Notes on Wide-Band Multi-Wire "Folded Dipoles"
Part 1: Some Idealized Illusions

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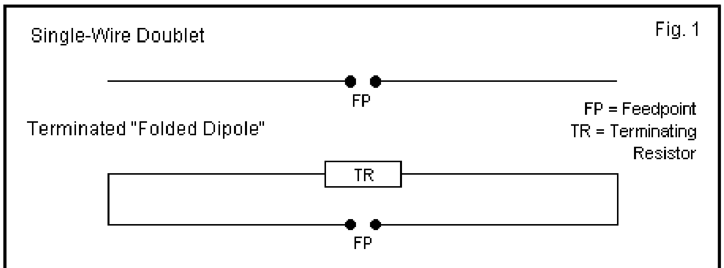
In "Notes on the Terminated Wide-Band 'Folded Dipole'", I briefly touched on the 3-wire version of the antenna. In this note, I want to expand a bit on that antenna as part of a larger look at multi-wire "folded dipole" antennas using a terminating resistor to extend the SWR bandwidth. In fact, we shall review and expand coverage of 4 antennas: the standard single-wire doublet, the most familiar 2-wire terminated version, the sometimes mis-drawn 3-wire version, and a 5-wire version of the antenna. The goal is to enlarge our understanding of how these antennas work and what features count as advantages and disadvantages of them.

In the process, we shall examine some interesting properties of models of wide-band multi-wire terminated antennas based on idealized models. There are some techniques of model formation that are very useful under certain circumstances. However, if inappropriately relied upon, they can mislead us. As well, we may sometimes collect only partial data from an antenna model and be equally led astray. In this first part of the exercise, let's allow ourselves to be led and see where the path may wind.

The basic antenna will be 27.2 m (89.14') long. **Fig. 1** outlines the single-wire doublet and the common 2-wire version of the terminated antenna having the same length. The sketch does not specify any particular spacing between wires of the terminated antenna. Any reasonable spacing will work, from very close to some larger spacing that is still only a small percentage of the total length. The models for this antenna us a spacing of 0.2 m (6.5"), which is well under 1% of the antenna's length. However, before we close, we shall explore the effects of using the relatively narrow spacing of our initial models and using wider element spacing.



Basic Outlines: Equal Length
Single-Wire Doublet and Wide-Band Terminated "Folded Dipole"

The TR (terminating resistor) element in the 2-wire wide-band antenna is 820 Ohms in this model. However, values between 800-900 Ohms are most common, and versions exist with resistors ranging from 400 Ohms to 1200 Ohms. The resistor must be non-inductive, ruling out wire-wound power resistors. The resistor inductance would count as a loading coil, adding very significant reactance. In fact, the reactance would climb with frequency and eventually form an effective RF choke. To overcome the problem of finding a desired resistance power value that will not over-weight the center of the antenna, many builders use higher value resistors in parallel. For receiving only, the resistors can be of any power value. However, for transmitting, the terminating resistor must be capable of dissipating about one half of the anticipated power applied to the antenna. Paralleled resistors must allow for air flow to carry away heat, while at the same time providing protection from the weather in which the antenna operates. Weight, heat, and weather are the three primary enemies of a terminated "folded dipole."

The terminated "folded dipole" only looks like a folded dipole. The wire configuration does not perform an impedance transformation like an ordinary folded dipole without the terminating resistor. As well, the standard folded dipole is a narrow-band antenna, like the simple dipole. In a terminated 2-wire wide-band antenna, the impedance at the feedpoint is a function of the terminating resistor. In fact, the actual impedance at any frequency is a joint function of the termination and the antenna length in wavelengths.

The chief reason for using a 2-wire wide-band terminated antenna is to obtain a satisfactory feedline SWR level across a wide range of frequencies. For the 27.2-m antenna, I shall sample 2 through 30 MHz as a preliminary operating range. **Fig. 2** outlines on the same graph the SWR of a single-wire doublet and of a 2-wire terminated antenna. The most common feedline used with a single wire doublet is parallel 450-Ohm transmission line. Therefore, the doublet SWR curve uses that reference impedance. For all frequencies, the SWR ranges from moderately high to very high. The doublet works by having low line losses, even with fairly high SWR levels, and an antenna tuner in the shack provides the impedance transformation to the 50-Ohm input/output of the transceiver or other equipment. The impedance at the antenna tuner terminals is unlikely to be the same as at the antenna feedpoint terminals. When the feedpoint impedance and the characteristic impedance of the line are different, the transmission line acts as an impedance transformer for each electrical half-wavelength. Hence, the tuner terminals show an impedance that is a joint function of the original feedpoint impedance, the line characteristic impedance, and the electrical length of the transmission line.

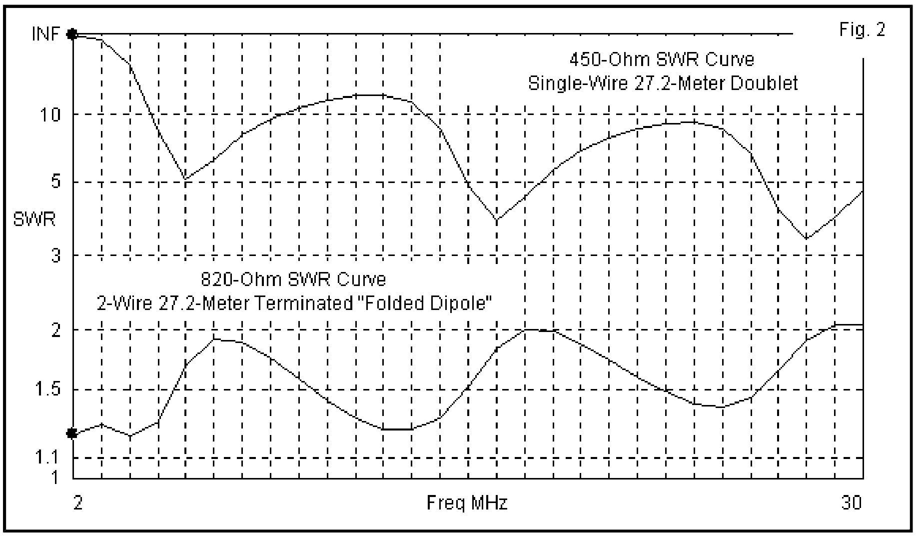
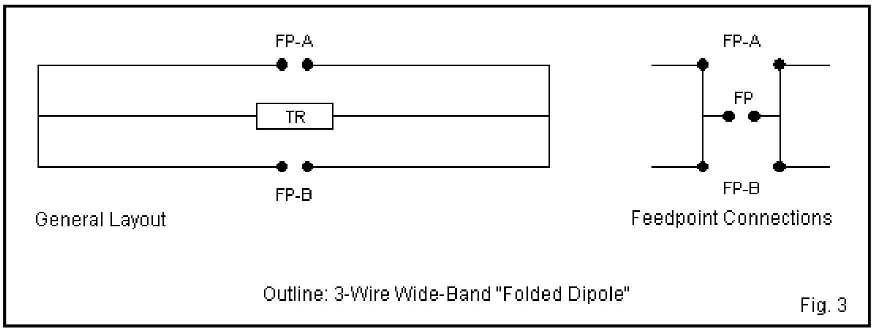


Fig. 2

The wide-band 2-wire terminated antenna SWR curve uses 820 Ohms as its reference impedance. The precise value is non-critical so long as it is close to the value of the terminating resistor. The curve in **Fig. 2** shows only minor peaks above the 2:1 level, and those peaks tend to grow with increasing frequency. However, most versions of the antenna employ 50-Ohm coaxial cable as the feedline. The reference impedance and the cable impedance show a 16:1 ratio. Although a 16:1 balun is possible, many builders employ 2 4:1 baluns (although one of them can be an unun). Many balun designs become lossy with rising reactance. Although those losses may be low compared to the power dissipated in the terminating resistor, some antenna makers use a standard transformer to effect the wide-band match. The key factor in any such transformer is to avoid core saturation. See the end of Chapter 6 of the ARRL Handbook for a brief characterization of the 2 types of impedance transformers and the basic needs of each kind. A final alternative involving impedance transformation concerns the terminating resistor itself. I have heard of using a 50-Ohm resistor and placing a 16:1 transformer between it and the wire to create the effect of an 800-Ohm terminating resistor.

To take care of any remnant SWR peaks that exceed 2:1 at the junction with the coaxial cable and the antenna and its impedance transforming devices, some wide-band antenna makers recommend very long lengths of coaxial cable. The rationale is simple. Coaxial cable losses are real, but will be relatively small--even at 30 MHz--compared to the losses due to the dissipation of applied energy in the terminating resistor. Hence, the use of a long cable is operationally insignificant relative to antenna performance. Moreover, the long cable will usually prevent the triggering of fold-back circuitry that protects the final amplifier in the presence of excessive SWR values.

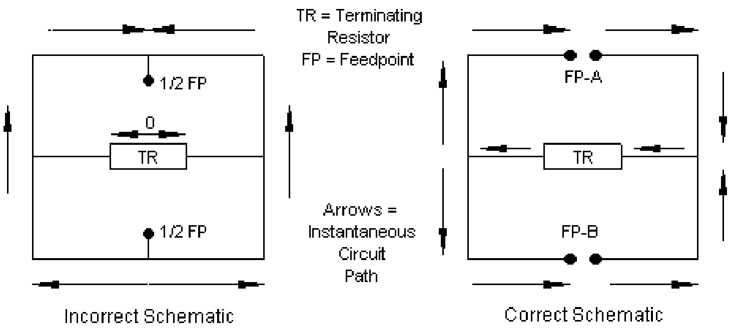
The 3-wire terminated wide-band antenna is an extension of the 2-wire version. The general claim associated with the 3-wire version is higher gain with equal or better SWR curves. We shall eventually examine the gain claim in some detail. For the moment, we may simply see the schematic outlines of the 3-wire wide-band antenna in **Fig. 3**. For the sample model, the terminating resistor is 900 Ohms.



Outline: 3-Wire Wide-Band "Folded Dipole"

Fig. 3

The right side of the sketch shows the parallel connection of the antenna feedpoint terminals on the 2 non-terminated lines. This configuration yields proper connections for wide-band service. In some sketches (that do not pretend to be electrical schematic diagrams of the antenna), I have seen simplified connections that can mislead the home builder. The sketches seem to show the center point of each non-terminated wire as comprising each side of a proper series feedpoint. For normal installations with no special components, this system will not work. **Fig. 4** shows why.



Correct and Incorrect Ways to Schematically Draw the Feedpoint System of the 3-Wire Wide-Band "Folded Dipole"

Fig. 4

The left side of the sketch shows the circuit path of the antenna if we join the center points and connect the source between them. The path leads at any instant away from one connection and toward the other through 2 parallel paths. At the ends of the antenna (obviously not drawn to scale in **Fig. 4**), the junctions with the line carrying the terminating resistor at its center have equal voltage. The net voltage drop across the resistor is therefore zero, and that component has no function in the antenna, when set up in this way. In fact, models created using this system show no difference of pattern, impedance, or termination-line current for any value of resistor, from zero to very high.

The system on the right provides the correct path for the terminating resistor to do its work. When I modeled the antenna, I used the terminating resistor line as a center point. Then I set up the fed lines 0.2 m away from the center line. The need to connect the feedpoints in parallel presents an interesting geometry challenge if we model the antenna using only wire entries. However, there is a simple technique of connecting feedpoints in parallel that may be useful to newer antenna modelers. The following model description from EZNEC may illustrate the general technique.

```
                   EZNEC/4 ver. 4.0

3-Wire Wide-Band FD                           6/24/05     9:28:16 AM

        --------------- ANTENNA DESCRIPTION ---------------

Frequency = 12 MHz
Wire Loss: Copper -- Resistivity = 1.74E-08 ohm-m, Rel. Perm. = 1

             --------------- WIRES ---------------

No.           End 1     Coord. (m)              End 2     Coord. (m)        Dia (mm)  Segs
          Conn.     X         Y       Z       Conn.     X         Y       Z
1          W4E2    -13.6,      0,      15      W2E1      13.6,      0,     15        #12   69
2          W5E1     13.6,      0,      15      W3E1      13.6,      0,   15.2        #12   1
3          W2E2     13.6,      0,    15.2      W4E1     -13.6,      0,   15.2        #12   69
4          W3E2    -13.6,      0,    15.2      W7E2     -13.6,      0,     15        #12   1
5          W1E2     13.6,      0,      15      W6E1      13.6,      0,   14.8        #12   1
6          W5E2     13.6,      0,    14.8      W7E1     -13.6,      0,   14.8        #12   69
7          W6E2    -13.6,      0,    14.8      W1E1     -13.6,      0,     15        #12   1
8                   -0.1,      1,      15                 0.1,      1,     15        #20   1

Total Segments: 212

             -------------- SOURCES --------------

No.      Specified Pos.     Actual Pos.      Amplitude     Phase     Type
      Wire #   % From E1   % From E1  Seg       (V/A)       (deg.)
1      8        50.00       50.00    1         1            0         V

         -------------- LOADS (R + jX Type) --------------

Load     Specified Pos.     Actual Pos.         R          X
      Wire #   % From E1   % From E1  Seg      (ohms)     (ohms)
1      1        50.00       50.00    35       900        0

               -------- TRANSMISSION LINES ---------

No.    End 1 Specified Pos End 1 Act  End 2 Specified Pos End 2 Act  Length      Z0      VF  Rev/Norm
       Wire #    % From E1 % From E1  Wire #    % From E1 % From E1  (m)        (ohms)
1      3           50.00      50.00   8           50.00      50.00   0.01        500      1      N
2      6           50.00      50.00   8           50.00      50.00   0.01        500      1      N
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```
Ground type is Free Space
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Wire 1 is the terminated line, as indicated by the Load entry. Wires 3 and 6 are the lines with the feedpoints shown in the original antenna sketch. Wires 2, 4, 5, and 7 are the end-connecting wires. Wire 8 is the feedpoint wire segments, as indicated by the Source entry in the description. The wire is only a meter away from the main wires, but it is so short and thin (0.2 m by AWG #20) that it does not materially affect the performance figures of the main wires.

Now note the 2 transmission-line entries. Each runs from the center of one of the fed wires to the new distant source wire. A transmission line is not a physical or radiating wire within a model. It is only a mathematical construct factored into the model after completion of basic matrix calculations. In fact, the physical or geometrical distance between the source wire and the wire segment at the other end of the transmission line does not define the line length. Instead, we specify the line's electrical length (as well as the characteristic impedance) when we enter the transmission line data, and calculations use this length. Note that the length for each of the 2 lines is 10 cm (about 4"). We could have made it even shorter (down to something like 1e-10). But 4" effects virtually no impedance transformation down the line. In fact, the specified characteristic impedance (500 Ohms) is also non-critical, and changing it by a few hundred Ohms creates virtually no impact on the reported final feedpoint impedance.

The technique of using near-zero lengths of transmission line to connect wires in parallel is very useful to many types of models that connect feedpoints in parallel. NEC-2 and -4 have some limitations with very shallow angles that are often involved in these kinds of connections. The wire surface can penetrate the center third of the other wire segment at the junction, creating errors in the current calculations. The transmission-line technique avoids those problems. As well--and especially apt to this case--the technique avoids involving us in extra wires, odd changes of wire direction, and the inevitable expansion of the model size as measured by the number of segments. Nevertheless, we must recognize that our models are idealizations. Any implementation of a 3-wire wide-band terminated antenna will necessarily have leads to the common feedpoint at which we find the impedance transformation device. Whether the ease of modeling with the TL-based parallel connections serves us well or ill we shall not determine until we explore Part 2 of the exercise.

I used a similar system to parallel-connect the feedpoints of 4 wires surrounding a terminating resistor wire. The 5-wire wide-band terminated antenna appears in schematic form in **Fig. 5**. The schematic does not attempt to replicate the modeled physical structure, but is handy to represent the 4 paralleled feedpoints. The sketch on the right gives an end-on view of the antenna. The two new wires are at right angles to the existing wires, forming a cage of sorts around the center wire. The square represents the terminating resistor at the center of the center wire.

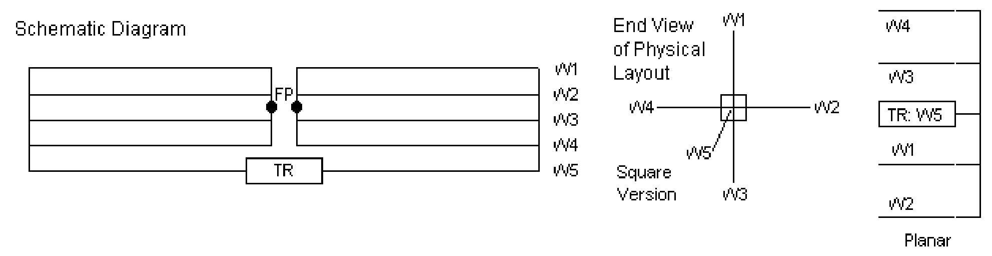


Fig. 5 Outline: 5-Wire Wide-Band Terminated "Folded Dipole"

As an alternative version, I modeled the 5-wire wide-band terminated antenna as a planar construct. The far right sketch shows the general idea, but not at all to scale. The fed wires lie in a single plane with the termination wire, 2 above and 2 below the terminating resistor. The model uses the same spacing--0.2 m--between each wire. As well, the model uses the same short transmission-line technique to connect the feedpoints in parallel. In both versions of the 5-wire antenna, the terminating resistor is 800 Ohms. The planar version seems to show slightly better performance than the square version, so I shall use it for the initial data-gathering exercise.

We can now examine the SWR bandwidths of the 2 expanded versions of the wide-band terminated antenna. **Fig. 6** shows the 500-Ohm SWR curve for the 3-wire version and the 300-Ohm curve for the 5-wire version. The 3-wire antenna shows a very well-behaved SWR curve, with an excursion above 2:1 only between 3 and 4 MHz, below the frequency that I shall eventually recommend as the minimum usable frequency for all of these 27.2-m antennas. However, note a change relative to the 2-wire antenna. For the smaller antenna, the center of the feedpoint impedance excursions occurs at about the same impedance as the terminating resistor. However, the SWR reference for the 3-wire antenna is only about 55% of the value of the terminating resistor (500 vs. 900 Ohms).

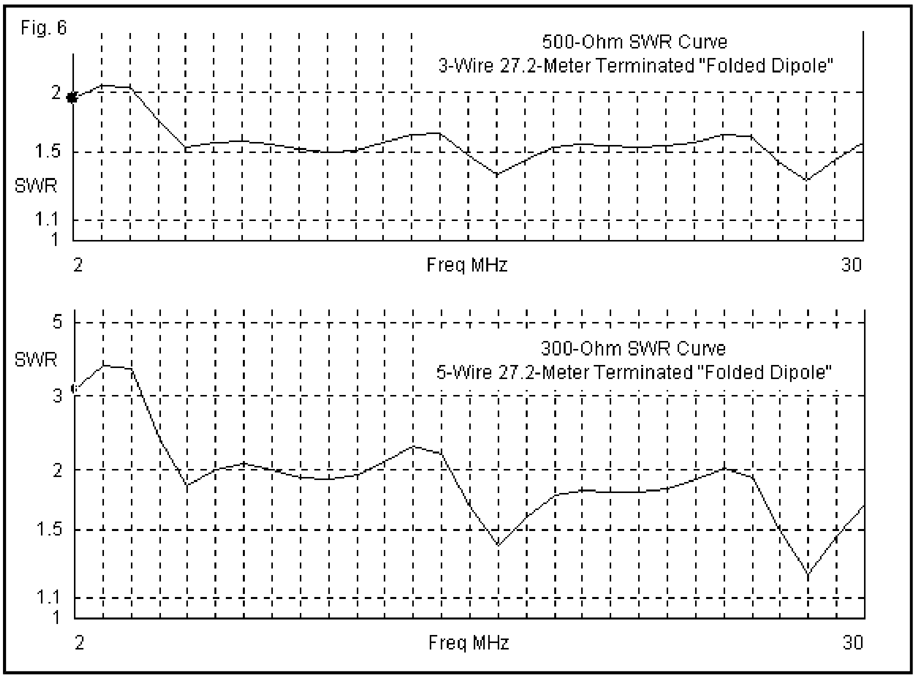


Fig. 6

The curve for the planar 5-wire version of the wide-band array is less well behaved, with 3 humps above the 2:1 SWR level. Although the terminating resistor is 800 Ohms, the reference level for the SWR is down to 300 Ohms, or under 40%. As we drop the necessary reference impedance, due to having more wire feedpoints in parallel, the reactance at any given frequency plays a larger role in determining the SWR. Hence, the lower the feedpoint reference level, the more likely we are to find higher SWR levels.

The 3- and 5-wire antennas shows interesting parallels between the curves, with peaks near 3-4, 7-8, 14-15, 20, and 25-26 MHz. In this respect, the curves are only vaguely similar to the 2-wire version of the antenna, despite the similarities in the terminating resistor values (800-900 Ohms). For SWR bandwidth, either the 2-wire or the 3-wire versions of the antenna show the more promise. While the 2-wire antenna requires a 16:1 impedance transformation for use with 50-Ohm coaxial cable, the 3-wire antenna requires a 10:1 transformation. The 5-wire version sets up a conflict: the reference impedance requires a 6:1 transformation, a value within construction limits for a single balun. However, the SWR excursions suggest a considerable reactive component that may induce higher losses in at least some balun designs.

If SWR bandwidth were the only consideration, then the simplicity of the 2-wire antenna would dictate its use. The addition of more wires complicates the antennas structure and adds weight, especially in the separators needed to keep the antenna from corkscrewing in the wind. So our final question is whether we obtain any advantage in turning to a more complex wide-band terminated "folded dipole."

The brief answer is a qualified "yes:" we obtain more gain from adding fed wires to the system. The following table illustrates the gain advantage of adding wires.

Comparison of Maximum Free-Space Gain Values of 27.2-m Antennas at Selected Frequencies

Frequency	**6 MHz**	**12 MHz**	**18 MHz**	**24 MHz**
Antenna		**Free-Space Gain dBi**		
1-Wire Doublet	**2.18**	**4.37**	**3.73**	**4.59**
5-Wire Wide-Band	**1.32**	**0.19**	**2.78**	**1.56**
3-Wire Wide-Band	**-0.36**	**-0.80**	**1.64**	**0.50**
2-Wire Wide-Band	**-2.59**	**-2.36**	**0.04**	**-1.07**

For each of the selected frequencies in 6-MHz increments, the larger the number of wires in the wide-band antenna, the higher the gain. In some cases, the 5-wire antenna comes within 0.9 dB of matching the non-terminated doublet, while in other instances, the differential is almost 4.2 dB. However, by the time we get down to 2 wires in the terminated antenna, the gain differential can be as much as 6.7 dB. **Fig. 7** provides maximum free-space gain curves for all 4 antennas from 2 through 30 MHz in 1 MHz intervals.

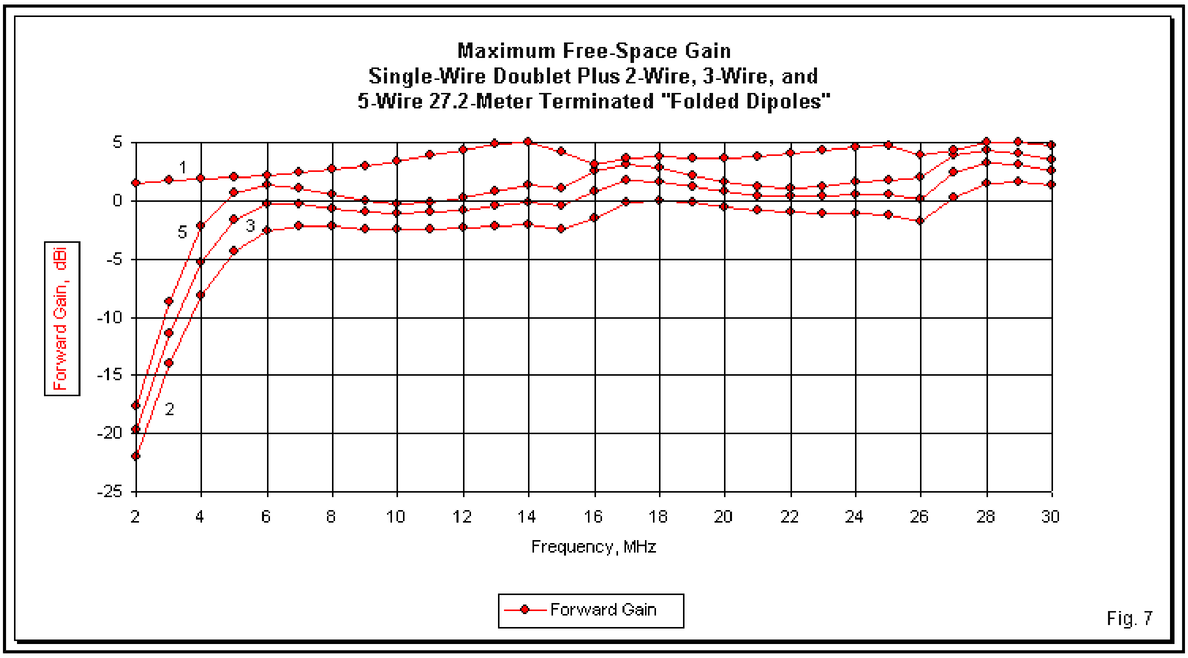


Fig. 7

The curves show several items of interest. First, the more wires in the array, the greater the variability of maximum gain across the entire scanned range. Despite the higher variability of gain in the 5-wire curve, the gain curves for the 3 terminated antennas show a tight parallelism. On a few of the sampled frequencies (1-MHz increments), the 5-wire antenna comes close to equaling the gain of the doublet used as a standard. However, a 3-dB differential is more common. The 2-wire antenna averages about 5-6 dB differential from the doublet values. Note that all of the models set up their wires parallel to the Z-axis, so the gain reports are taken in the X-Y plane or broadside to the plane of the wires.

More significant is the fact that all 3 terminated antennas show a knee in their curves, Below the knee frequency, the gain drops very rapidly. The knee frequency occurs when the antenna passes below an electrical 1/2-wavelength at the operating frequency. Broadly speaking, the knee for the 27.2-m antennas occurs around 5.5 MHz. The larger the antenna, the lower the knee frequency, as the multitude of wires act like a fatter single wire. However, below the knee frequency, the 5-wire antenna loses gain faster than the simpler wide-band versions. Although the doublet exhibits quite reasonable gain below the knee frequency, at a certain point, the gain may be unobtainable in practical terms. As an antenna falls to 3/8 wavelength or shorter, the reactance climbs rapidly while the resistance sinks to a very low value. The combination will show considerable line loss, even using low-loss parallel transmission line, and the antenna tuner may have difficulties in effecting a match to the values that appear at its terminals.

To obtain a better view of comparative gain with the recommended operating range, we may omit the region at and below the knee from our graph. **Fig. 8** provides the same data as **Fig. 7**, but the frequency range restriction expands the Y-axis. With a knee at about 5.5 MHz, the recommended operating range for the 27.2-m antennas is about 6-30 MHz. For operation down to 2 MHz, I would suggest an antenna (of any of the 4 types) that is about 71-72 m (about 235'). Since we are not seeking precise resonance, the exact length is not important so long as the antenna is at least 1/2 wavelength at the lowest operating frequency.

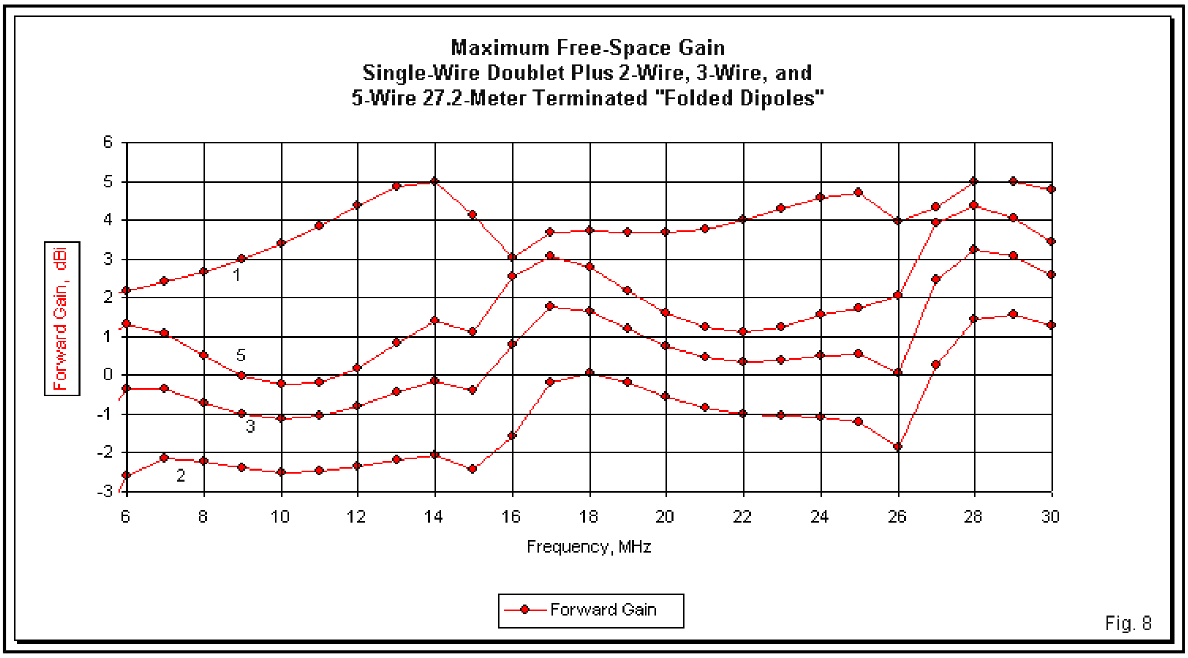


Fig. 8

The expanded curves in **Fig. 8** show more clearly the parallel structure of the 2-wire, 3-wire, and 5-wire gain values across the recommended spectrum. As well, Y-axis expansion shows the high variability of the 5-wire gain curve. It sometimes almost reaches the level of the doublet, but on other frequencies, it falls closer to the level attained by the 3-wire antenna. Of course, the exact structure of these curves is subject to variation with small changes in construction--either overall length or spacing--or in the exact value of the terminating resistor. Nevertheless, the most notable trends remain intact.

Gain variations are NOT the result of any changes in antenna pattern as we move from one 27.2-m antenna to another. In fact, the antenna patterns are functions of the overall wire length, and the presence of multiple wires and the terminating resistor does not affect any other property than lobe strength. (This statement requires a bit of modification: the wire length is the electrical length of the antenna rather than its simple physical length. Multiple wires tend to act like a single fat wire, making the antenna longer by a wider margin than a single wire. Hence, if all the subject antennas from 1 to 5 wires are the same physical length, the larger the number of wires, the electrically longer the antenna. The planar 5-wire may further complicate the calculation of electrical length due to the end connecting wires. **Fig. 9** overlays the patterns of all 4 antennas at 12 MHz. Perhaps the only difference detectable is at the junction of the main lobe with each of the minor lobes. The more wires, the softer the curve at the junction. It is likely that the need for end wires to connect the horizontal wires is the main reason for the softened junction.

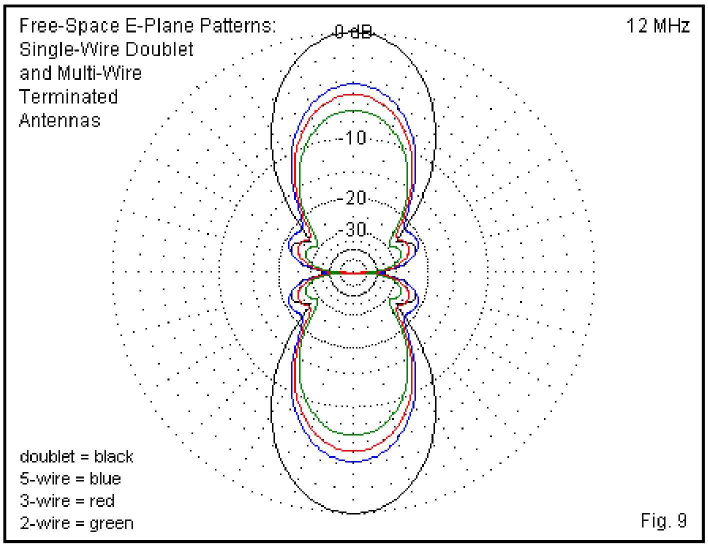
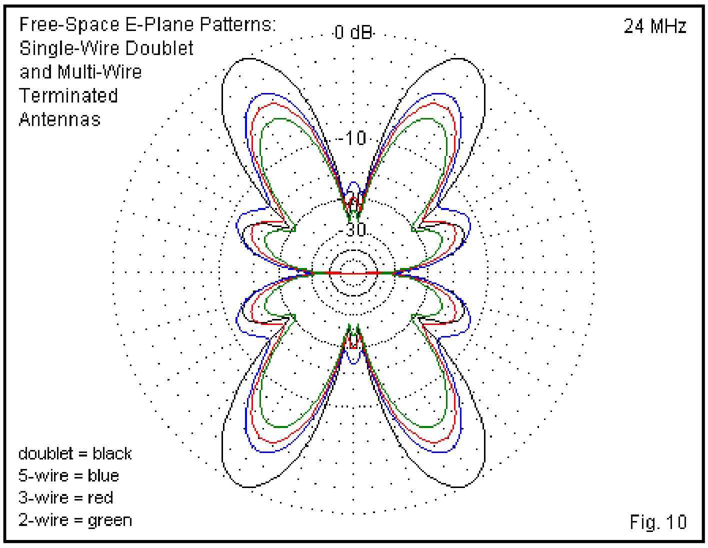


Fig. 9

The pattern test is repeatable on any frequency. **Fig. 10** provides a second sample of overlaid patterns at 24 MHz. Where lobes join (at pattern nulls), we once more find that if we have more wires and end wires in the antenna structure, the null points soften into curves. Other than that single phenomenon, the patterns are wholly congruent and vary only in lobe strength.



Before we close this exploration, it may be wise to examine the effect of spacing between the wires in a terminated array. In a standard folded dipole, there is no significant difference in performance between narrow and wide spacing values, at least up to the point where the distance exceeds a value that will support 2-wire transmission-line operation. However, as we have noted, the terminated arrays only look like folded dipoles.

All of the terminated antennas used so far are 27.2 m long with a spacing between wires of 0.2 m (about 7.9"). I revised the spacing for a series of test models to a value of 1.5 m (59"). Because initial tests using diamond and fan configurations proved unpromising, I maintained the parallel runs of AWG #12 wires.

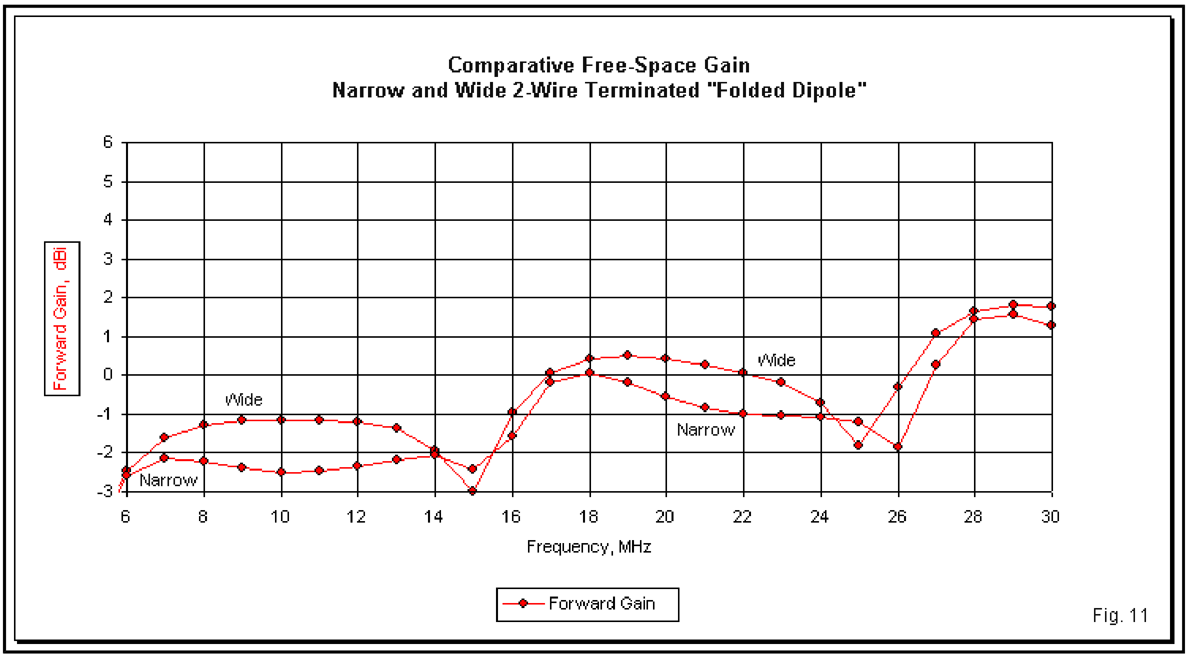
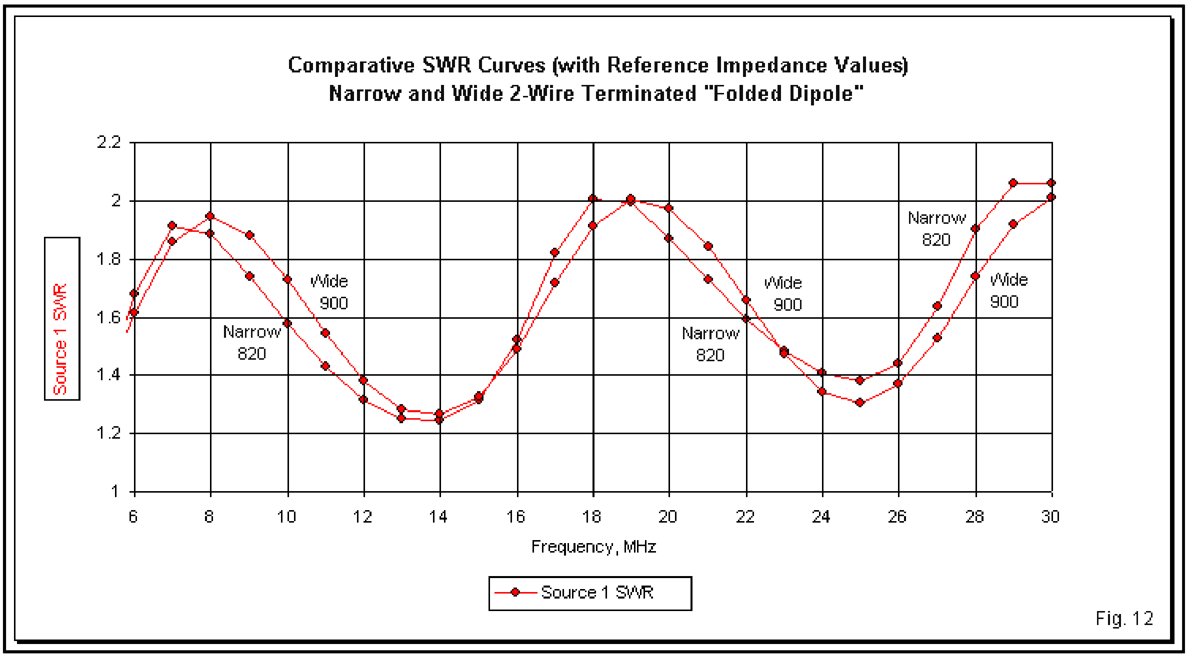
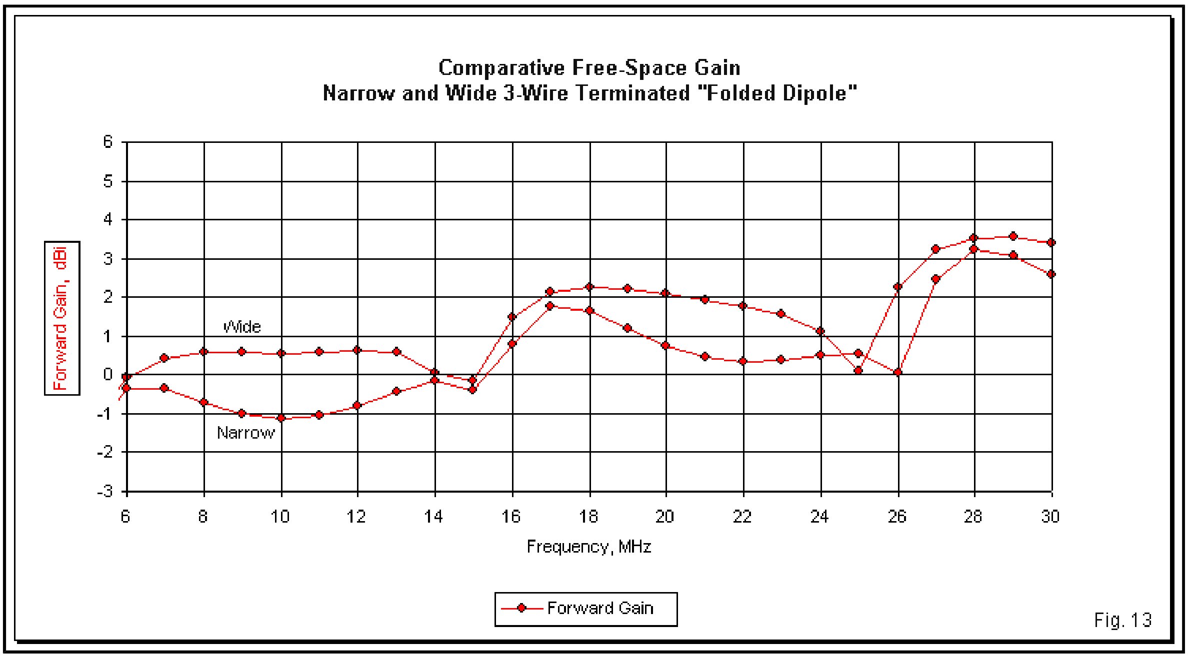


Fig. 11 compares the maximum free-space gain values for the 2 versions of the 2-wire terminated array. The wider array shows an average gain increase of about 1 dB, although that increase does not appear at every frequency in the test range (using 6 MHz as a starting frequency). The original narrow version of the antenna used an 820-Ohm terminating resistor and a similar value for the SWR reference impedance. Widening the antenna required an increase in both values to 900 Ohms. **Fig. 12** compares the SWR curves for both 2-wire antennas on the assumption that each will use an optimized impedance transformation device for any adjustment to match a coaxial cable. The SWR curves show no features that would dictate the use of one antenna version over the other.



The 3-wire version of the terminated array used the same 1.5-m spacing in the wide version. The result is an array that is 3-m wide overall, with the terminated line between the fed wires. **Fig. 13** shows the comparative gain curves for the two antennas. The wide-version curve shows similar characteristics to the corresponding curve for the 2-wire antenna. However, the gain differential between wide and narrow antennas averages close to 1.5 dB.



The terminating resistor for both the narrow and wide antennas is 900 Ohms. However, the best reference impedance for the wide version is about 450 Ohms, about 50 Ohms less than for the narrow version. **Fig. 14** traces both SWR curves. The curve for the wider version of the antenna shows larger excursions, but remains below 2:1 across the entire test range.

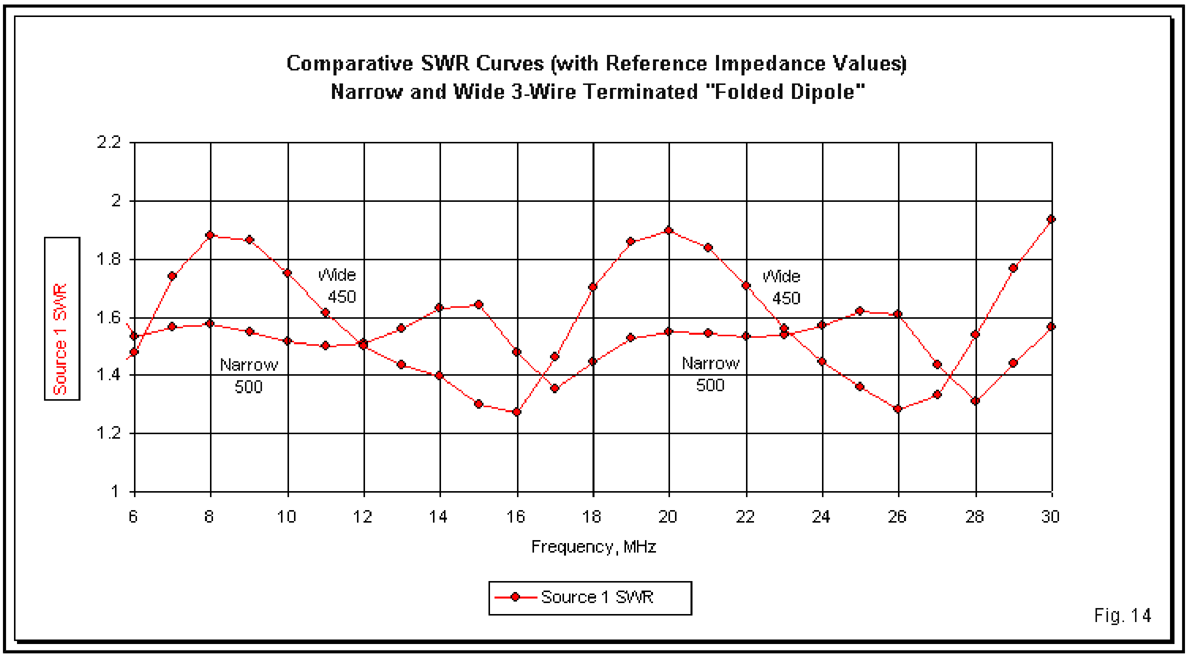


Fig. 14

Although the 5-wire array remains the same length, its area grows by a factor of 7.5. The inner fed wires are 1.5 m from the terminated center wire, while the outer fed wires are 3.0 m from center. **Fig. 15** provides one measure of whether the increased width is worth while in terms of the overall gain advantage of the wider antenna. The wide array provides almost 2-dB average gain over the narrower (0.8-m) version. Unlike the 2-wire and 2-wire arrays, where the gain lines cross at certain frequencies, the wide 5-wire antenna shows a gain advantage throughout the operating spectrum.

(Remember that the gain measurements are for free space and are taken broadside to the plane of the wires. Part 2 in this exercise will give us good reasn to remember these limiting factors of this initial study.)

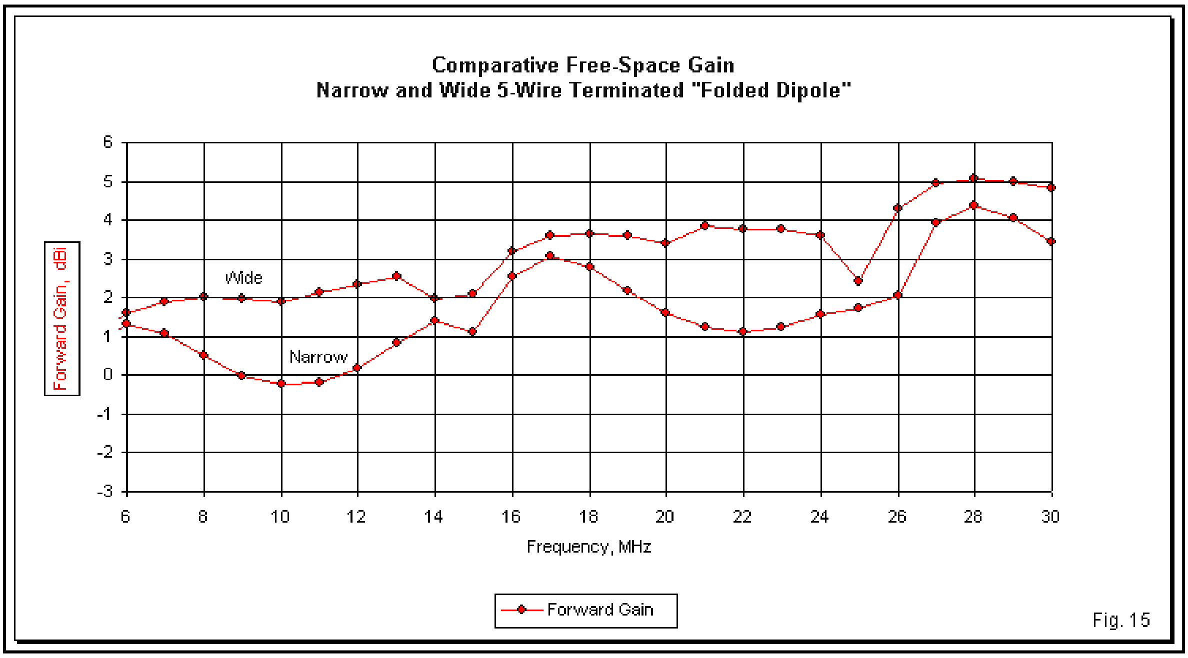


Fig. 15

Both versions of the 5-wire antenna use 800-Ohm terminating resistors. As well, the reference impedance for both SWR curves is 300 Ohms. The average 300-Ohm SWR is lower for the wide antenna, although the specific value may vary at some selected frequencies. Unlike the narrow array, from 6 MHz upward, the wide array SWR makes only one excursion above the 2:1 level and remains below 2.2:1 at 13 and 14 MHz.

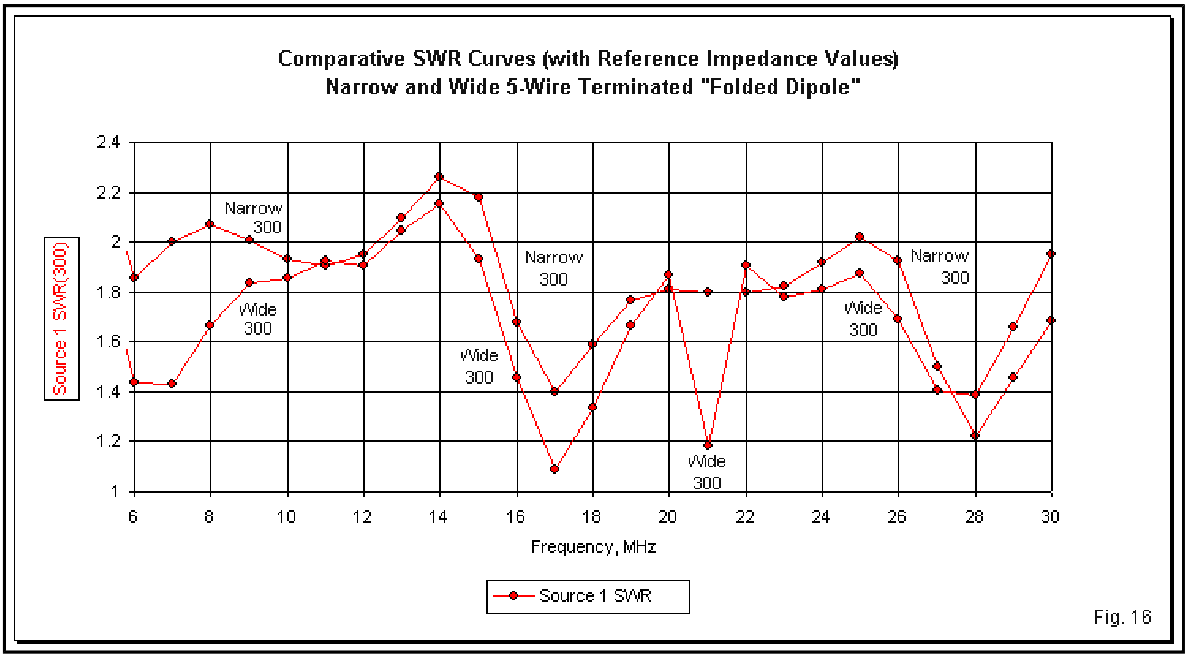


Fig. 16

The following short table samples some of these results in tabular form. For a few frequencies between 6 and 12 MHz, the table lists the maximum free-space gain of each of the 6 terminated arrays. For comparison, the table adds a 7th gain column, listing the maximum gain of a single wire 27.2-m doublet.

Maximum Gain Comparison Among 27.2-m Antennas at Selected Frequencies.

				Maximum Free-Space Gain dBi			
Frequency	Doublet	2-Wire Narrow	2-Wire Wide	3-Wire Narrow	3-Wire Wide	5-Wire Narrow	5-Wire Wide
6	2.18	-2.59	-2.47	-0.36	-0.05	1.32	1.62
8	2.66	-2.22	-1.27	-0.70	0.58	0.50	1.99
10	3.38	-2.51	-1.15	-1.11	0.55	-0.25	1.91
12	4.37	-2.36	-1.20	-0.80	0.63	0.19	2.35

The table makes clear that the narrow 3-wire array is superior in gain to the wide 2-wire antenna and that the narrow 5-wire array is superior in gain to the wide 3-wire antenna. However, each wide version is superior in gain to its corresponding narrow version. However, even the highest-gain terminated array (the wide 5-wire planar version) is deficient in gain by 0.5 to 2.0 dB relative to the single-wire unterminated doublet of the same length.

These results emerge from exploring only the plane that is broadside to the axis of the multi-wire antennas. We have not looked at the plane that would be edgewise to the wires. Nor have compared patterns taken broadside and edgewise to the plane of the wires. Moreover, we have not explored the relative gain of the various antennas at some common height above a specified ground quality.

Some Tentative Conclusions

This initial attempt to take a fresh look at multi-wire terminated wide-band antennas seems to justify a few general conclusions. These conclusions rest on 2 features of the investigation. One is the use of idealized models for 3- and 5-wire arrays that use virtual zero-spacing between the wires forming the parallel connections at the feedpoint. The second feature is the use of only partial data from the collection available to us from the models. Nevertheless, the project appears to show high promise for potentially improving the multi-wire wide-band terminated antennas that we might build.

1. All terminated wide-band "folded dipoles" have knee frequencies, below which the gain drops very rapidly. The recommended operating range for any of the antennas is from an electrical length of about 1/2 wavelength upward in frequency.

2. As we add more fed wires to a terminated antenna, we increase its average gain over the operating spectrum. The gain increase never quite reaches the level of a single-wire doublet.

3. As we add more wires to a terminated wide-band antenna, the center or reference SWR impedance decreases both intrinsically and with respect to the value of the terminating resistor.

4. 2- and 3-wire terminated wide-band arrays show stable SWR curves through their operating ranges. However, adding further wires tends to produces curves with greater SWR excursions relative to the reference impedance.

5. Terminated wide-band antennas show increased gain by widening the distance between wires. Spacing adjustments may require revision of the optimal terminating resistor value and the reference SWR impedance.

Some of these conclusions are in fact generally true. Others may be only partially true or simply illusions based on the limiting factors of model formation and use in gathering data. In Part 2, we shall explore the available data in greater detail and develop some all-wire models of the various arrays. That effort will allow us to sort out which of the conclusions are useful as they stand and which require modification, revision, or deletion.

For the moment, we may simply allow ourselves to be enthusiastic about the potential improvements that we have seemingly uncovered.

Updated 05-01-2007. L. B. Cebik, W4RNL.