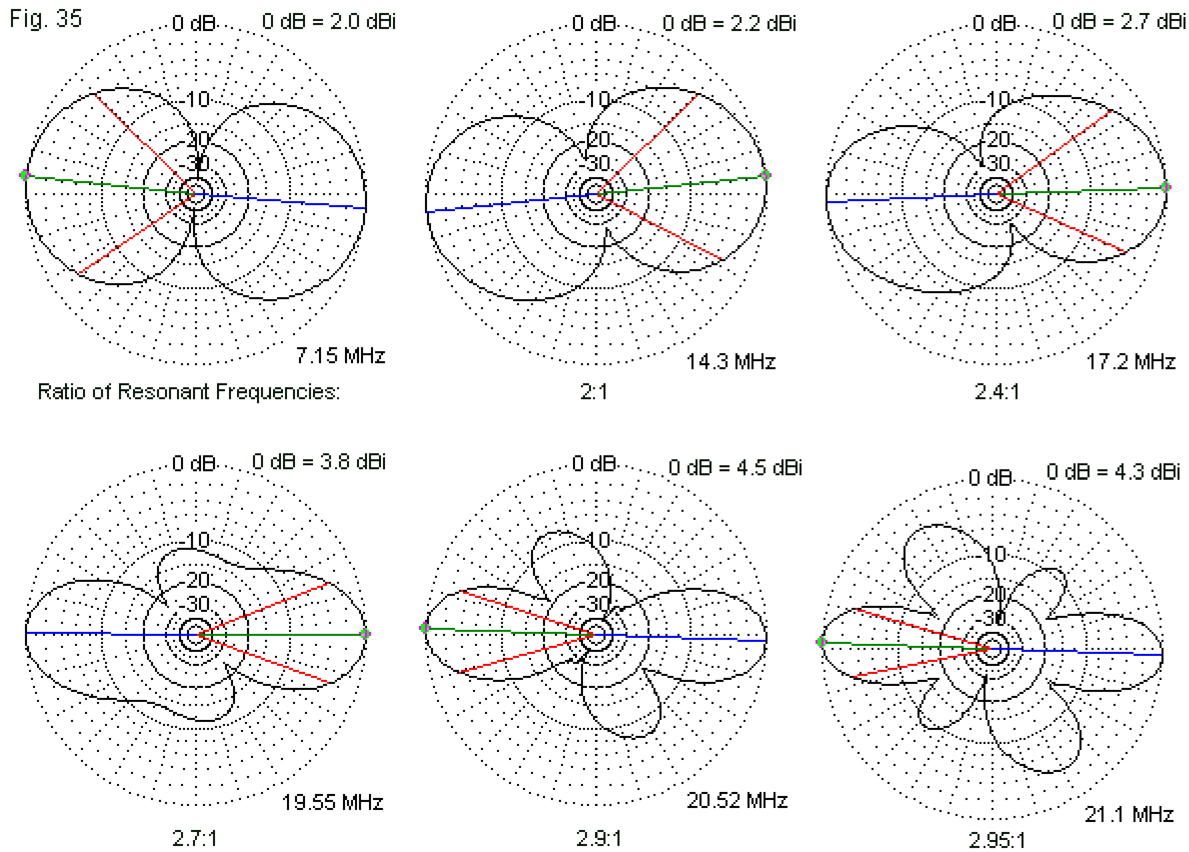
In the end, the 80/75-meter DEWD array is for the serious antenna installer. Its construction and support requirements likely surpass the needs of a casual operator whose antenna is quite low. For such operators, using an antenna tuner on the uncovered portions of the band for which cable losses are low, even with up to 5:1 SWR levels, may be a better match of needs and required resources. Even for the serious antenna builder and 80/75-meter user, these notes provide some initial guidance only. Refinements in preparation for an actual installation will require significant design work involving both the precise antenna height and the best estimate of ground quality at the site.

*Appendix 5: The Limit of the Offset-Element Dual-Band Dipole Frequency Spread*

At the end of Appendix 1, we left open the question of the upper frequency limit for an offset-element dual-band dipole version of DEWD, where the question is more precisely the maximum frequency ratio between the upper and lower resonant frequencies of the array. At a ratio of nearly 3:1, the longer element plays a dominant role in the pattern formation. In part, then, the question becomes at what point the pattern may be no longer acceptable for use in a dual-band dipole.

The general outline of the dual-band scheme appears in **Fig. 23**. **Fig. 26** shows the patterns for the upper and lower frequencies in the E-plane but taken broadside to the flat plane formed by the element pair. The present exercise will take E-plane patterns off the edge of the plane formed by the elements. The goal will be to explore these patterns with a rising upper resonant frequency. **Fig. 35** provides most of the data that we need.

Fig. 35




Evolution of the Upper-Band E-Plane Free-Space Pattern with Increases in the Ratio of the Upper-to-Lower Resonant Frequencies for an Offset-Element Dual-Band Dipole

At the upper left is the pattern for 7.15 MHz. It remains virtually constant, regardless of the upper resonant frequency. The half-power lines vary from one array version to another by no more than 1°. The remaining patterns derive from variations in the array that involve shortening the shorter half-elements incrementally to arrive at higher upper-band resonant frequencies. Two phenomena are immediately apparent in the sequence of patterns. First, the maximum gain increases with each increase in the ratio of the upper to the lower resonant frequency.

Second, pattern distortion relative to the anticipated dipole figure-8 pattern begins with as low a frequency ratio as 2:1 and increases as we raise the ratio. The distortion of the pattern with a frequency ratio of 2:1 seems harmless enough until we place it within the overall sequence of patterns.

On major change occurs between the ratios of 2.4:1 and 2.7:1. At the lower ratio, the pattern tilt appears to be simply a function of the offset element arrangement. However, with a frequency ratio of 2.7:1, we see the emergence of a significant lobe in the direction of the longer half-element pair (as indicated by the tilt direction at 7.15 MHz). The tilt and distortion at a ratio of 2.4:1 thus becomes a composite of the radiation from both the shorter and the longer elements. By a ratio of 2.7:1, the current magnitude on the longer element has grown to a level capable of yielding a distinct second lobe. In the process of lobe separation, the main lobe from the shorter element realigns itself to a more nearly broadside position.

The final two patterns for frequency ratios of 2.9:1 and 2.95:1 reveal the increasing current magnitude on the longer element. The growing current level initially yields a well-defined secondary lobe with only a hint of a tertiary lobe. However, by a resonant frequency ratio of 2.95:1, the third lobe has achieved high definition.

The initial question, then, has no definite answer. Upper resonant frequency pattern distortion becomes recognizable with frequency ratios as low as 2:1. At what ratio the pattern becomes unusable may depend upon the use to which one places the antenna. A fixed wire antenna may some times benefit from having two predictable and usably strong lobes on each side of the array. In other cases, the distortion with a resonant frequency ratio of 2.4:1 may exceed mission limits.



*Appendix 6: DEWD Design with a 1.1:1 Maximum 50-Ω SWR*

The calculation spreadsheet noted in the main text uses a 1.5:1 maximum 50-Ω SWR value to set the bandwidth of the dual element wideband dipole design. Within the passband, the SWR does not exceed the limit either at mid-band or at the band-edges. The design criterion satisfies the needs of most applications involving broader bandwidths, such as on the U.S. 80/75-meter band or in the VHF/UHF spectrum.

As one of the sample applications showed, it is possible to obtain even better SWR performance across a band as wide as the entire 10-meter amateur band (28.0 to 29.7 MHz) if the element diameter is both sufficiently large and natural to element structures at the design frequency (in the case of the sample, 0.5"). The maximum 50-Ω SWR value across the amateur band did not exceed 1.1:1 using the DEWD configuration. Since many bands are narrower than the 80/75-meter amateur band and have natural element sizes that result in a favorable ratio of wavelength to element diameter, I redeveloped the spreadsheet also to calculate DEWD dimensions for a 1.1:1 SWR limit.

The development steps are identical to those used in the original spreadsheet. I optimized design using element-diameter steps whose base-10 logs form a linear progression. The process resulted in the dimensions (in wavelengths) that appear in **Table 9**. You may (and should, as we shall see) compare the data baseline dimension sets to those for the 1.5:1 design sheet from **Table 2**. The required spacing or cross-wire lengths do not change by much, but the lengths of the longer and the shorter half-elements do change considerably, although not radically.

| DEWD 1.1:1 SWR Model Calculation Data Points | | | | | Table 9 |
|---|---|---|---|---|---|
| Dia wl | log Dia | Spacing | Llong | Lshort | BW% |
| 1E-05 | -5 | 0.0158 | 0.2542 | 0.2220 | 5.3 |
| 3.2E-05 | -4.5 | 0.0190 | 0.2545 | 0.2187 | 6.0 |
| 0.0001 | -4 | 0.0226 | 0.2548 | 0.2142 | 6.7 |
| 0.000316 | -3.5 | 0.0288 | 0.2550 | 0.2080 | 7.0 |
| 0.001 | -3 | 0.0355 | 0.2555 | 0.1993 | 9.0 |
| 0.003162 | -2.5 | 0.0497 | 0.2545 | 0.1868 | 11.7 |
| 0.01 | -2 | 0.0760 | 0.2535 | 0.1690 | 15.0 |
| Notes: | All dimensions in wavelengths | | | | |
| | Dia wl = Element diameter in wavelengths | | | | |
| | BW% = 1.1:1 50-Ohm SWR bandwidth | | | | |

I subjected the data to regression analysis, from which the spreadsheet emerged. **Fig. 36** shows the calculation page set for a design frequency of 3.65 MHz and a wire diameter of 2-mm. As was the case for the initial design sheet, the wire is lossless and the environment is free space. Therefore, for very thin wires that have small but significant losses and for wires placed less than about 1 λ above ground, further adjustments are required when planning an antenna installation.

| **1.1:1 SWR Design** | | **Input** | Units | **Calculations** | | **Notes** | | | Fig. 36 |
|---|---|---|---|---|---|---|---|---|---|
| Step 1. Enter design frequency and element diameter. | | | | | | | | | |
| Design frequency in MHz | FQ | **3.65** | MHz | **82.13493** | WL-meters | | | | |
| Wire Diameter Units | See Note | **3** | | | | If **AWG**, enter **1**. If **Inches**, enter **2**. If **Millimeters**, enter **3** | | | |
| Enter Wire Diameter | WD | **2** | See Note | **2.4E-05** | WL | If cell G7 is 0, then re-enter line 6 as 1, 2, or 3 | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Step 2. Dimensions | Dimension | | | Dimensions in Various Units of Measure | | | | | |
| Spacing | A | **0.0191** | WL | **1.569** | meters | **5.148** | feet | **61.77** | inches |
| Length long half element | B | **0.2544** | WL | **20.892** | meters | **68.544** | feet | **822.53** | inches |
| Length short half element | C | **0.2193** | WL | **18.016** | meters | **59.108** | feet | **709.30** | inches |
| Calculated Bandwidth | D | **5.7877** | % | Note: Bandwidth is based on a maximum 50-Ohm SWR of 1.1:1 | | | | | |

We may compare the results directly with an identical set of inputs for the 1.5:1 design sheet, shown in **Fig. 37**. Not only are the dimensional differences clear, but as well, we note a very great difference in the SWR bandwidth, when each is referenced to the maximum allowable SWR value for the design. The 1.5:1 design provides about 2.35 times the spectrum coverage of the 1.1:1 design.

| **1.5:1 SWR Design** | | **Input** | Units | **Calculations** | | **Notes** | | | Fig. 37 |
|---|---|---|---|---|---|---|---|---|---|
| Step 1. Enter design frequency and element diameter. | | | | | | | | | |
| Design frequency in MHz | FQ | **3.65** | MHz | **82.13493** | WL-meters | | | | |
| Wire Diameter Units | See Note | **3** | | | | If **AWG**, enter **1**. If **Inches**, enter **2**. If **Millimeters**, enter **3** | | | |
| Enter Wire Diameter | WD | **2** | See Note | **2.4E-05** | WL | If cell G7 is 0, then re-enter line 6 as 1, 2, or 3 | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Step 2. Dimensions | Dimension | | | Dimensions in Various Units of Measure | | | | | |
| Spacing | A | **0.0197** | WL | **1.618** | meters | **5.308** | feet | **63.70** | inches |
| Length long half element | B | **0.2569** | WL | **21.097** | meters | **69.218** | feet | **830.61** | inches |
| Length short half element | C | **0.2160** | WL | **17.741** | meters | **58.204** | feet | **698.45** | inches |
| Calculated Bandwidth | D | **13.6288** | % | Note: Bandwidth is based on a maximum 50-Ohm SWR of 1.5:1 | | | | | |

Despite the bandwidth differential, the 1.1:1 DEWD antenna provides significant bandwidth enhancement over a single-wire dipole that is resonant at the same design frequency. Of course, a free-space 2-mm dipole will be resonant at about 75 Ω, in contrast to the 50-Ω reference impedance values uses by the DEWD. **Fig. 38** provides a set of relative SWR bandwidth curves for a 300-MHz group of antennas using 0.001-λ diameter elements. At any reasonable SWR limit, the 1.1:1 DEWD design provides a greater improvement over the dipole than the 1.5:1 DEWD design provides over the 1.1:1 version.

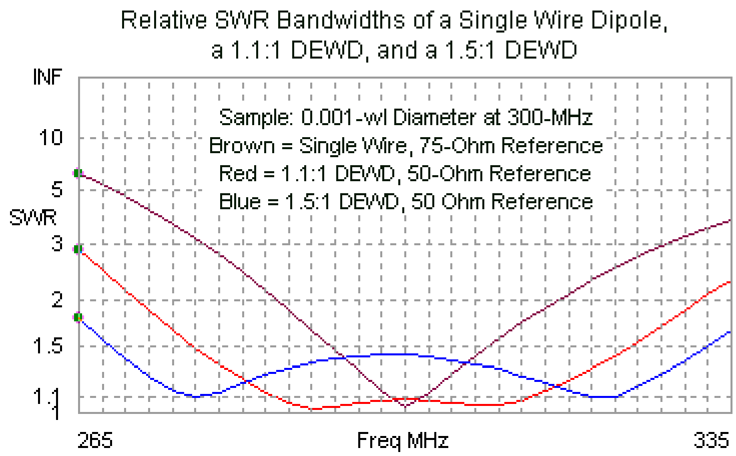
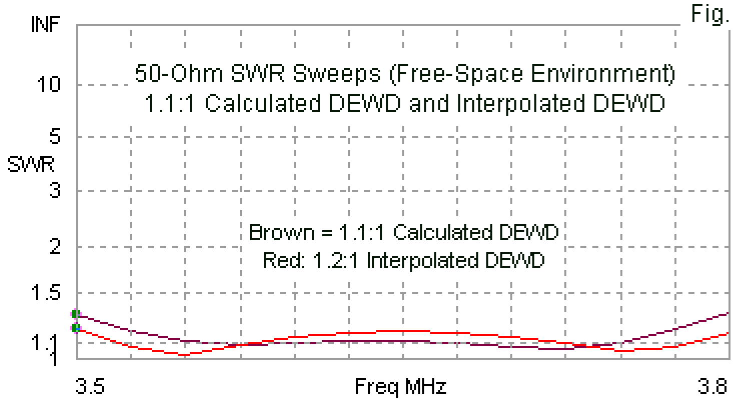



Fig. 38

The 1.1:1 DEWD design has some limitations. One limit concerns the precision of the calculations derived from regression analysis. The longer half-element length curve reverses directions in its upper range, limiting the precision of a normal regression equation with limited constants. As a consequence, NEC-4 models derived from the spreadsheet may show 50-Ω SWR values as high as 1.12:1 somewhere along the curve. However, once the model is in place, one may optimize it easily with slight adjustments to the variables.

A second limitation is inherent in the design parameters: the SWR bandwidth. Suppose that we wish to develop a DEWD antenna to cover 3.5 to 3.8 MHz, as is common practice in Europe. The 5.8% bandwidth of the 1.1:1 DEWD design will not yield the desired coverage, as shown by one of the curves in **Fig. 39**. The band-edge SWR value rises to 1.32:1 using the 1.1:1 design sheet directly. (The curve also shows the mid-band peak SWR of 1.12:1.

Fig. 39




With access to both the 1.1:1 and 1.5:1 design sections on the same page of the spreadsheet, one may quickly develop a compromise design via interpolation of element lengths by proportional parts. As a sample, I simply took the approximate midpoints between the two sets of dimensions in **Fig. 36** and **Fig. 37**. I constructed a model with a spacing or fed-cross-wire length of 0.0181-λ, a pair of longer half-elements 0.2552-λ long, and shorter half-elements 0.2186-λ long. The SWR sweep overlays the original 1.1:1 design in **Fig. 39**. The result is a version of DEWD with a 50-Ω SWR value that never exceeds 1.2:1 across the passband. To a limited extent, a designer may use the two calculation sections to extrapolate values for SWR limits higher than 1.5:1, although the process may be useful only for initial guidance rather than for definitive designs.

As described in Appendix 4, the 80-meter DEWD would require adjustment and detailed modeling for heights at which amateurs usually install low-band dipoles. As well, obtaining a model that remains within the prescribed SWR limits may prove difficult at some heights, especially at a height of 10 meters or about 33'. For upper HF bands and higher, the free-space dimensions will be quite close to reality for antennas above 1 λ over ground.