160- vs. 80-Meter Isolated Off-Center-Fed Antennas

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In a recent set of notes, "The Isolated Off-Center-Fed Antenna: Some Less-Explored Facets" (http://www.cebik.com/wire/iocf.pdf), we explored some of the interesting but less discussed aspects of the behavior of off-center-fed (OCF) antennas used for multi-band HF service. The basic antenna that we used was a 3.5-MHz AWG #14 copper wire element. There is a second version of the antenna that has been from time to time popular: an OCF cut essentially for 160 meters as the fundamental frequency. In these notes, we shall compare the two antennas relative to features other than length alone. In some ways, the two versions of the isolated OCF are very similar; in others, they have a few notable differences.

Back to Basics

In the earlier notes, I grouped OCF antennas into three general types, as shown in **Fig. 1**. The oldest type is the original Windom that used a single wire feedline. For further detailed information on the 1929 antenna, see "Notes on Mr. Windom's 'Ethereal Adornments'" (http://www.cebik.com/wire/wind.pdf). The center sketch shows a common "convenience" antenna where the feedpoint position is normally a matter of obtaining the shortest run of parallel transmission line to the transceiver and the antenna tuner. This antenna almost defies precise analysis because the parallel feedline carries both transmission line and radiation currents. The line may be of any length and run at almost any set of angles between the antenna and the tuner. It has largely supplanted the Windom and serves many stations well in general communications work.

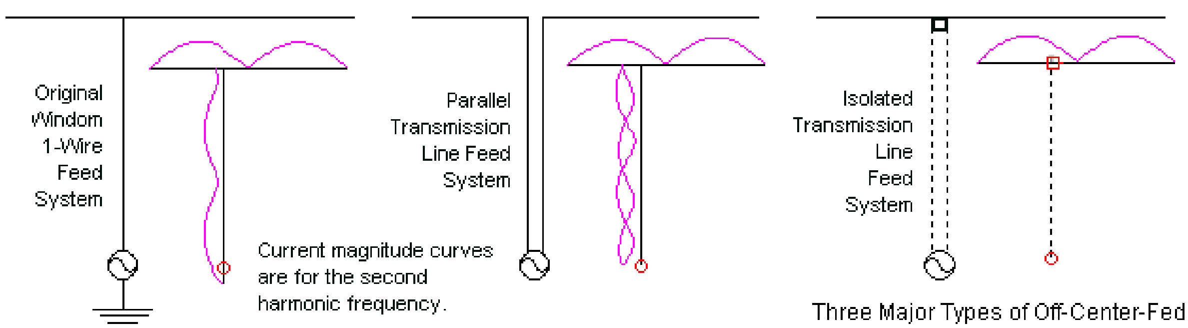
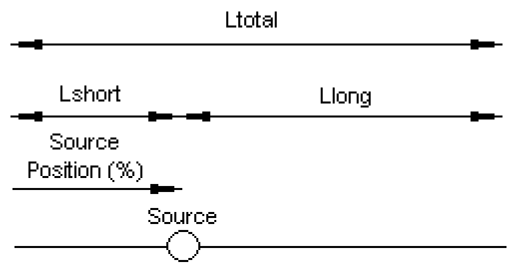


Fig. 1

The third type is the basis for a number of designs over the last three decades. At the horizontal wire's feedpoint, we install an impedance transformer, usually a balun. The goal is to isolate the horizontal wire from the feedline so that the latter caries only transmission line currents and does not participate in the formation of the radiation patterns. Although earlier designs tended to use 6:1 baluns, presuming a 300-Ω feedpoint, more recent versions have settled upon a 4:1 balun on the presumption of a 200-Ω horizontal wire feedpoint impedance level. Besides a balun, we often find a ferrite bead choke at the 50-Ω terminals of the impedance transformer to enhance feedline isolation. We shall work with this type of OCF in these notes.

The OCF antenna has a fundamental feedpoint impedance that varies with the distance of the feedpoint from one end of the antenna. **Fig. 2** shows the conventional way of specifying OCF dimensions. We may fully describe the dimensions of an OCF by reference to the antenna length, the wire size, and the feedpoint position as a percentage of the total length from one end. The latter figure establishes the length of the short and the long ends of the antenna by simple arithmetic.

Fig. 2



Conventions for Listing Dimensions of an Off-Center-Fed (OCF) Element

Regardless of the selected fundamental frequency, the fundamental resonant impedance is relatively invariant as a percentage of the antenna length. **Table 1** provides the free-space dimensions of two OCFs, one for 1.75 MHz, the other for 3.5 MHz as fundamental frequencies. In both cases, the same listed feedpoint position percentage values provide the nominal feedpoint impedance values within a few Ohms. The particular percentages are a function of the modeling technique used. Since NEC models use an integral number of segments (in this case 200), the fractional percentages emerge. The actual dimensions are not quite as finicky as the table suggests. As well, dimensions do not change significantly with wire size excursions between AWG #10 and AWG #16. However, on bands where the antenna is quire close to the ground, interactions between the horizontal wire and the ground may result in performance variations relative to the free space model.

Table 1. Dimensions of isolated off-center-fed elements considered in these notes

Impedance Ω	Feedpoint Position %	Fundamental Freq. MHz	Length feet	Fundamental Freq. MHz	Length feet
100	32.75	1.75	274.0	3.5	137.1
150	24.25	(AWG #12)	274.7	(AWG #14)	137.3
200	20.25		274.9		137.45
250	17.75		275.2		137.6
300	16.25		275.6		137.8
350	14.75		275.9		137.9

Critical to understanding OCF behavior is a basic fact: the OCF is more closely related to the end-fed wire than to the center-fed doublet, especially in terms of pattern formation above the fundamental frequency. With a center-fed doublet, we generally relate the development of lobes in the E-plane or azimuth pattern to the antenna length in integral multiples of a wavelength. Hence, a 1-λ doublet has two lobes, while a 2-λ doublet has 4. An end-fed wire develops lobes in length increments of ½-λ. Hence, a ½-λ end-fed wire has two lobes (that are virtually identical to those of a ½-λ center-fed dipole), but at 1 λ, we find 4 lobes. The 2-λ end-fed wire has 8 lobes.

The OCF follows the general end-fed pattern of lobe development. This fact has a further consequence. The OCF has a potential operating window with an impedance value similar to the impedance at the fundamental frequency at increments of frequency corresponding to the fundamental frequency of the antenna. The increment is usually slightly greater in frequency than the fundamental frequency because only the end current excursions show wire end effects. Hence, in estimating the actual frequency increment between potential operating windows, add between 1% and 2% to the antenna's fundamental frequency.

Early OCFs tended to use relatively high values for the feedpoint position percentage value—up to 33% or so. Later versions placed the feedpoint position closer to the end of the wire to obtain a fundamental impedance value in the 300-Ω vicinity. The most recent OCF designs have settled upon the 20% position. One reason for this evolution is the convenience of using a common 4:1 balun at the feedpoint. As well, whatever the fundamental feedpoint impedance value, the upper band impedance levels tended to settle into a region between 100 Ω and 350 Ω, well within the functional limits of most 4:1 balun designs.

Potential vs. Actual Windows for a 3.5-MHz OCF

We may illustrate some of the consequences of shifting the feedpoint position by looking at the 3.5-MHz fundamental OCF. We shall perform a similar task for the 1.75-MHz OCF before very long. Let's make 200-Ω frequency sweeps of three variations of the antenna, using fundamental impedance levels of 100, 200, and 300 Ω. **Fig. 3** overlays the sweeps. Even though identifying each line may be difficult, certain critical data emerge from the exercise.

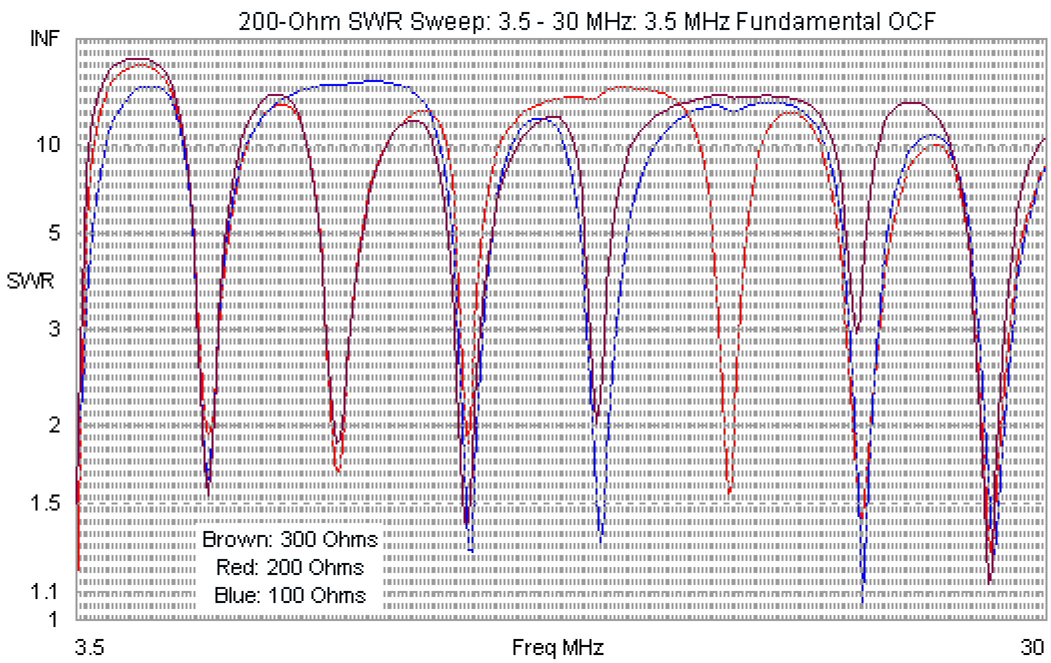


Fig. 3

The first item to note is the fact that the lower-impedance operating windows tend to fall at the same frequencies within fairly narrow margins—but with notable exceptions. The 200-Ω curve shows the greatest number of actual operating windows. However, we may notice a "dimple" in the other curves that do not show a lower impedance value. These dimples represent resonant frequencies, but at very high resistive values.

To be certain that we have not missed an opportunity for operating windows in the vicinity of 200 Ω, let's repeat the exercise using fundamental impedance values of 150, 250, and 350 Ω. **Fig. 4** provides the results. (Had we combined the two graphs, the results might be impossible to read. However, it is relatively easy to mentally overlay the two figures to obtain a total picture of OCF behavior between 3.5 and 30 MHz.)

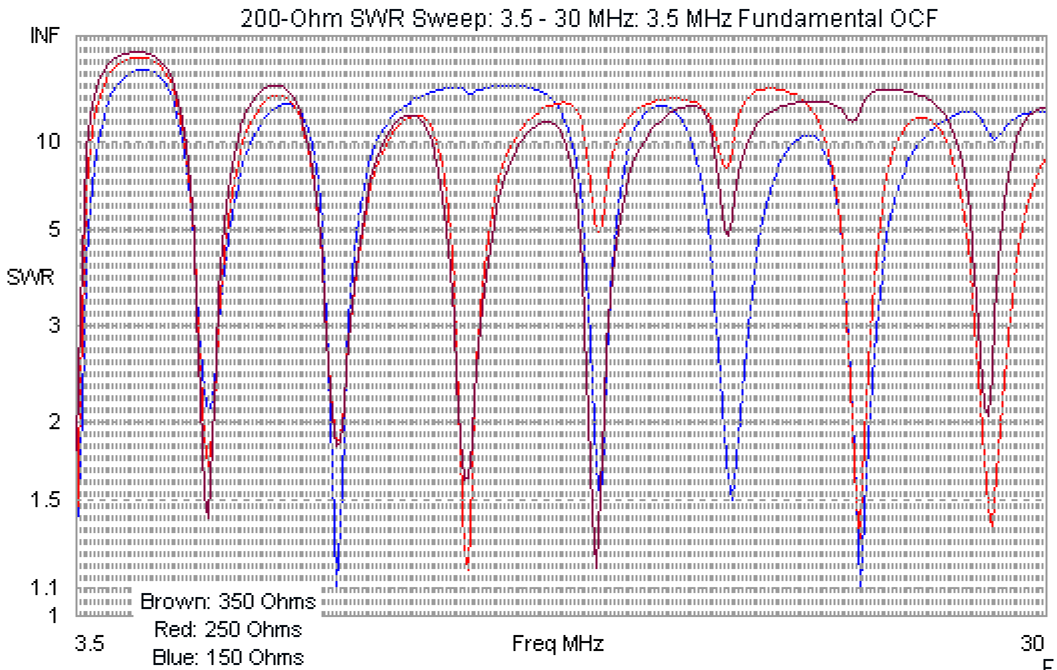


Fig. 4

Like the first graph, we find the actual operating window frequencies at the same frequencies. However, this set of graph lines presents fewer nearly complete sets of windows, that is, the chance to operate with a lower impedance value over all potential frequencies.

An alternative way to approach the same information is by inquiring into how many of the HF amateur bands between 3.5 and 30 MHZ show operating windows with impedance values suitable for transformation by a 4:1 balun to an impedance compatible with our usual coaxial cable feedlines. If we scan the sweeps at all fundamental impedance values between 100 Ω and 350 Ω, we obtain the information in **Table 2**.

We may take a window to be any low impedance value with an SWR of less than 2:1 at 200 Ω for at least part of the amateur band. For methods of developing full-band coverage, see "How Much Coaxial Cable? A Case Study" (http://www.cebik.com/wire/tlocf.pdf). If we obtain the desired window, the table enters "yes." The 60-meter entries show only a dashed line indicating that the band does not fall close enough to a harmonic of the fundamental frequency. 5.3 MHz is only about 1.5 times 3.5 MHz. If a window is theoretically possible but does not materialize—and therefore shows a resonant impedance with a very high resistive value—the table enters "no."

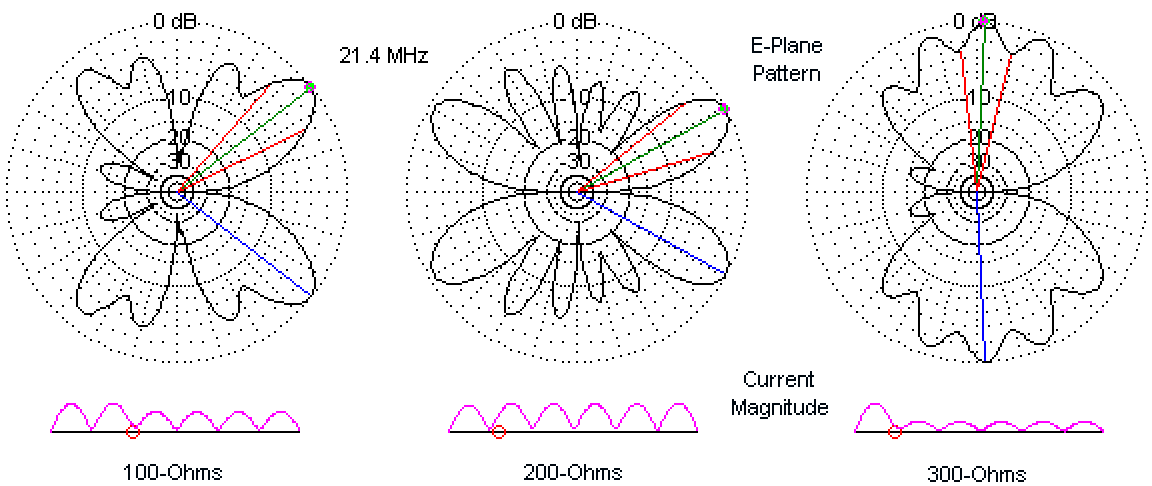
The table also contains two other entries of note. One is the word "high." This entry indicates that there is a reasonably near resonant frequency that is too high to cover the closest amateur band. 30 meters (10.1 to 10.15 MHz) is the primary case, because the sequence of harmonic frequencies places the operating window at 10.7 MHz (+/-0.1 MHz). Likewise, an entry of "low" indicates a nearby resonance that falls a bit too far below the nearby amateur band. The 17-meter band (18.068 to 18.168 MHz) is slightly above the resonance sequence at about 17.8 MHz (+/-0.1 MHz), and the windows tend to be quite narrow.

Table 2. Amateur bands included in coverage by a 3.5-MHz fundamental frequency OCF

Band	Fundamental Impedance						
Meters	100	150	200	250	300	350	
80	yes	yes	yes	yes	yes	yes	
60	-----	-----	-----	-----	-----	-----	
40	yes	yes	yes	yes	yes	yes	
30	no	high	high	high	high	high	10.7 MHz
20	yes	yes	yes	yes	yes	yes	
17	low	low	no	no	low	low	17.8 MHz
15	no	no	yes	no	no	no	
12	yes	yes	yes	yes	yes	no	
10	yes	no	yes	yes	yes	yes	
Total Included Bands	5	4	6	5	5	4	

Notes: 1. "yes" = at least partial coverage at a low 200-Ω SWR
2. "no" = impedance too high for 200-Ω coverage
3. "high" = resonance too high in frequency to cover band
4. "low" = resonance too low in frequency to cover band
5. "-----" = no resonance on or near band

Fig. 5 shows why the fundamental impedance and the associated feedpoint position determine whether potential operating windows become actual operating windows. The graphic shows the E-plane (azimuth) patterns of three versions of the OCF at 21.4 MHz, one of the potential operating windows. As well, for each pattern there is an associated current magnitude distribution graph. With the 200-Ω OCF, we obtain a normal pattern relative to what we expect from an end-fed wire of the same length at the same frequency. As well, the 200-Ω feedpoint does not coincide with one of the minimum current points along the horizontal wire element.



Why Not All Potential Operating Windows Are Actual Operating Windows
21.4-MHz E-Plane Patterns for 100-, 200-, and 300-Ohm Off-Center-Fed Elements

Fig. 5

Both the 100-Ω and the 300-Ω patterns are aberrant relative to our expectations. They might be highly usable if we had an operating window at 21.4 MHz. However, in both cases, we find that the horizontal wire feedpoint is very close to a current minimum. We may note two results of the feedpoint placement. One consequence is a very high resonant impedance at the potential operating window. The other result is a significant disturbance to the maximum current of the peaks, especially on the shorter end of the element. The altered current distribution is largely responsible for the changes in the pattern shape relative to the "normal" 200-Ω pattern. As well, if we look closely at the current curves (or examine the data tables from which they emerge), we find that the curves do not have equal length (or symmetry) on each side of the 100-Ω and 300-Ω feedpoint positions. The degree to which a very nearby feedpoint can "pull" the curves both limits the available operating windows and slightly shifts some of the window frequencies (usually by no more than about 0.1 MHz) from an anticipated position.

Because the 200-Ω version of the OCF, with its feedpoint position about 20% from one end of the wire element, provides the highest number of actual operating windows—relative to the potential windows that might be possible—it has become a de facto standard for isolated OCF design. As the earlier notes on the design have shown, the OCF has limitations, but at a length under 140', it offers the highest number of bands available for a coaxial feed system.

Potential vs. Actual Windows for a 1.75-MHz OCF

Our review of the basic properties of the 3.5-MHz fundamental OCF prepares us to consider a longer OCF. Essentially, the longer OCF is a 160-meter version of the antenna that we have just considered. **Table 1** lists the dimensions required for very nearly resonant operation of the antenna at its design frequency at various impedance levels. Although the antenna may offer some operation at the low end of 160 meters (1.8 MHz), we use a design frequency of 1.75 MHz to ensure that the operating windows occur within higher amateur bands. The same harmonic rule for the frequencies of operating windows applies to the long OCF as to the shorter version that we have been exploring. The 1.75-MHz fundamental OCF simply provides more windows between 3.5 and 30 MHz, as shown in the 200-Ω SWR sweeps in **Fig. 6**. We may restrict ourselves to sampling just the versions of the antenna for 100, 200, and 300 Ω.

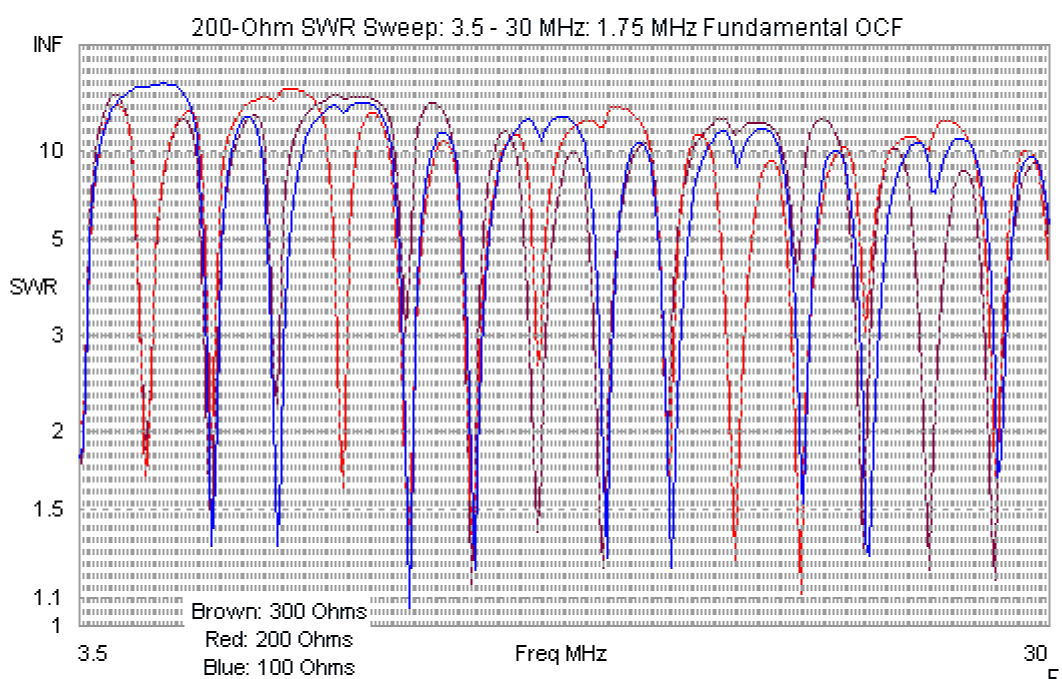


Fig. 6

Table 3. Amateur bands included in coverage by a 1.75-MHz fundamental frequency OCF

Band	Fundamental Impedance			
Meters	100	200	300	
160	yes	yes	no?	(3:1)
80	yes	yes	yes	
60	no	yes	yes	
40	yes	yes	yes	
30	no	high	no	10.7 MHz
20	yes	yes	yes	
17	low	no	low	17.8 MHz
15	no	yes	no	
12	yes	no	yes	
10	yes	yes	yes	
Total Included Bands	6	7	6	

Notes: 1. "yes" = at least partial coverage at a low 200-Ω SWR
2. "no" = impedance too high for 200-Ω coverage
3. "high" = resonance too high in frequency to cover band
4. "low" = resonance too low in frequency to cover band

Table 3 summarizes the coverage of the antenna for the amateur bands between 160 and 10 meters. Once more, the 200-Ω version of the antenna appears to offer the greatest number of amateur operating windows. Although SWR sweep offers more potential and actual operating windows than the shorter OCF, virtually all of the new windows (except for 60 meters) fall outside the amateur allocations. In fact, the usable operating windows fall almost precisely on the same frequencies for both antennas. 10.7 MHz is too high for 30-meter operation, and in most instances, 17.8 MHz will be too low for 17-meter operation. In fact, if we opt for the 200-Ω version of the longer OCF, 17 meters will not be available due to the feedpoint position that will produce a high resistive impedance in that window.

Even where the nearby windows are favorable, for instance, when using a 150-Ω version of the antenna (of either length), the windows are offset from the 30-meter and the 17-meter amateur bands. **Fig. 7** provides 200-Ω SWR sweeps across the region for each of the two bands using antennas of both lengths. The color stripe indicates the limits of the amateur band. For both OCF antennas the 30-meter band is simply too far from the operating window as defined by a relatively low 200-Ω SWR.

The 17-meter band for both antennas is less certainly excluded, at least for the 150-Ω version of the OCFs of both lengths. The decision as to whether to include 17 meters among the usable bands depends upon the SWR limits that one sets for the antenna system. The 18-MHz region shows increased coaxial cable losses. As well, the resistive and reactive components of the 17-meter impedance may not yield the highest efficiency from the impedance transformer (balun). Moreover, equipment-end decisions may play a role in the feasibility of using 17 meters. The use of an antenna tuner at the station may allow a relatively easy match to a 50-Ω transceiver. Relying upon the coaxial cable run to broaden the SWR bandwidth may give less certain results, especially when we consider the normal construction variables that go into hanging a wire antenna. Of course, if we opt for the 200-Ω version of either antenna, the window will not be present. There is no perfect solution to the quandaries surrounding either length OCF.

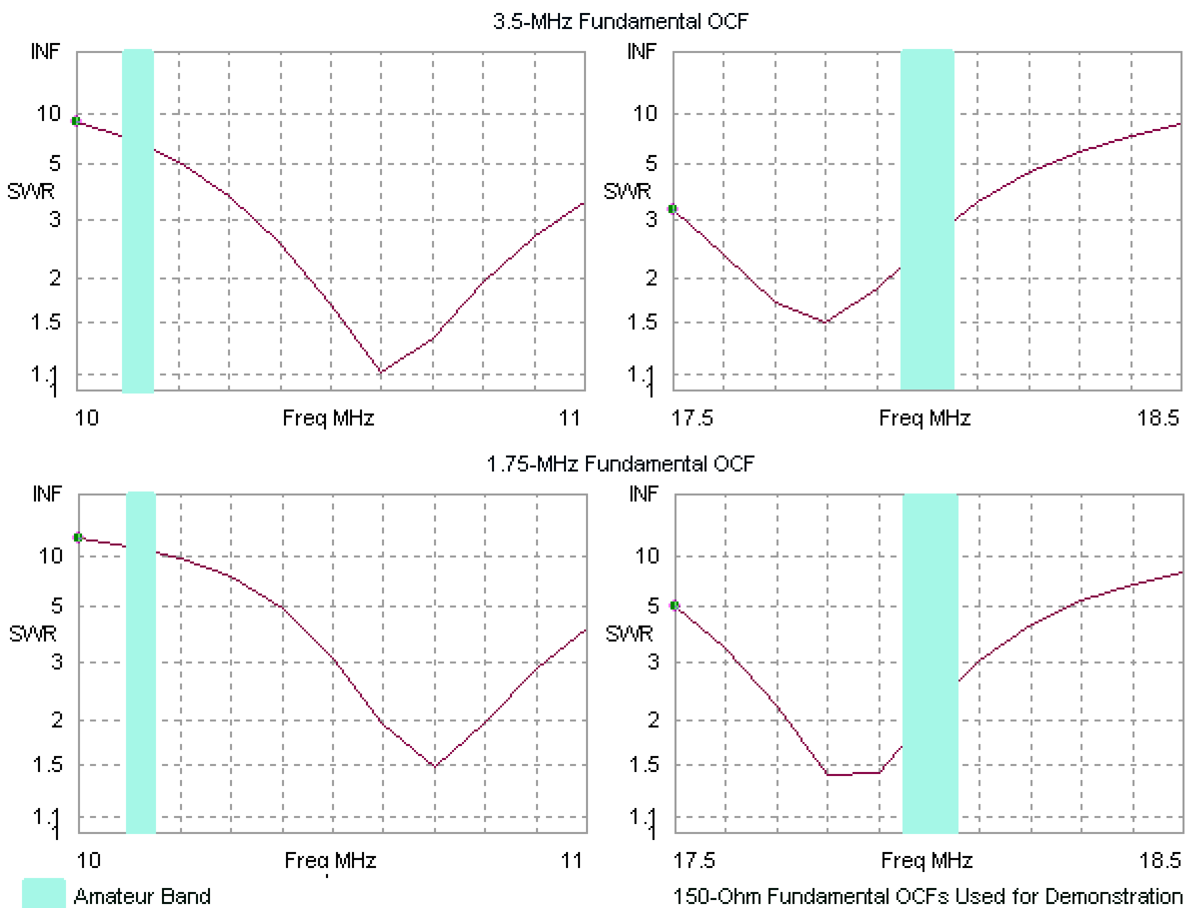


Illustration of High and Low Resonant Frequencies Relative to Two Amateur Bands

Fig. 7

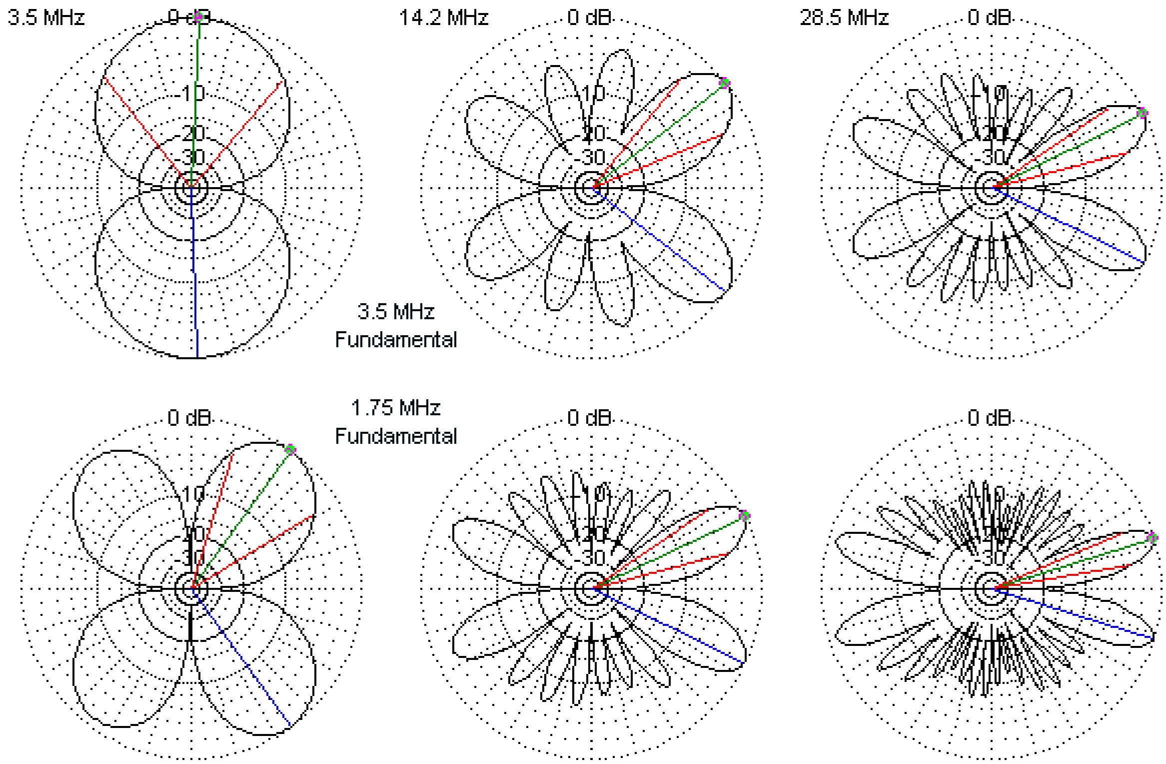
Choosing an OCF

If one needs a bit of 160-meter operation from an OCF, then the longer version that we have explored is the only possible choice. However, at the heights normally used for these antennas (perhaps 50'), the 160-meter operation—and indeed, the 80-meter operation—would be NVIS only. Even 40 meter patterns will show a take-off angle of about 38° elevation using either the longer or the shorter OCF designs. Of the two basic versions of the OCF, only the 1.75-MHz fundamental option allows 60-meter operation.

From 80 meter through 10 meters, both antennas show virtually identical potential for operating windows, regardless of the selected fundamental resonant impedance. In both cases, the 20% or 200-Ω version of the antenna offers the most actual operating windows, with the 15-meter band disappearing much above or below a fundamental impedance of 200 Ω. The question then becomes whether there is any good reasons—outside of limited 160-meter operation and the use of 60 meters—for selecting the longer OCF.

Part of the answer may lie in the azimuth patterns that one wishes to obtain from the antenna. As an end-fed variant, the OCF directs its main lobes more nearly toward the wire ends as we raise the operating frequency than we find in the patterns for a center-fed doublet. However, when the antenna is ½-λ long, the pattern is bi-directional broadside to the wire. At a

50' height, the NVIS patterns will not show the crisp figure-8 or cloverleaf on 80 meters, as displayed by the free-space E-plane patterns of **Fig. 8**. The nulls will be very shallow indeed on that band.



E-Plane Pattern Differences Between a 3.5 MHz Fundamental and a 1.75-MHz Fundamental Off-Center-Fed Element

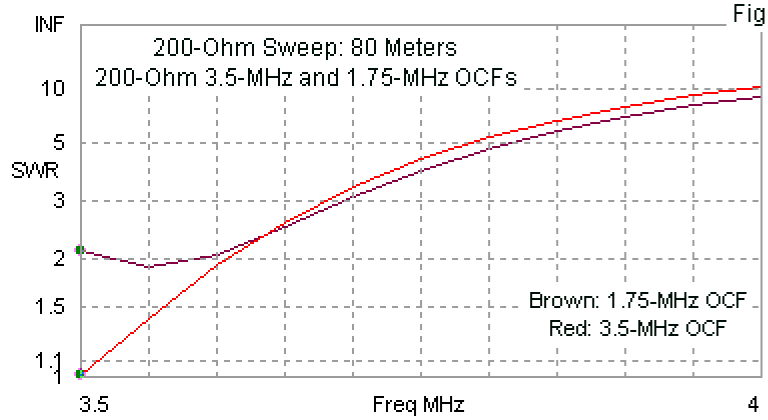
Fig. 8

Still, for any given band, the longer OCF will direct its strongest lobes with a band-to-band closer alignment than will the shorter version of the antenna. The difference is most likely to reveal itself from perhaps 20 meters downward.

One factor that might seem to play a role in selecting the longer OCF concerns 80-meter coverage. The 3.5-MHz OCF has the lowest SWR at the lower edge of the band in order to allow the higher frequency operating windows to fall within amateur bands. Hence, the user may only operate using half of the potential bandwidth on 80 meters. In contrast, the 1.75-MHz OCF uses a frequency below 160 meters for basic resonance, but for the same reason: to place the operating windows within amateur bands at higher frequencies. In most instances, the increment from the initial resonant frequency to the next higher window is larger than succeeding increments between windows. Hypothetically, the resonant 80-meter frequency should fall above the lower band edge of 80 meters, thus providing a wider operating bandwidth.

However, several factors militate against much advantage from this ploy. One such factor is that the difference in 80-meter resonant frequencies is small: perhaps 0.05 MHz. A second contributing factor is that the second window impedance tends to fall below the fundamental resonant impedance. (Because not all operating windows appear at any one fundamental impedance selection, tracking them for extended patterns is not practical.) Together, the factors add up to a relatively insignificant difference in the operating bandwidth on 80 meters between the two antennas. **Fig. 9** provides the free-space 200-Ohm SWR sweeps that illustrate how small the difference is between 1.75-MHz and 3.5-MHz 200-Ohm versions of the antenna when operated on 80 meters.

Fig. 9

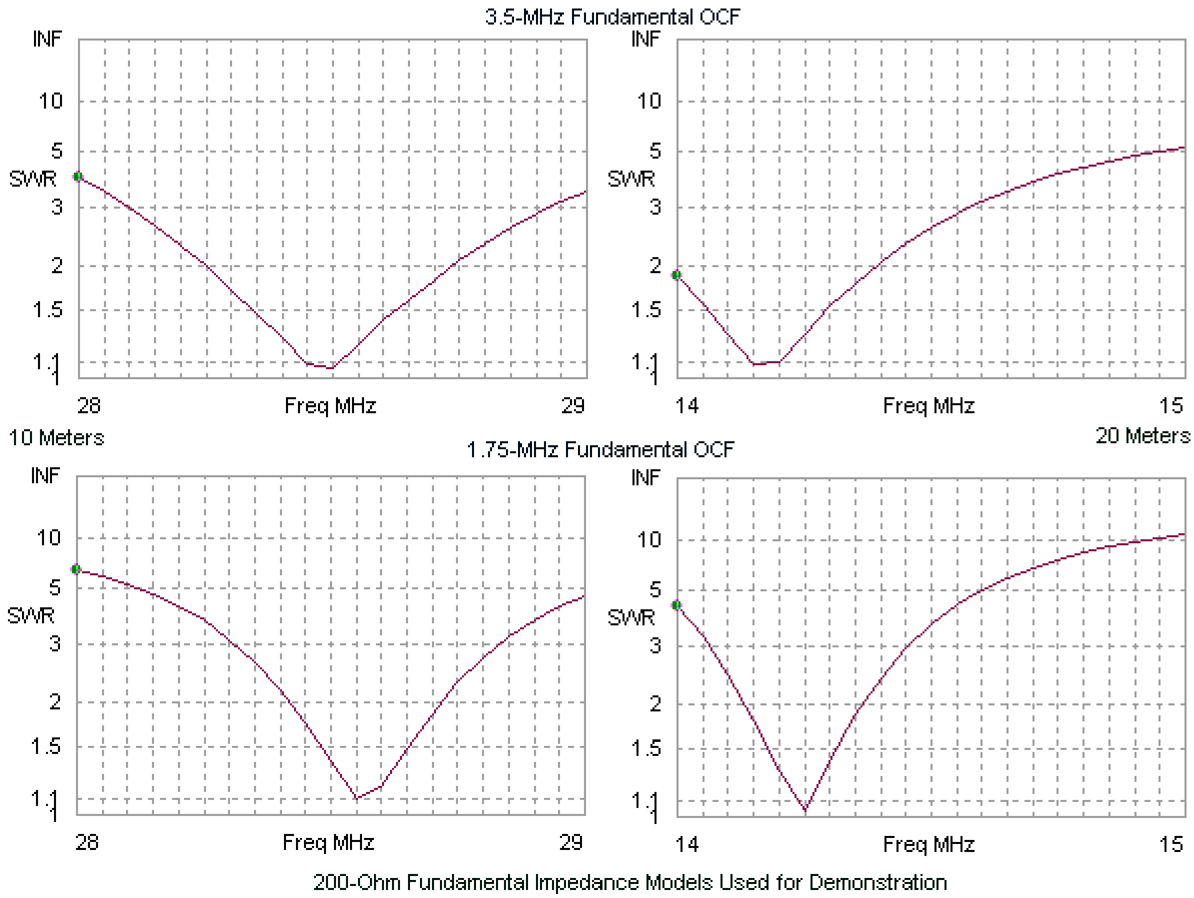


The use of free-space SWR sweeps is subject to modification when we place the antenna over real ground at a fixed height. 50' is only about 0.2-λ above ground on 80 meters, a region in which we may find large swings of feedpoint impedance in a fixed-length antenna for relatively small changes in antenna height. Any decisions in this matter would have to rest upon more detailed analyses tailored to the height at which a user proposes to install the antenna.

Ideally, the best height for any OCF is about 1 λ or more above ground. Under those conditions, the free-space calculations for the antenna's impedance performance for all operating windows would hold within very tight limits. At normal amateur antenna heights, low-band performance may deviate considerably from the calculated norm due to ground interactions. However, the deviation disappears as we increase the operating frequency and effectively raise the antenna height as a fraction of a wavelength. Modifications that we might make to the antenna length or to the feedpoint position may result in a displacement of the higher frequency operating windows. Ultimately, the installation of an OCF will represent a compromise between upper and lower frequency performance. (With either center-fed or end-fed multi-band wire antennas, we do not face this compromise, since both antennas generally use parallel transmission line to a wide-range antenna tuner. Hence, in neither case would we be concerned with precise resonance at any frequency.)

Because the longer OCF has more potential operating windows than the shorter version, each window is slightly narrower for the 1.75-MHz OCF. **Fig. 10** provides a small sample by comparing the SWR sweep of each antenna version across 20 and 10 meters. Both pairs of sweeps use the 200-Ω fundamental impedance versions of the OCF. As well, for comparison, each SWR sweep uses the actual resonant impedance of the antenna on the specified band in order to bring the SWR curve to minimum level with the increment selected for each band.

Although the resonant frequency on each band is not exactly the same for the two antennas, we may estimate the rate of change in the SWR value by examining the band-edge values. In both sample cases, the 1.75-MHz OCF reaches higher SWR values within the same frequency span. The 3.5-MHz OCF manages a "flatter" SWR curve on both bands. The difference is not large, but it may show up in the method we use to expand the SWR bandwidth. If we try to use a long cable with its inherent losses as the vehicle of SWR bandwidth expansion, the 3.5-MHz version of the antenna may prove more obliging to our efforts. However, if we employ an antenna tuner, then the difference is likely to disappear. (In both cases, the examples presume the presence of a 4:1 or similar balun at the horizontal wire feedpoint, followed by such other means as may be necessary to achieve effective OCF isolation from the coaxial cable feedline.)



Relative Sharpness of Operating Windows
for 3.5-MHz and 1.75-MHz Fundamental OCFs

Fig. 10

Conclusion

In the end, there appears to be few persuasive reasons for using a very long OCF like the 1.75-MHz version unless we simply must have a bit of 160-meter operating space at the lower end of the band for some NVIS operation. The long version also provides operation on the 60-meter band in the vicinity of 5.3 MHz. Relative to the other HF amateur bands, the 3.5-MHz version covers as many bands with relevantly similar performance except for the azimuth patterns on the lowest bands. In the end, matters of available supports and space may count as much as the absolute number of operating windows in determining which of the two isolated OCF antennas that one selects.