Notes on the Terminated Wide-Band "Folded Dipole"

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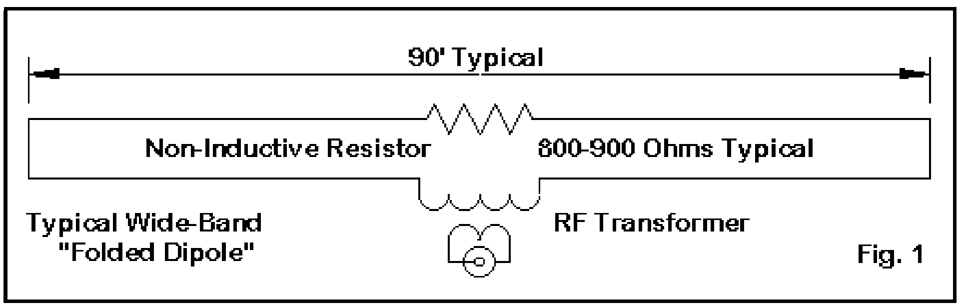
As space for antennas continues to shrink in the present era of smaller urban and suburban yard, hams have begun to turn to 1-antenna solutions to their operating needs. Among the choices for a horizontal antenna that operates on all of the HF amateur bands, the wide-band "folded dipole" (WBFD) has been gaining popularity. I thought that it might be useful to do some comparative studies using this antenna as a base-line.

The basic WBFD looks something like **Fig. 1**.



The antenna design appears to be a folded dipole. However, a folded dipole is a resonant antenna, while the WBFD is designed to operate with a low feedpoint impedance across a wide range of frequencies. Moreover, the WBFD contains a non-inductive terminating resistor usually located at the point in the loop directly opposite the feedpoint. Normally, the resistor is in the 800-900 Ohm range. This impedance is roughly replicated at the feedpoint. Therefore, builders install a 16:1 RF transformer (either of transmission-line transformer or normal transformer design) at the feedpoint. The result is a low SWR value for 50-Ohm coaxial cable across the entire frequency range.

For receiving use, such as in SWL service, the terminating resistor can be a low wattage carbon type. For transmitting service, the resistor must have a power value capable of dissipating a fair share of the applied power. The exact amount will vary with frequency, but commercial versions of the antenna are often rated for reduced power at the low end of the operating range, where power dissipation is highest.

Commonly, WBFD antennas are offered in a 90 to 100 foot length (27-28 meters) for service between 2 and 30 MHz. However, one can build WBFD antennas in almost any length. Only the effective operating range of frequencies will change.

Since we may also construct doublets of the same length and feed them with parallel transmission line to an antenna tuner, it seemed fair to compare the gain of such a doublet with that of a WBFD of the same length across the 2-30 MHz range. The model I chose for the WBFD is 27.2 m (89.24') long, with the wires separated 0.2 m (7.8"). The terminating resistor is 820 Ohms, a standard value used in some commercial models. (Other commercial units use 900 Ohms, often composed of 3 2700-Ohm resistors in parallel.) The wire is #14 AWG. The doublet is a simple length of #14 copper wire exactly as long as the WBFD.

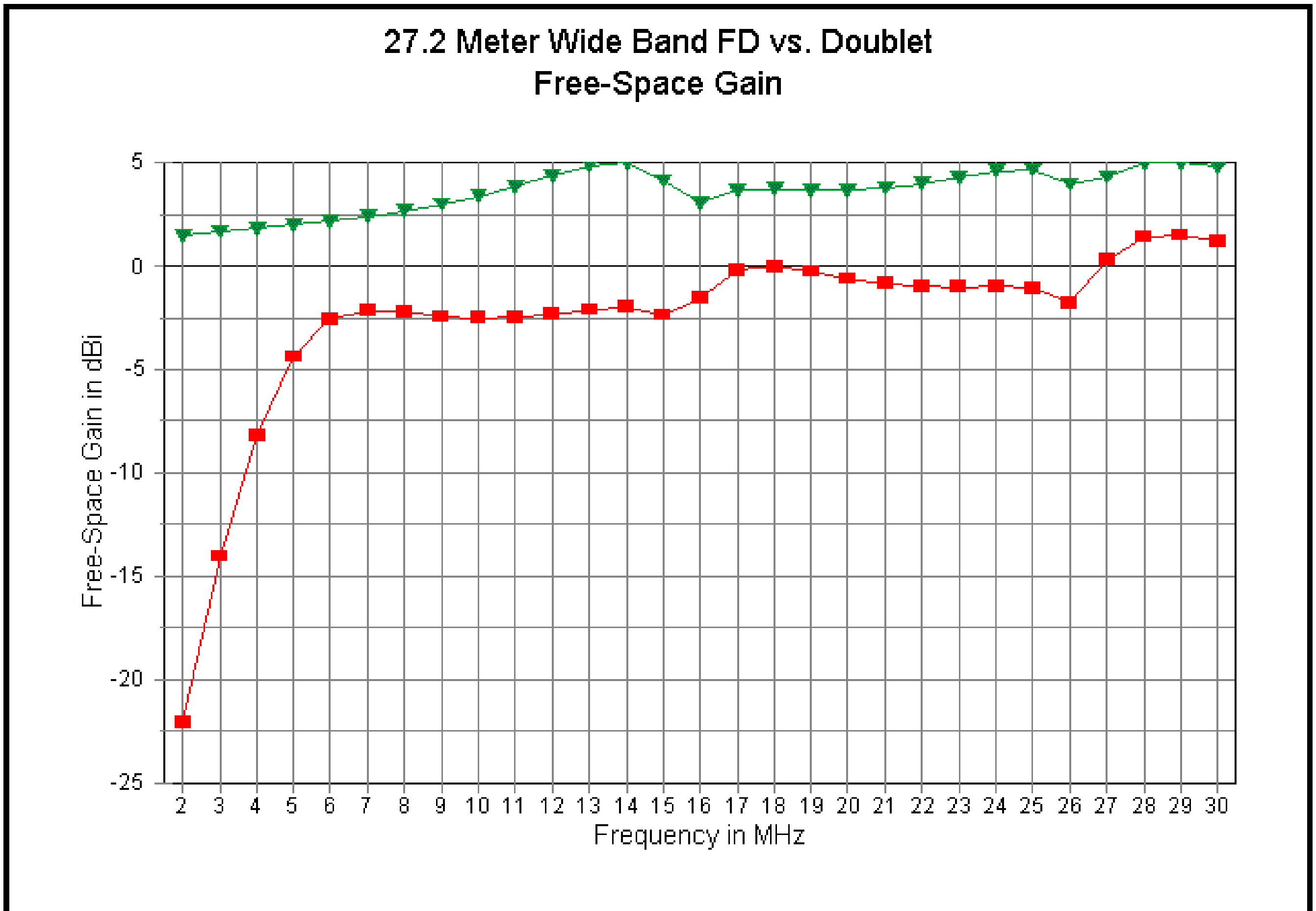


Fig. 2

Fig. 2 compares the free-space gain of the two antennas at 1 MHz intervals from 2 to 30 MHz. Since the elevation angle of maximum radiation will be the same for both antennas for any height above ground and for any ground conditions, any differences that show up in the free-space model will also show up in actual antennas at any height above ground.

Several instructive notes emerge from the comparison of gain in **Fig. 2**. First, the overall average difference in gain between the two antennas is nearly 6.3 dB, with the advantage going to the doublet. If we neglect frequencies below 7 MHz, the average difference diminishes to 5.0 dB. For most of the range of use of the WBFD, then, there is about a 1 S-unit deficit in gain relative to a standard doublet of the same length in the same position.

Second, the WBFD gain curve displays a significant knee--a frequency below which its gain deteriorates rapidly. In the case of the current model, that frequency is about 6 MHz. At or below the knee-frequency, the terminating resistor dissipates more and more of the power. The result is not only a large decrease in gain and higher temperature stresses on the resistor, but as well, very low SWR values at the feedpoint. The knee-effect as the WBFD becomes significantly short relative to the length of a resonant dipole easily accounts for the need to de-rate the antenna relative to transmitting power below a certain frequency.

The deficit in gain is not necessarily a disadvantage for receiving purposes. Modern receivers tend to be equipped with receiving pre-amplifiers that the user can switch in as desired. The gain may range from 10 to 20 dB, depending upon design, and in some receivers may be stepped or variable. Therefore the gain deficit can be largely made up in the lower HF range. Moreover, the basic receiver, apart from pre-amplification, already has excess gain that is rarely used in the lower HF region.

In addition, one of the major problems in reception in the lower HF range, especially with respect to SW broadcast stations, is front-end overload from excessive signal strength. The overload also tends to produce spurious products within the receiver. Hence, reduced gain of the antenna can be in some circumstances an advantage rather than a disadvantage. Combined with the RF attenuator built into many receivers--which may be a single reduction value or stepped--the WBFD offers a potential for excellent lower HF reception, free of some of the problems that occur with higher gain antennas.

Because the WBFD is also a closed loop with a terminating resistor, many users claim quieter reception relative to doublets for a given receiver input signal strength. The degree to which this is both true and separable from the freedom from front-end overload is difficult to determine. Nonetheless, SWLs have found the WBFD a very useful tool for their efforts.

In order to establish that the WBFD has the same pattern as a doublet of the same length for any given frequency and height above ground, let's look at a couple of sample free-space patterns. For example, see **Fig. 3**.

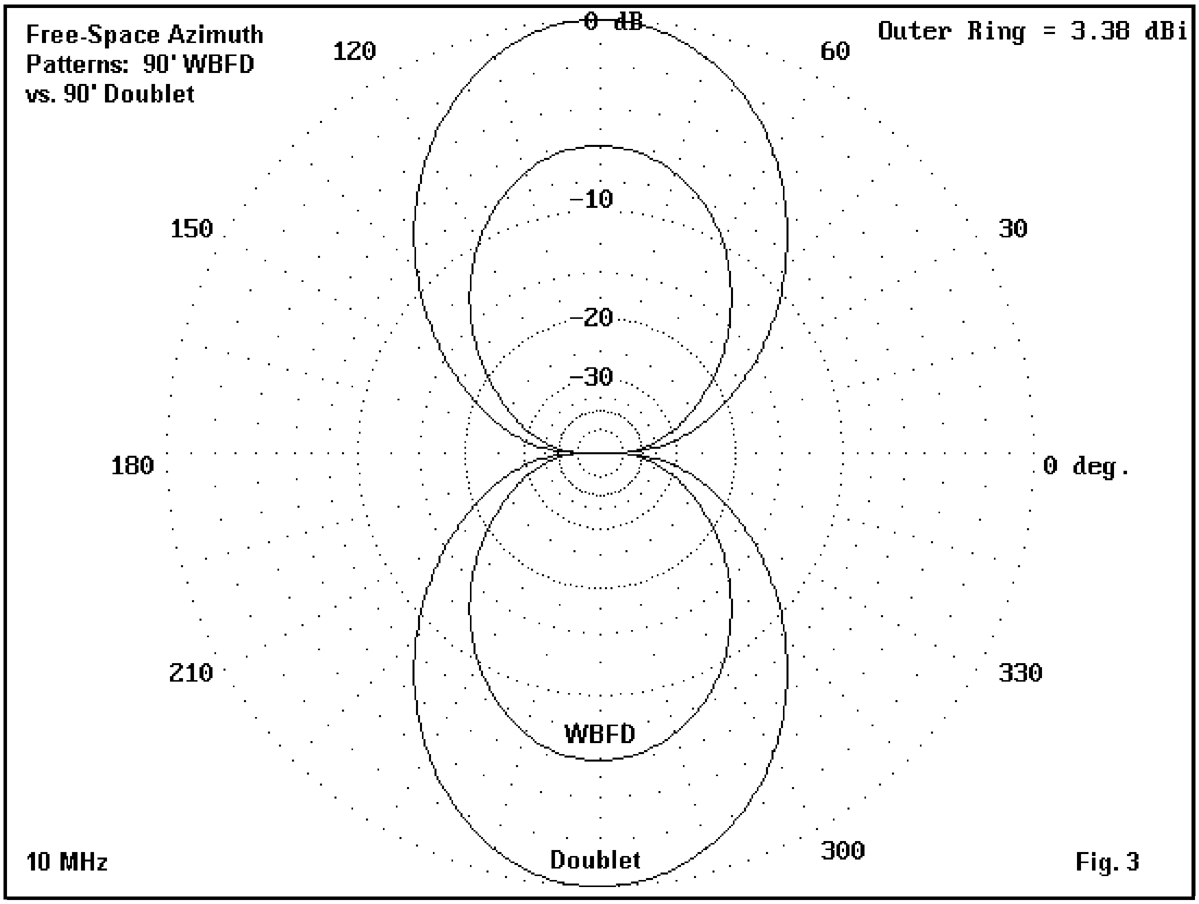


Fig. 3

The 27.2 meter WBFD and its comparison doublet exhibit a bi-directional pattern at 10 MHz. The shape of the pattern is identical, with only the 6 dB gain differential separating the two antennas. The -3 dB beamwidth points are also virtually identical. Since the take-off angle (elevation angle of maximum radiation), the reflection from a given set of ground conditions, and other such factors are not dependent upon signal strength, the two antennas would also show elevation patterns for any equal antenna height that are likewise congruent.

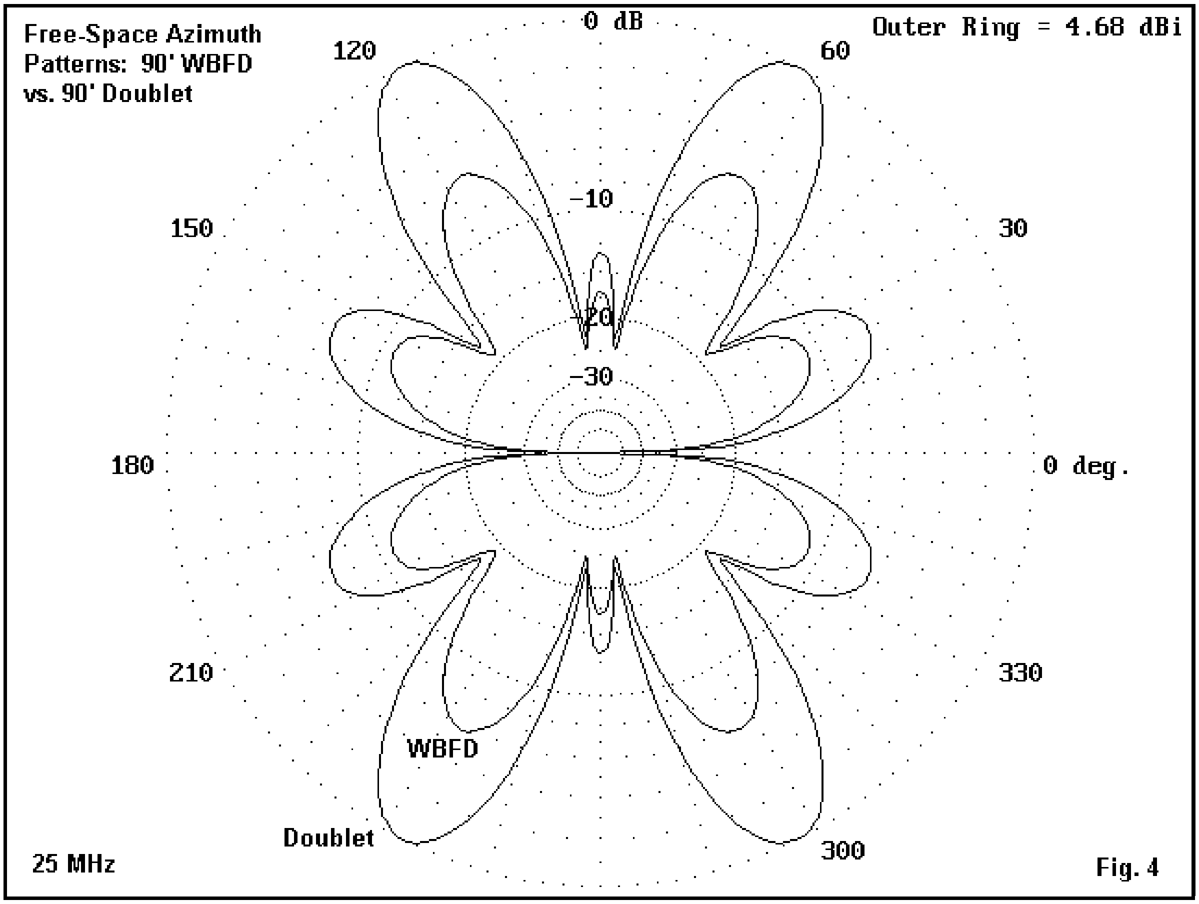


Fig. 4 shows comparative free-space azimuth patterns for the two antennas at 25 MHz. The WBFD pattern is simply a "mini" version of the doublet pattern, with about a 6 dB difference in strength.

There is an additional point in displaying these patterns. The exact pattern of lobes and nulls in the azimuth readings for a WBFD is identical to that of a doublet. As the length of the antenna exceeds 1.25 wavelength and approaches 1.5 wavelength, the bi-directional pattern at lower frequencies will break up into a collection of lobes and a collection of nulls. Therefore, the antenna is variably selective in its favored directions of good signal strength as one changes frequency. Those who contemplate installing either a doublet or a WBFD antenna need to consider well the patterns at key frequencies of interest in order to orient the antenna for maximum effectiveness.

The antenna type has also been used vertically to provide omni-directional coverage. However, in this orientation, when the antenna exceeds 1.25 wavelength in over length, the pattern begins to show primarily high angle radiation--exactly the opposite of what one normally desires from the upper HF band. As a result, some installations may use a pair of vertical WBFDs for full low-angle HF coverage.

A Note on Knees and Length

The knee of our 27.2-meter wide-band folded dipole occurs at about the frequency at which a center-fed doublet of the same length would be self-resonant, that is about 1/2-wavelength. We know that a doublet that is shorter than 1/2 wavelength exhibits a feedpoint resistance that declines with length and a capacitive reactance that increases with length.

The knee we observed in the gain of the 27.2 meter WBFD is interesting, since it suggests that we may vary the low frequency gain by changing the length of the antenna. Altering the length, of course, will also change the frequency at which the antenna transitions from a bi-directional pattern into a multi-lobed pattern.

To examine this question, I recreated the 27.2-m antenna model to perform frequency sweeps on both longer and shorter versions. As a sample, I ran a 50-m version and a 15-m version. All of the models used 820-Ohm terminating resistors, #14 AWG copper wire, and a spacing of 0.2 meters.

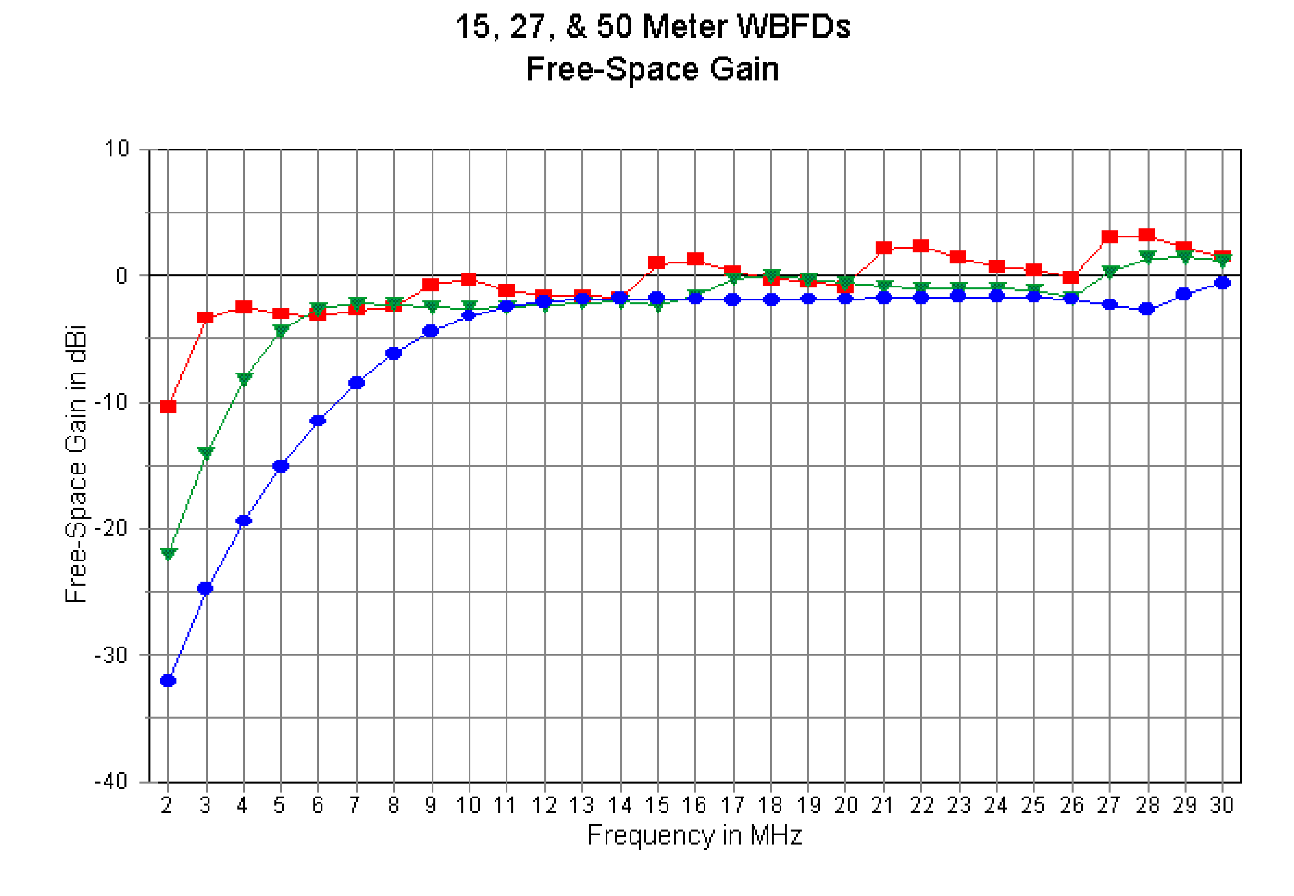


Fig. 5

Fig. 5 compares the gain of the three antennas from 2 through 30 MHz in 1 MHz steps. As suspected, the 50-m antenna reduces the knee frequency to about 3 MHz. In contrast, the 15-m version increases the knee frequency to about 10 MHz. In general, a home builder may interpolate values for the knee frequency for other lengths in the overall range.

The longest of the antenna models shows a mere -10 dBi gain at 2 MHz, a value easily made up by the receiver and only about 1.5 to 2 S-units below the average gain of the antenna. Hence, it is likely to be more satisfactory as a transmitting antenna in the lower HF region. In contrast, the 2 MHz performance of the 15-m version is more than 30 dB lower than the average antenna performance, making it more suitable for higher HF transmitting.

The variations in gain among the curves in the relatively flat region of performance are a function of lobe formation. Maximum gain tends to attach to the major lobes of patterns taken at just higher than integral multiple of a wavelength, relative to antenna length. Minimum gain levels tend to be associated with antenna lengths near the "x+.5" wavelength (where x is an integer) points. When an antenna is 1.5, 2.5, 3.5, etc. wavelengths long, its pattern consists of a combination of emerging and disappearing lobes, all of relatively equal strength. For example, a 1-wavelength wire has 2 strong lobes that are 180 degrees apart and a 2 wavelength wire has 4 strong lobes that are roughly 90 degrees apart. A 1.5 wavelength wire has 6 lobes, as the 1 wavelength lobes diminish and the 2 wavelength lobes grow. Hence, coverage is wide, but at a reduction in maximum strength.

The number of peaks and valleys in the three gain curves is a function of length. The 50-m antenna passes through many more transitions from x wavelength to x.5 wavelength (where x is an integer) across the frequency span than do either of the shorter antennas. Hence, we should expect more highs and lows in the gain pattern.

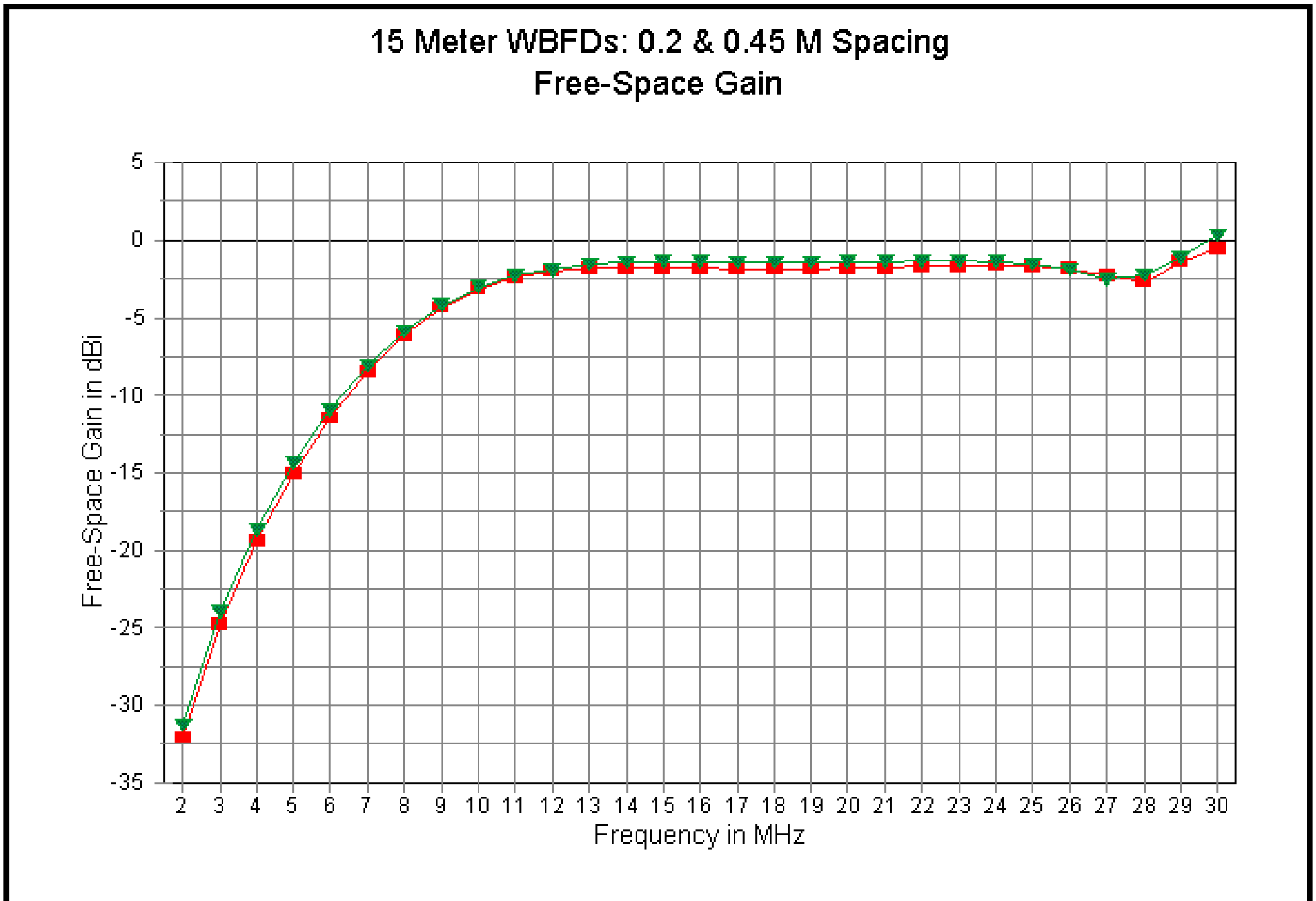


Fig. 5a

One question posed by various recommended wire spacings in past literature is whether wire spacing makes a difference to performance. **Fig. 5a** provides something of an answer as it compares the gain values for models of a 15-meter long version in 0.2-m and 0.45-m spacing. The gain values are insignificantly different, ranging from 0.2 to 0.4 dB.

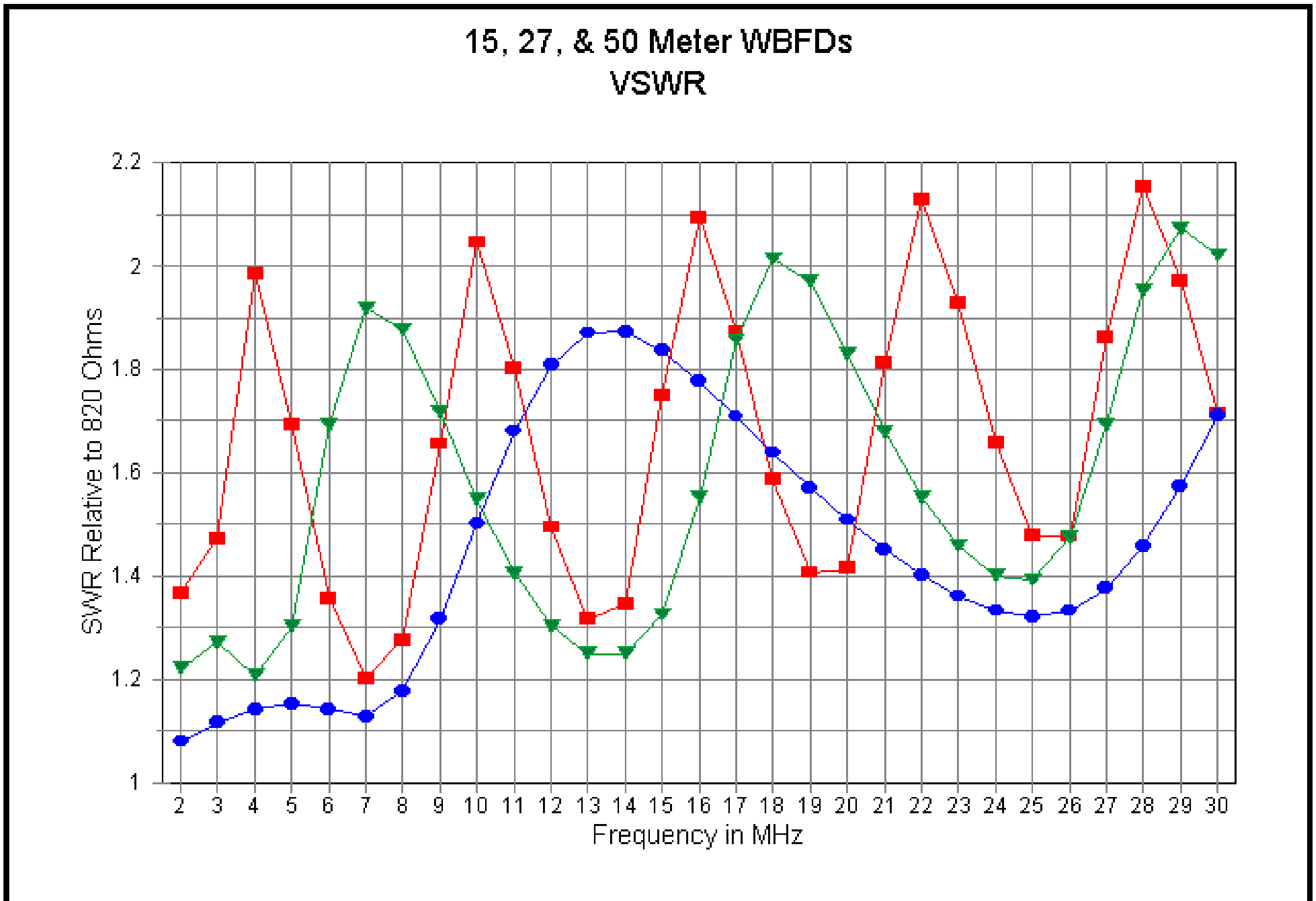


Fig. 6

We find that the curve of SWR relative to the value of the terminating resistor will also show similar transitions according to WBFD antenna length. **Fig. 6** shows the SWR pattern for the three antenna models. If we look at the most dramatic fluctuations--in the case of the 50-m antenna, we discover SWR peaks at x+2/3 wavelength points (where x is an integer). In contrast, we find SWR minimum values at the x+1/6 wavelength points (where x is an integer). The frequency span between points relative to the antenna length is 1/2 wavelength. The shorter antennas show the same pattern. However, the pattern is less evident because there are fewer maximum and minimum values to sample.

We may also note that the longer the WBFD, the higher the SWR excursions for a given value of terminating resistor. However, if we examine the lowest values of minimum SWR and exclude the region below the gain knee of the curve, the corresponding low points in the curve show the longest antenna also to exhibit the lowest minimum value of SWR. In other words, for a given wire size, spacing, and terminating resistor, longer WBFDs will exhibit a larger range within any given SWR cycle. As we approach the upper HF range, the values may exceed the desired 2:1 SWR limit.

The amount by which a long WBFD exceeds a 2:1 SWR is not great, but it is noticeable. For receiving applications, mild excursions beyond the 2:1 limit have virtually no affect on the received signal strength for any length of 50-Ohm coax. Some transmitters use automatic power reduction circuitry as the SWR approaches 2:1 (using an internal reverse voltage sensor), and some linear amplifiers begin reducing power at lower levels of SWR in order to protect expensive transmitting tubes.

There are two means of overcoming the potential problems of "high" SWR. Some manufacturers recommend the use of very long coaxial cables. Since the losses in the line increase with frequency, the SWR observed at the station end of the line will be lower at higher HF frequencies than at lower HF frequencies for any given value of SWR at the antenna end of the cable. The result of using longer coaxial cable runs will then be an SWR curve at the transmitter output that never exceeds 2:1. Compared to the reduced gain already inherent in WBFD design, the added losses of a long cable run are not considered excessive when totaling the overall system gain.

Alternatively, modern amateur transceivers (and those in other services) are routinely (but not universally) equipped with automatic antenna tuner circuitry. Although limited in range compared to a wide-range external antenna tuner, these tuners are certainly adequate to handle the modest SWR values presented by even the longest WBFDs. Hence, the transmitter output circuitry prior to the tuner will show a very low SWR.

Construction

The decision to use a WBFD involves an evaluation of one's goals in operating or listening. Only with a set of specifications of this order can one decide whether the WBFD will meet the needs. The description of the antenna's advantages and limitations must be set against the operating specifications and along side other potential antennas that are candidates. Then selection becomes a matter of choosing the antenna that does most of the jobs well enough.

If you do decide to use a WBFD, you can purchase one of the commercially made types. B&W (USA), Giovannini (Italy), and others produce these antennas in a variety of lengths. Alternatively, you can build your own.

The antenna proper uses standard techniques of wide-spaced folded dipole construction. You will need twice the length of wire as you determine the antenna length to be. There is nothing critical about the exact length, although the general length will be a function of where you decide to place the frequency that forms the knee separating relative even performance at higher frequencies from diminishing gain at lower frequencies.

Fig. 7 Two Methods of Making Spacers

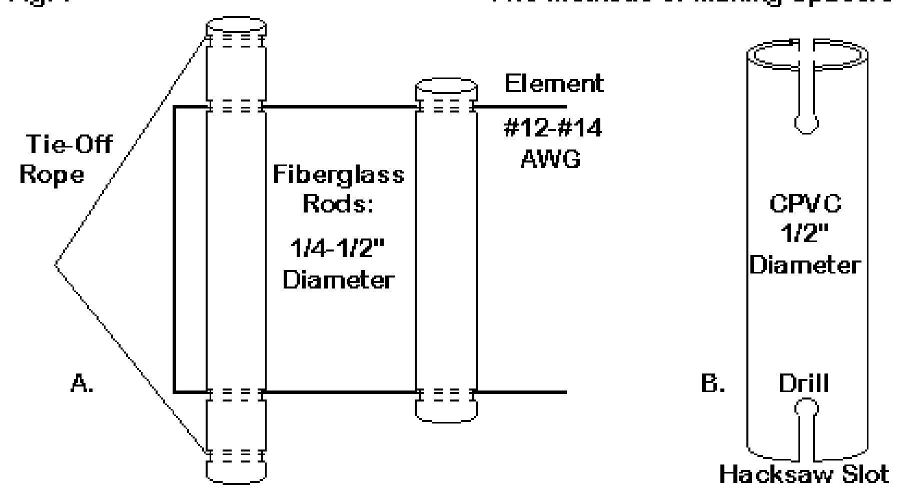


Fig. 7 shows just 2 of many ways to space the wires along their length. In the 1930s, we might have used wood dowels boiled in paraffin. Today, we have access to a variety of better materials. Part A of the sketches shows fiberglass rods, with holes drilled to pass the size wire we decide to use. #12 to #14 AWG copper wire (0.06-0.08" or 1.5-2.0 mm) is likely to be the most common choice. The end post can be longer to hold tie-off ropes for the assembly. Fiberglass rods can be purchased from mail order sources. However, local home improvement centers often carry adaptable materials. For example, I recently spotted some 1/2" diameter fiberglass rod under the guise of chimney flue brush extension handles.

Alternatively, I have also had good luck using 1/2" diameter CPVC, a thin-wall form of PVC tubing that replicates copper tubing sizes, shown in Part B of **Fig. 7**. A hacksaw cut in each end leads to a hole drilled to pass the chosen wire size. The wire press fits down the slot and into the hole. If the holes are not deburred, the wires stay put, although the spacers can be repositioned with fair ease.

These are simply two of many ways to make the required spacers. Narrow strips of polycarbonate, acrylic, or Plexiglas would also work. Polycarbonate likely has the best UV resistance of this group. When adapting materials to a new use and environment, it is wise to check the structure every so often to ensure that it is wearing well under the influence of sunlight, precipitation, and temperature excursions. Of course, cut any spacers that you use to the desired length--about 8" (0.2 m) between wire holes for the models examined here. However, this spacing is not very critical.

Locating a non-inductive resistor of sufficient power dissipation is likely to be the chief problem for WBFD builders who intend to transmit with the antenna. Unless you can find a suitable resistor at one of the surplus outlets, purchasing an antenna may prove economical in the long run, if we add both cost and parts-searching time together. Any value in the 800-900 Ohm range--or even "thereabouts," if a bargain appears--will serve.

Manufacturers use different methods of packaging the resistor into the antenna assembly. Some prefer a total enclosure to weatherproof and bug-proof the resistor. However, one might have to de-rate the resistor's power handling capability under these circumstances. To maximize power dissipation, the resistor can be placed within a tube that is about twice the diameter and about 1.5 times the resistor's length. Air passing through the tube provides cooling, while the tube itself protects against immediate weather impacts. Since the antenna wire and resistor terminals will attach to strips of metal bonded to the tube, the resistor itself is relieved of strain. The down side of this technique is the need to clean out bugs and others debris on a regular basis. However, semi-annual inspection and antenna maintenance is always a good policy.

For receiving-only applications, the resistor problem is much simplified. A series-parallel combination of carbon resistors with a net value of about 820 Ohms is easy to arrange. 1 to 5 watt non-inductive resistors provide the sturdiest construction. The assembly should be mounted in a UV-resistant plastic housing with strong terminals for connecting the antenna wires.

The other challenging component is the 16:1 RF transformer. The builder has two general types of transformers to use: a transmission-line transformer or a standard wide-bandwidth transformer using a toroidal core. Transmission-line transformers are slightly more efficient for transmitting purposes, although they prefer purely resistive loads. Jerry Sevick, W2FMI, has written extensively on these units, with instructions on how to build them for many impedance transformation ratios. In a pinch, one might place two 4:1 baluns in series.

There are proponents of standard RF transformers using toroidal cores. Doug DeMaw, W1FB, has written on their use, including calculating the power-handling capability of various cores. For receiving-only applications, small cores can be used, and the basic requirements and calculations are described in recent editions of the *ARRL Handbook*, Chapter 6.

Whatever form of RF transformer you use, package it to withstand weather. A sealed UV-resistant plastic box with a correctly placed "weep" hole for moisture drainage is a good choice. Obviously, you will need connections for the antenna wires as well as a coax connector.

A 3-Wire Version of the WBFD

The WBFD has many variations, and from time to time--as I encounter and model them--I shall add a few notes on them. The first addition to the list is a 3-wire WHFD, outlined in **Fig. 8**, with the 2-wire version shown for contrast.

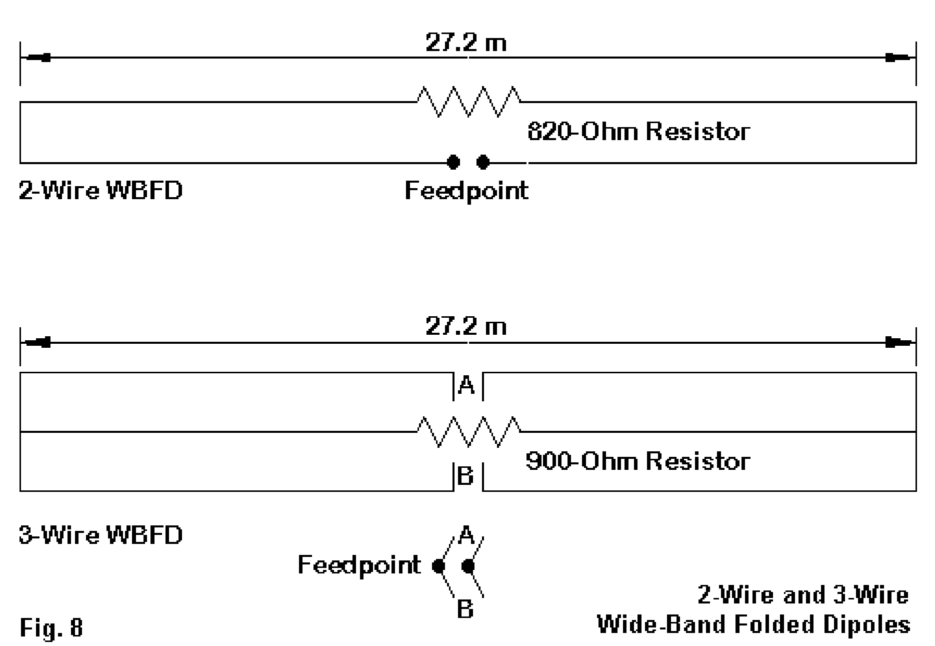


Fig. 8

For comparative purposes, I have made each antenna 27.2-m long, with a 0.2-m separation between wires. The 3-wire version places the terminating resistor in the "center" wire and parallel feeds the two "outer" wires. Although the arrangements is shown as a flat configuration, one can, as a variation, create a triangle of wires.

With two parallel-fed wires, the terminating resistor needs to be about 1.5 times the anticipated center feedpoint impedance. Hence, the model uses a 900-Ohm resistor, with 600-Ohms as the expected feedpoint impedance. Of course, the feedpoint impedance is a nominal value, since the actual resistive component of the impedance will fluctuate continuously above and below that value as we move across the operating span.

In general, the 3-wire version of the WBFD is capable of about 1-3 dB (depending upon frequency) gain advantage over the 2-wire version. The following brief table provides a glimpse at the fluctuations for the 27.2-m antennas. All gain values are for free-space.

Frequency MHz	2-Wire Gain dBi	3-Wire Gain dBi	3-Wire Advantage dB
5	-4.39	-1.62	2.77
10	-2.51	-1.11	1.40
15	-2.42	-0.39	2.02
20	-0.56	+0.74	1.30
25	-1.20	+0.53	1.73
30	+1.28	+2.58	1.30

Despite these fluctuations, the gain curves for the two versions of the WBFD are remarkable congruent, as shown in **Fig. 9**. The dual or parallel feed system of the 3-wire WBFD increases gain by feeding 2 wires, but it does not change the main characteristics of the antenna. Besides the congruence of gain curves, the patterns yielded by the 3-wire antenna differ from those of the 2-wire version only in peak gain, but not in strength. Since the gain increase is marginal, both antennas have patterns that replicate those of a simple doublet (with its widely varying impedance with changes in frequency), but remain smaller, that is, have much lower peak gain values.

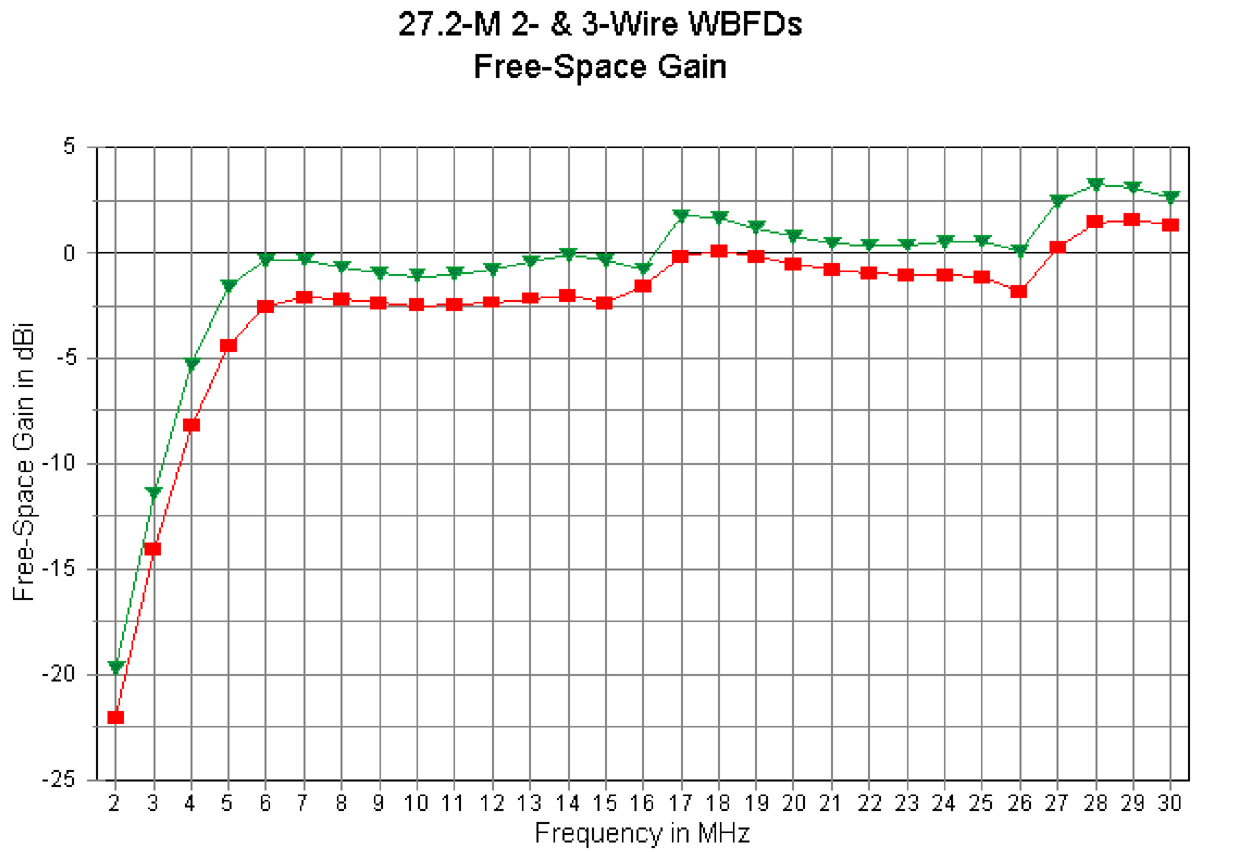
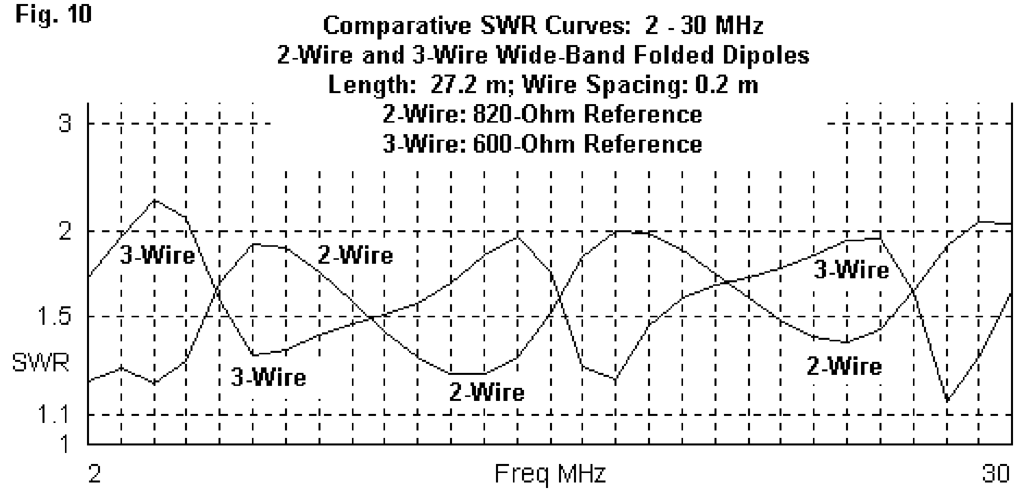


Fig. 9

The cost for the small increase in gain is a wider fluctuation in the impedance about a central impedance value. The reactance tends to be somewhat higher than for the 2-wire WBFD. **Fig. 10** shows the comparative SWR curves for the two antennas, with each one using its own reference value: 820 Ohms for the 2-wire version and 600 Ohms for the 3-wire version.

Fig. 10



In addition to having higher peak values in the 2-30-MHz span, the 3-wire version curve slopes differ from the corresponding 2-wire slopes. The shallower parts of the curves are on opposite sides of the peaks.

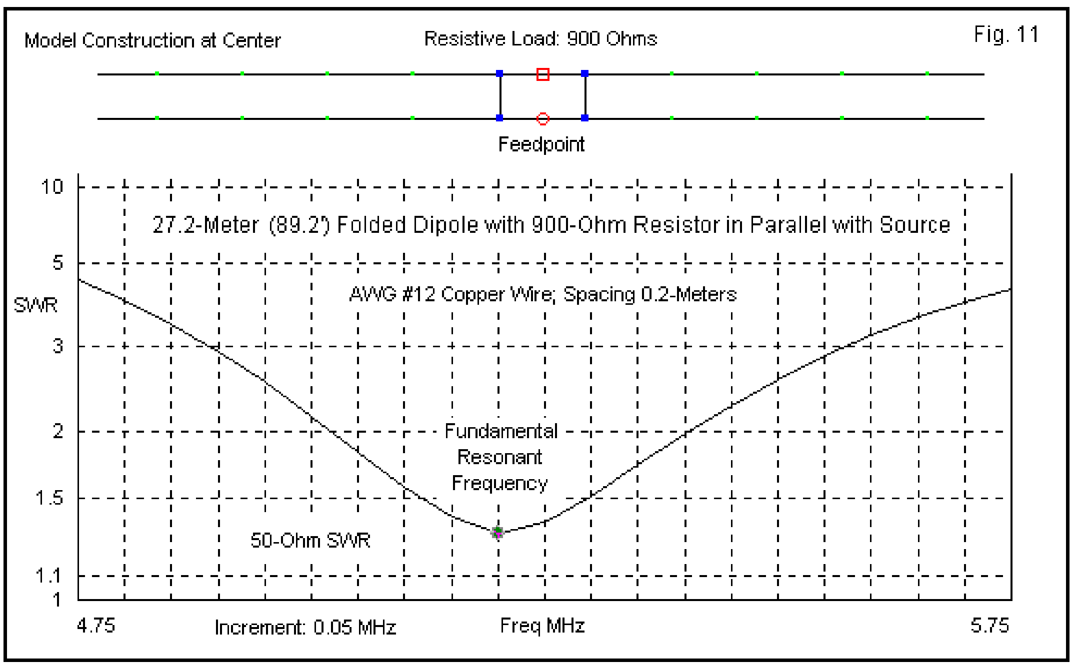
The construction of a 3-wire WBFD can generally follow the same set of techniques used for the 2-wire antenna, with the separators enlarged to handle the broader plane. The additional wire will increase the weight of the antenna proper by nearly 50%, and center support of the terminating resistor and the feedpoint area is advisable. Short sections of 600-Ohm (or thereabouts) open-wire feedline can create the feedpoint junction. Like the 2-wire WBFD, the 3-wire version requires a balun system or a wide-band transformer to match a 50-Ohm coax feedline.

WBFDs can be used in inverted-Vee configurations. However, expect a decrease in the broadside gain and some vertically polarized radiation off the ends of the array--just as you would find in a simple doublet. The steeper the angle of the two side of the antenna, the greater will be the radiation off its ends. As the antenna length exceeds 1 wavelength, the patterns may increasingly differ from those of the antenna used horizontally.

A Common Mistaken View of the Wide-Band Folded Dipole

We may look at the wide-band folded dipole from another perspective, one encouraged by a 1983 B&W patent (#4,423,423). The patent sketch shows shorting wires close to the center of the array. The wires connect the feedpoint to the terminating resistor. In addition, they also connect the inner or feedpoint ends of each wire pair.

The result of this variation is an antenna that is NOT a WBFD. Instead, as revealed by the sketch portion of **Fig. 11**, the new configuration places the resistor in a simple parallel connection with the feedpoint. The wires extending from the junctions of this parallel connection form virtual "fat" single wires to complete what amounts to a center-fed doublet.



The sketch shows a 900-Ohm resistor in parallel with the feedpoint of the 27.2-m antenna. The SWR curve that accompanies the sketch reveals a property that is unlike the true WBFD antenna: a resonant feedpoint at about 5.2 MHz. The actual reported resonant impedance is about 63 Ohms. The parallel combination of 900 Ohms (the resistor) and 70 Ohms (the typical resonant dipole resistance) is about 65 Ohms.

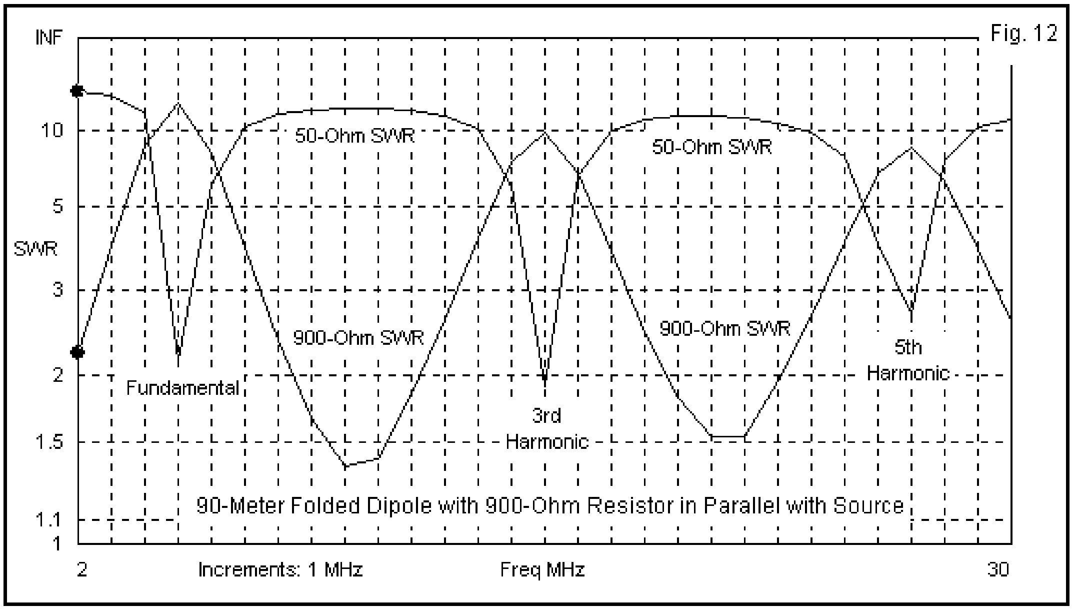


Fig. 12 provides a set of SWR curves across the 2-30-MHz span that we have used in the examination of the true WBFD. Since the increment between readings is 1 MHz, the 50-Ohm curves do not necessarily show the best SWR values possible. However, the 3 SWR minimum points show that the antenna acts completely normally when treated as a center-fed doublet. The 3 low 50-Ohm SWR values occur at the fundamental, the 3rd harmonic, and the 5th harmonic frequencies for the wire.

The 900-Ohm SWR curve, of course, shows the opposite trend relative to the 50-Ohm curve. Minimum SWR values occur at the 2nd and 4th harmonic frequencies of the wire (between 10 and 11 MHz and again between 20 and 21 MHz). At these frequencies, the antenna feedpoint impedance would show very high values of resistance and reactance (except for a tiny frequency region where the reactance passes through zero as it changes type). Under these conditions, the 900 Ohm resistor dominates the parallel combination.

We may compare the gain performance of this "faux" WBFD with a true WBFD of the same length. Construction would be identical except for the use or non-use of the shorting wires. At the fundamental and the odd harmonic frequencies, as shown in **Fig. 13**, the new antenna shows higher gain. However, at the 2nd and 4th harmonics, the gain values are virtually the same for both antennas.

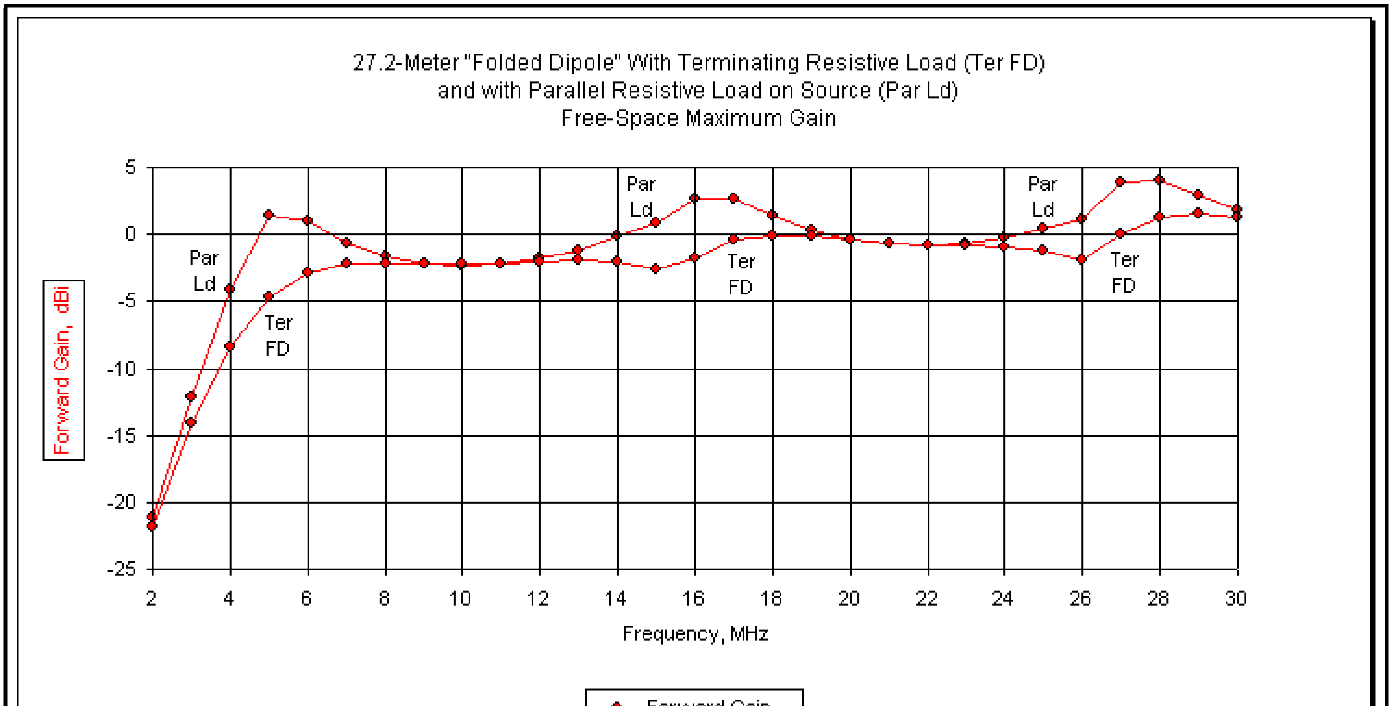


Fig. 13

The dominant problem with the faux WBFD is the changing feedpoint requirement as we alter the frequency of operation. A direct coaxial feed is applicable in only 3 narrow frequency regions of the spectrum. Likewise, the 16:1 balun treatment shows equally limited application. Given the feeding limitations, one might well use a simple center-fed doublet with a parallel feedline and a wide-range antenna tuner. **Fig. 14** overlays free-space E-plane (azimuth) patterns for 5.2, 10.4, 15.6, and 20.8 MHz to provide a better performance comparison among the doublet, the WBFD, and the faux WBFD.

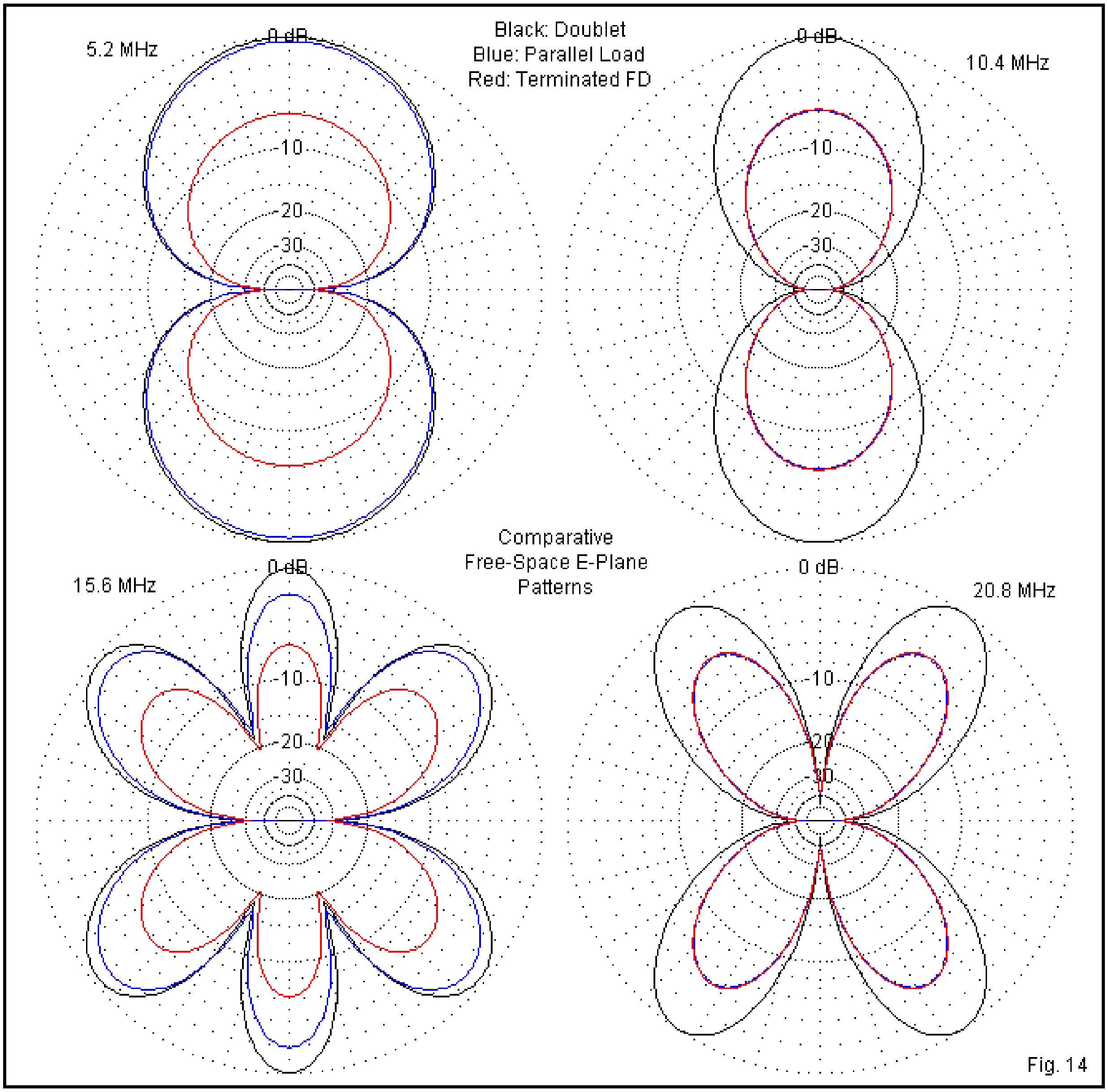


Fig. 14

In all cases, the center-fed doublet exhibits the highest maximum gain. On the fundamental and the odd harmonics, the faux WBFD is nearly as strong, and the true WBFD is considerably weaker. On even harmonics, the doublet's gain is very significantly higher than both versions of the folded antenna with a resistor. The consistent aspect of the patterns is their shape. They are perfectly congruent throughout, differing only in the gain value.

The faux WBFD turns out to be a simple center-fed doublet with a resistor that parallels the feedpoint terminals. Unless one needs an antenna that operates only on even harmonics of the antenna's fundamental length, it offers no useful advantages over the single-wire doublet without the resistor. At many frequencies, its gain deficit can be a distinct disadvantage.

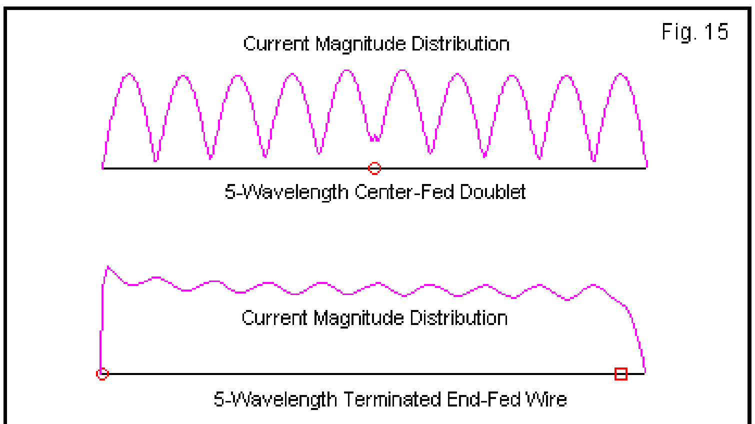
What Kind of Antenna is the True WBFD?

We have been exploring the behavior of the WBFD so intently, that we have overlook an interesting and significant question: What kind of antenna is the WBFD? We have already shown some reasons why it is not a true folded dipole. But, we have not placed the WBFD into an appropriate category of antennas.

The answer to our question is both easy and difficult: the terminated folded is a variety of traveling-wave antenna. Entire books have been devoted to traveling wave antennas. See, for example, C. H. Walter, *Traveling Wave Antennas* (1965): a classic and very thorough text on traveling-wave fundamentals for all relevant types of antennas. More commonly recognized traveling wave antennas are terminated long-wires, V-beams, and rhombics. However, many types of traveling wave antennas require no resistive or other termination.

For our very limited purposes, we may contrast standing-wave and traveling-wave antennas in an over-simplified manner. Consider a transmission line that is lossless or perfect. If we leave the load end of the line without a load in an open condition, the entirety of the energy from the source returns to the source. In a transmission line, we usually view this condition as a system fault, since we obtain no useful work from the source energy. However, if we separate the transmission-line wires to create a doublet, something else happens. We have the energy reaching the line ends and returning. The result is a set of standing waves along the wire. Since the separate-wire situation creates a transducer, we obtain useful work in the conversion of the energy into into a field that expands without limit. An ideal antenna would show standing waves that reach the same peak value (however measured) at every peak. As well, all wave minimums would go to zero.

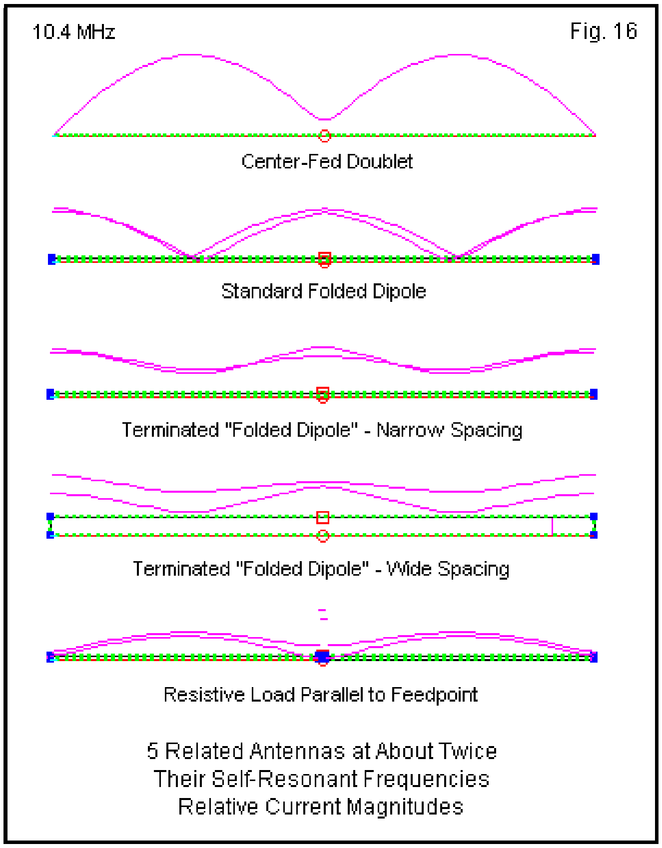
There is no such thing as a perfect standing-wave antenna. Consider a 5-wavelength center-fed doublet composed of lossless wire. It will show a feedpoint current minimum value that is limited by the impedance at the feedpoint. As well, other current minimum points will not reach zero except at the very ends of the antenna. Likewise, the peak values will not be identical along with wire, with the highest peaks occurring closest to and farthest from the feedpoint. The top portion of **Fig. 15** shows a typical (imperfect) standing wave current pattern.



Standing-Wave and Traveling-Wave Current Distribution

The lower portion of **Fig. 15** shows the current distribution along a terminated end-fed long-wire, one of the simplest traveling-wave antennas. Since we have a terminating impedance, the ideal situation would show a constant current magnitude all along the wire. The termination impedance prevents the return of energy necessary to create stading waves. For a variety of reasons, terminated wires fail to achieve a perfect traveling-wave status. The termination is normally and for highly practical reasons a non-inductive resistor. However, the required impedance turns out to be both complex and finicky. So we only approximate a traveling wave, a basic current level with superimposed standing waves that are small but detectable. (The example shown uses a technique for setting up a traveling-wave long wire described by E. A. Laport in *Radio Antenna Engineering*, pp. 55-58, 301-339 (1950).)

The relevance of these notes to the WBFD and related antennas is straightforward: we may use the current distribution along an antenna to determine in a general way whether an antenna is a standing-wave or a traveling-wave antenna. **Fig. 16** shows the current distribution at 10.4 MHz of several antennas, all 27.2 m long. 10.4 MHz is the second harmonic of the 5.2-MHz fundamental frequency. The arbitrary feedpoint current for all of the antennas is 1.0 (A) with a 0.0-degree phase angle. All current values are relative to this convenient value.



The center-fed single-wire doublet, a prime example of a standing-wave antenna, shows peak current values about half-way between the feedpoint and the wire ends. The peak currents are over 5 times the feedpoint value, a typical situation for a 1-wavelength doublet. The second antenna is a folded dipole operated at its second harmonic. It gain is low due to the very low value of the feedpoint resistance (about 7 Ohms). Hence, even the copper wire construction removes almost 3 dB of the antenna's theoretical gain if made from lossless wire. Nevertheless, within these restrictions, the antenna shows the folded-dipole version of a standing wave. Relative to the single-wire doublet, the standing wave is displaced by a quarter-wavelength along the wire due to the fact that folded dipoles show a combination of radiation and transmission-line currents. (For more on this subject, see "Unfolding the Story of the Folded Dipole".) Note that the current minimums are very close to zero (actually about 0.02 to 0.03 relative magnitude).

The next two antennas shown in **Fig. 16** are alternative narrow-spaced and wide-space versions of the true WBFD. The narrow version spaces the wires by 0.2 m; the wide version uses a spacing of 1.0 m. In the wide version, each current curve is relative in height to the distance from its associated wire. In both cases, the antennas exhibit a standing-wave property, but overlaid on a traveling-wave current value of about .75 relative magnitude. The standing-wave component is about +/-0.30 relative magnitude. Hence, the minimum current level is a bit over 0.45 relative to the feedpoint value. (Values for the 2 versions of the antenna may vary by about 0.03 in relative magnitude from the listed values or about 5%.) The fact that we see the overlaid standing-wave component in current graphs may obscure the basic traveling-wave component of the current distribution until we realize that the current magnitude never approaches zero and remains well above zero throughout the antenna structure.

All traveling-wave antennas that use terminations dissipate energy in the resistive portion of the termination. Although "sound-bite" wisdom about terminations uses a dissipation value of 50%, we should generally ignore that figure. The actual dissipation in the termination depends on the antenna configuration and frequency of operation. The actual value may be over or under that value by a considerable amount. However, any energy dissipated is unavaiable for the radiated field, and hence, we obtain the WBFD gain levels that fall considerably short of comparable fields from the center-fed doublet.

The bottom current distribution pattern in **Fig. 16** completes the survey by including the curves for the faux WBFD. The curves have the general shape of those for the center-fed single-wire doublet and the minimum values approach zero. The parallel resistor does not change the antenna's classification as essentially a standing-wave antenna.

Although the last antenna is indeed a faux WBFD, since is has no relationship except physical appearance to a folded dipole of any sort, I have avoided calling the WBFD a faux folded dipole. The WBFD is not a true folded dipole because it is a traveling-wave antenna. Nevertheless, it retains more than vestigial traces of its folded-dipole origins in the overlaid standing wave pattern on the baseline traveling-wave current level.

Conclusion

A WBFD antenna is not for everyone. However, gaining some understanding of its operation, its nature, its advantages, and its limitations may be useful in the process of choosing an antenna--or even simply learning more about what various antenna types can do. The WBFD has its niche among amateur, governmental/military, and SWL antennas, but that niche is certainly not universal. The government and the military find the antenna useful for ALE (very rapid frequency excursions), and some amateurs are experimenting with these techniques. Within more normal time periods allowed for frequency changes, antenna tuner automation is generally fast enough for most contest environments, and manual tuning suffices for other communications--using a single-wire doublet.

Receiving versions of the antenna can be home built for not much more than the cost of the wire, since the materials necessary for low-power terminating resistors and wide-band RF transformers are low. However, building a transmitting version of the antenna at home may be much more problematical, since parts may be hard to find or hard to fabricate. The alternative, of course, is one of the commercial versions, in an exchange of bucks for bother.